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 NOVA SCOTIA GREENHOUSE GAS ACCOUNTS *for the* GENUINE PROGRESS INDEX

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EXECUTIVE SUMMARY

The GPI Greenhouse Gas Accounts are primarily an educational tool. This report first identifies key concepts, principles, assumptions, evidence and uncertainties in the climate change debate (Chapters 1 and 2 and Appendix B). The report then goes on to examine potential impacts of climate change in Atlantic Canada (Chapter 3). Details are given of Nova Scotia's greenhouse gas (GHG) emissions and their estimated costs to global society as well as the estimated costs of reducing GHG emissions (Chapters 4 and 5). Opportunities for reduction of emissions are outlined briefly, along with a general overview of the potential costs and benefits of these measures and some recommendations for future action and study (Chapters 6, 7 and 8).

Appendix A places this study in the context of the Nova Scotia Genuine Progress Index (GPI) as a whole. Appendix B provides a detailed explanation of the science of climate change. Appendix C relates this study to the current development of an energy strategy for Nova Scotia. Appendix D presents a detailed case study of costs and benefits of reducing GHG emissions in the Nova Scotia Freight Transportation Sector and thereby demonstrates the utility and applicability of GPI full-cost accounting methods to specific emission reduction scenarios.

The GPI Greenhouse Gas Accounts are one of 22 components of the Nova Scotia GPI, a measure of sustainable development being constructed as a pilot project for Canada. Current measures of progress based on the gross domestic product (GDP) misleadingly count many adverse circumstances as contributions to prosperity and well-being simply because they fuel economic growth and spending. Increased fossil fuel combustion and GHG emissions along with crime, pollution, sickness, natural disasters and natural resource depletion all contribute to the GDP and to the economic growth statistics.

By contrast, the GPI recognizes such activities as costs rather than gains to the economy. Unlike measures of progress based on the GDP, in which "more" is always "better," *less* is frequently better in the GPI and so a reduction in GHG emissions signifies genuine progress. From the GPI perspective, money saved by reduced spending on prisons, pollution clean-up, disaster costs, cigarettes, sickness costs, and fossil fuel combustion, can be invested in more welfare-enhancing activities that can contribute to more desirable forms of economic development. Appendix A explains the principles, purposes and methods of the GPI in more detail.

Questions such as whether observed global warming is the result of increasing emissions of GHGs may never be definitively answered because simple cause and effect can rarely be proved, even with the best science. The more appropriate question to ask is, "What is the likelihood that the warming is related to increased GHG emissions?" Because of the high correlation of GHG emissions with increasing global temperatures and because the science of GHGs tells us that they are indeed capable of trapping heat within the earth's atmosphere, the International Panel on Climate Change (IPCC) concluded in 2001 that:

"In the light of new evidence and taking into account remaining uncertainties, most of the observed warming over the last 50 years is likely (66-90% chance) to have been due to increase in greenhouse gas concentrations."

Based on a review of the scientific evidence (Appendix B) and the internationally accepted precautionary principle, as well as recent statements by the IPCC, Chapter 2 of this study accepts that the evidence is too great and the potential impacts too severe to ignore that climate change is significant and is likely linked to human activities. The chief impacts of climate change that are expected in Atlantic Canada include sea level rise, drought, increase in extreme weather events and changes in rainfall, all of which can have an adverse impact on our social infrastructure, tourism, fisheries, forestry, agriculture, ecosystems and water resources (Chapter 3).

Total GHG emissions for Nova Scotia in 1997 were 20 million tonnes, an increase of 3% over the 1990 amount of 19.4 million tonnes. 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.

Chapter 4 identifies the major sources of GHG emissions as being 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 emissions.* Globally, 25-30% of total human-caused carbon emissions are the result of deforestation and land use change, but this study has not been able to ascertain comparable estimates for Nova Scotia.

Chapter 4 concludes that reasonable initial targets for reduction of GHG emissions in Nova Scotia include a low target (Kyoto accord) of 2.9 million tonnes between 2000 and 2010, or a higher target of 5.2 million tonnes. In the Nova Scotia GPI, movement towards and attainment of these targets is the main indicator of "genuine progress." However, since 1995, 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 literature by climate change researchers. Based on these estimates, Nova Scotia's 1997 GHG emissions alone will cause between $760 million and $21 billion 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 and $348 million. The more ambitious target of a 5.2 million tonne reduction in emissions proposed by the David Suzuki Foundation will cost between $52 million and $624 million.

* 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.

These gross damage and control costs do not include the health and other co-benefits of cleaner air and exclude other co-benefits of reducing GHG emissions. 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. Using gross control cost estimates, avoided primary and secondary damage cost estimates, and a limited range of co-benefits, the net benefit of meeting the Kyoto reduction target of 2.9 million tonnes would be $469 million to $10.4 billion (C$1997) over the period 2000-2010. The net benefit of meeting a 5.2 million tonne reduction target would be $840 million to $18.6 billion (C$1997) over the period 2000-2010.

Chapter 5 examines the assumptions of various cost estimates in detail and offers an interpretation of the potential enormity of damage cost estimates. Acceptance of the precautionary principle described in Chapter 1 requires that the higher range of damage costs be used in the GPI and therefore leads to the conclusion that investments in reducing GHG emissions are highly cost-effective. Estimated over 10 years there is likely to be an average global return of $31 in avoided damage costs for every $1 invested, even when a range of co-benefits is not included.

Chapter 5 indicates that in the year 2010, using low estimates of both control and damage costs from the literature, every $1 invested in reducing GHG emissions will produce $27 in savings due to avoided climate change damage costs. Using the high estimates from the literature, every $1 invested in reducing emissions will produce $53 in savings. Using a ten year estimate from 2000-2010, rather than a single year snap-shot, every $1 invested in reducing GHG emissions will save $17 in avoided damages using low end estimates and $31 using high end estimates.

Even more significantly, the cost effectiveness of reducing GHG emissions is shown in Chapter 5 *not* to be dependent on the differing assumptions of the climate change economists who have calculated both the 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 damages exceed the cost of reducing GHG emissions. In short, ***greenhouse gas 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***Atlantic* freight transportation study (Appendix D) has produced a **GHG Mitigation Index (GMI)**, which *does* include a wider range of concomitant benefits and costs than most conventional estimates, and thus provides a far more accurate and comprehensive assessment of the net cost or benefit to society of particular GHG reduction measures. For emission reduction strategies in the transportation sector, the GMI includes GHG emissions, air pollution, accidents, administration, policing, capital and a range of other costs. For the freight transportation study, the GMI was -$715 per tonne of GHG emissions reduced, indicating a net benefit to society of $715 for every tonne of GHG emission reduction. That case study concluded that a 10% shift of freight from truck to rail would result in a net benefit to society of more than $10 million per year.

Opportunities for reduction of GHG emissions in electricity generation, land transportation and residential energy use are examined in Chapter 6 to identify other actions that could also potentially produce net benefits to society when a full range of economic, social and environmental costs and benefits are included in the analysis. These "no regrets" measures could result in GHG emission reductions of between 2.9 million and 4 million tonnes, with estimated net benefits of between $142 million and $4.4 billion annually. More detailed analyses, along the lines of the freight study, are necessary to determine which of the actions outlined in Chapter 6 are the most cost-effective.

These emission reductions and savings 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 between 4.1 million and 5.7 million tonnes by 2010. This would exceed both the Kyoto and Suzuki targets.

This study concludes 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.

With that understanding, the province can set reasonable and sector-specific targets for reduction within the next six months; determine the most cost-effective ways to meet the targets; set up incentives or regulations to implement the reduction mechanisms; and create systems for monitoring progress. At the same time, the province may examine ways of adapting to the climate change that is likely already under way.

Appendix C examines the relevance of GHG accounting for the current development of Nova Scotia's new energy strategy. Dr Larry Hughes of Dalhousie University concludes that a fossil fuel-based energy policy is unsustainable both because of the environmental dangers of excess GHG emissions and because such a policy no longer makes economic sense:

In Appendix C, Dr. Hughes argues that the price of fossil fuel-based energy will continue to rise in step with increasing world demand. Already, the rising cost of home heating fuel is hurting many Nova Scotians on fixed incomes and the rising cost of gasoline is affecting Nova Scotian motorists and increasing the cost of shipping goods to and from Nova Scotia.

According to Dr. Hughes, the most obvious way both to reduce GHG emissions and to curtail the rising costs of fossil fuel resources that will become increasingly scarce is to "decarbonize" Nova Scotia's economy. If Nova Scotians were to reduce their consumption of fossil fuels using the measures outlined in this report, not only would they be "saving money" (by using energy more efficiently), they would also be "saving the environment."

Off-shore oil and natural gas will not last forever, writes Dr. Hughes, and a long-term sustainable "energy strategy" cannot be based on a short-term boom in off-shore exploration that will make these fuels temporarily more abundant. What is needed is a sustainable energy policy that will ensure the energy future for all Nova Scotians and that will:

- foster the growth of a renewable energy industry in Nova Scotia by adopting a "Renewable Portfolio Standard;"
- require all existing thermal stations (coal and oil) to convert to combined heat and power;
- offer low-cost loans to communities that wish to take advantage of combined heat and power;
- institute a provincial transportation strategy, consisting of community buses (operating in rural communities), regional buses (connecting rural communities to regional centres), and inter-city buses and trains (connecting regional centres);
- shift long-distance freight transport from road to rail, and handle local distribution through local trucking firms;
- re-implement the energy efficiency projects and programs formerly operated by the provincial government;
- introduce zoning laws that would require all new buildings to maximize their reliance on solar energy; and
- require the Auditor-General to present an annual report on the province's progress towards a sustainable energy future.

Such a policy will enable Nova Scotians to reduce their GHG emissions drastically, to become leaders in the field of sustainable energy, and to gain knowledge and expertise that could be shared with the world.

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Most of the work for this component of the GPI was done on a volunteer basis and through the support of GPI member contributions. The one exception is the concluding case study in this report (Appendix D), on the application of the GPI full-cost accounting methodology to an analysis of GHG emissions in the freight transport sector, which received funding from Environment Canada ($7,000) and the NS Departments of Environment ($4,000), Natural Resources ($2,000) and Transportation and Public Works ($2,000). **GPI***Atlantic* gratefully acknowledges this support.

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

GPI*Atlantic* has also received continuous assistance from Hans Messinger, Director, Industry Measures and Analysis Division, Statistics Canada, who has extended his expertise, generosity and practical support to the entire GPI project from its inception. The entire staff of the Statistics Canada regional office in Halifax, under Joanne Hughes, Andrew Maw and Paula Thomson, has provided practical hands-on assistance in countless ways at every stage of the GPI development. Without this ongoing support and assistance, the GPI enterprise would not be possible.

Space does not permit a complete description of the extraordinary contribution of each member of the Statistics Canada regional office staff, but data access and search; technical and facility support; advice on sources, methodologies and expert contacts; review and consultation; and generous hospitality are only a few of the many services provided. **GPI***Atlantic* can only hope that the results of its research can repay some of that support and make a modest contribution to Statistics Canada's own ground-breaking work in social and environmental accounting.

Jeff Wilson contributed data for Chapter 6 from his *Nova Scotia Ecological Footprint* report, which was released in March, 2001, and Leonard Poetschke contributed material for Chapter 5.
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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 attempt to build a more comprehensive and accurate measure of well-being 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.

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µm	Micrometre (10^{-6} metre)
AMG	Analysis and Modeling Group
AOGCM	Atmosphere-Ocean General Circulation Model
BAU	Business as Usual
CAC	Criteria (or Common) Air Contaminant
CCCGCM	Canadian Coupled Climate General Circulation Model
CGA	Canadian Gas Association
CH_4	Methane
CHP	Combined Heating and Power
CO_2	Carbon Dioxide
CRED	Centre for Research on Epidemiology of Disasters
CSERA	Canadian System of Environmental and Resource Accounts
CSNA	Canadian System of National Accounts
DICE	Dynamic Integrated Climate and the Economy Model
EBM	Energy Balance Model
EPA	Environmental Protection Agency (US)
EPEA	Environmental Protection Expenditure Accounts
FCCC	Framework Convention on Climate Change
GCM	General Circulation Model
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHGs	Greenhouse Gases
GMI	GHG Mitigation Index
GNP	Gross National Product
GPI	Genuine Progress Index
GRP	Gross Regional Product
Gt	Gigatonne
GWP	Global Warming Potential
HCFCs	Hydrochlorofluorocarbons
ICLR	Institute for Catastrophic Loss Reduction
IEW	Index of Economic Well-Being
IPCC	Intergovernmental Panel on Climate Change
ISEW	Index of Sustainable Economic Welfare
kt	Kiltonne
KW	Kilowatt
L	Litre
MEW	Measure of Economic Welfare
Mt	Megatonne
MW	Megawatt
N_20	Nitrous Oxide
NATO	North Atlantic Treaty Organization
NCCP	National Climate Change Process
NOx	Nitrogen Oxides
NRCan	Natural Resources Canada
NRTEE	National Round Table on the Environment and the Economy
NSPI	Nova Scotia Power Inc.
OCC	Opportunity Cost of Capital
OECD	Organization for Economic Cooperation and Development
PFCs	Perfluorocarbons
PJ	Petajoules
PM_{10}	Particulate matter of 10µm or less
$PM_{2.5}$	Particulate matter of 2.5µm or less
ppm	Parts Per Million
RPS	Renewable Portfolio Standards
SF_6	Sulphur Hexafluoride
SO_2	Sulphur Dioxide
SOx	Sulphur Oxides
SRTP	Social Rate of Time Preference
SUV	Sports Utility Vehicle
SVOW	Service Value of Wetlands
t	Tonne
TPM	Total Particulate Matter
TWAS	Total Work Accounts System
UN	United Nations
VOC	Volatile Organic Compounds
VOSL	Value of Statistical Life
WCED	World Commission on Environment and Development
WVDA	Western Valley Development Authority

The Nova Scotia Greenhouse Gas Accounts *for the* Genuine Progress Index

1. Introduction and Background

1.1. Genuine Progress Index: Valuing Our Natural Resources

We currently measure our progress as a society according to our economic growth rates. If the gross domestic product (GDP) (the sum total of all goods and services exchanged for money) is growing at a good rate, we describe the economy as "robust," "dynamic," and "healthy," which, we assume, translates into social well-being 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 the faster our current fossil fuel-based economy grows, the more rapidly we deplete our non-renewable natural resources and the more GHGs we emit. Because we assign no value to our natural capital, we actually count its depreciation as gain, with no regard to the reduced flow of services in the future. 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 (Repetto and Austin 1997), relying solely on the GDP as a measure of society's progress creates:

> *"... 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 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 in using the GDP alone was signed by over 400 prominent economists, 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 GPI is an important step in this direction*."[1]

In Nova Scotia we are constructing an index of sustainable development, the Genuine Progress Index (GPI), that is designed to give us a more accurate picture of our well-being as a society. Unlike the GDP, which values only man-made produced capital, the GPI also values natural, social and human capital. Among its 22 social, economic and environmental components, 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 our children and ourselves.

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 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 burgeoning eco-tourism industry.

Unlike our current measures of progress, based on the illusion of limitless growth, the GPI accounting framework therefore clearly recognizes that finite resource stocks have limited regenerative capacity and thus points to economic policies modeled on the balance and equilibrium that exist in nature. Scientists have noted that the only biological organism that has unlimited growth as its operational principle is the cancer cell, a disturbing analogy for conventional economic growth theory.

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[1] For more information, contact Redefining Progress, 1904 Franklin Street, 6th Floor, Oakland CA 94612 USA. Web site: http://www.rprogress.org/.

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.[2]

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 stabilization of the earth's climate and the objective of preventing potential damage from climate change that can adversely affect the lives of future generations.

A reduction in greenhouse gas (GHG) emissions, held by scientists to be the primary cause of climate instability and global warming, is therefore the primary indicator of success in moving towards that goal and in protecting a vital ecological and social asset – a climate conducive to human life on earth. Conversely, higher rates of GHG emissions signify a depreciation of that natural capital asset and an erosion of its value.

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 also clearly demonstrates how "less" can be "better:" The GPI recognizes a *reduction* in GHG emissions as a sign of genuine progress.

1.2. Nova Scotia Greenhouse Gas Accounts: Basic Principles

The GPI greenhouse gas accounts are directly related to the GPI natural resource accounts because GHG emissions result primarily from a direct depletion of natural capital and because they contribute to a stress on other natural resources, such as air quality, water quality, agriculture, fisheries and forestry.

The challenges of reducing GHG emissions and the question of how much such reductions will cost or benefit society have produced a major national and international debate. Predictions of the impact of major GHG reductions on the economy have ranged from beneficial to catastrophic. To put the problem in perspective, it is imperative to recognize the hidden costs of GHG emissions to society. As long as the arguments remain theoretical or are based on national and global scenarios alone, there will be little incentive to reduce GHG emissions in Nova Scotia. We need more research at the provincial level in order to understand potential impacts on Nova Scotia and to assess which reduction scenarios will work best for this province.

[2] 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 NS Government Inter-Departmental Consultation, March 3, 1998, World Trade and Convention Centre, Halifax. Available on the **GPI***Atlantic* web site at www.gpiatlantic.org.

This problem demands a rational approach in which all costs and benefits are evaluated. Many GHG reduction options, at many different levels (government, business, institutions, communities and individuals) are currently being explored. In order to identify the options that produce the greatest reductions with the greatest benefits to the economy and society, we need a standard means of comparing cost effectiveness across sectors. **GPI***Atlantic* has taken a step towards developing such a standard, the ***GHG Mitigation Index*** (**GMI**) (see Appendix D), which assesses the net cost or benefit to society of removing one tonne CO_2 equivalent from the atmosphere (or reducing emissions by one tonne annually). Economic, social and environmental costs are included in the index. While far from perfect, this index can provide a practical standard for comparing options which otherwise might be seen as too different for comparison.

The GPI Greenhouse Gas Accounts are based on four fundamental principles that run throughout the GPI as a whole and that illustrate the overall approach of the new measures of progress. While these principles may seem obvious, they are not yet accepted in conventional accounting systems and are therefore explained in some detail here.

The Context: Ecology and 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 base our assessments of prosperity and social well-being.

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 the human 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 human 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 social well-being is more entrenched than it was at its inception. We still adhere to this 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 UN, OECD, 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).

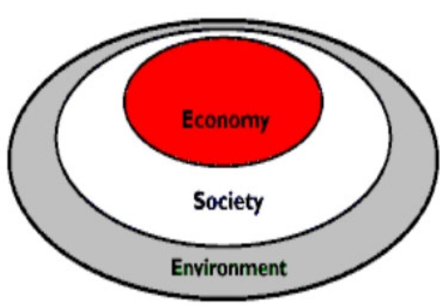
The CSERA bring natural resource accounts into the national balance sheets for the first time. Resource and waste flows appear in the input-output tables. Climate change is regarded as the most important environmental issue of the next century and it is therefore appropriate that Statistics Canada has designated GHG emissions as the first set of emissions to be included in the expanded national input-output tables. In addition, the CSERA is developing 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 short, there is no doubt that integrated environmental-economic accounting will be the basis of the new economy of the next millennium. In the year 2000 budget, Federal Finance Minister Paul Martin, announced that integrated environmental-economic accounting "*in the years ahead… could have a greater impact on public policy than any other single measure one might introduce*." This is a principle reason that Statistics Canada regards the Nova Scotia GPI with interest as a potential pilot project for Canada, providing a unique opportunity for this province to be a leader in charting the new course. The Finance Minister's announcement is also the basis of a new Sustainable Development Indicators Initiative by the National Round Table on the Environment and the Economy (NRTEE). **GPI***Atlantic* is currently on the steering committee guiding that initiative.

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 and 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 well-being of future generations as well as our own.

The Precautionary Principle

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. Thus 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 relevance of this vital principle for GHG emissions is clear. There is no absolute certainty that climate change and its potentially catastrophic impacts are caused by the GHG emissions that are one of the by-products of fossil fuel combustion. But the probability of a link is sufficiently strong in the eyes of the 2,000 scientists appointed by the United Nations to the Intergovernmental Panel on Climate Change (IPCC) that the international community has committed itself to significant reductions in GHG emissions.

The precautionary principle flows directly from the underlying principle of "sustainability" that is the unifying framework of the GPI. The essential components of any definition of sustainable development are that we live in such a way that the next generation will not be worse off than we are and that we live within the capacity of the natural world to provide essential resources and to assimilate human waste. From this perspective, the precautionary principle simply means viewing climate change from the perspective of our children rather than ourselves. If we are uncertain of the potential impact of climate change on the world that our children will inhabit, then we will act now to reduce any possible future damage rather than put our children at risk.

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. Just as good driving records will eventually lower premiums, it can be similarly argued that if the connection between GHG emissions and climate change is eventually disproved, fossil fuel reserves will still be available to be burned.

If, on the other hand, GHG emissions are partially responsible for the warming of the planet, as seems highly likely, then failure to act now could have catastrophic consequences for the planet and the next generation. Therefore the world community, including Canada, has recognized that simple prudence and responsibility to future generations demand immediate and concerted action.

The Nova Scotia GPI recognizes climate change as the number one environmental issue of this century, and therefore accepts the precautionary principle as the starting point of the GHG accounts. For that reason, as an index of *sustainable* development with a long-term perspective, the GPI counts any reduction in GHG emissions in the province as an indicator of genuine progress and a benefit that raises the overall index.

Though Nova Scotia is a small player on the world stage, whose actions may have limited effect, Nova Scotians are also global citizens obligated to do their part in tackling a global crisis. Beyond that, the power of example cannot be underestimated, and there is no reason Nova Scotia cannot lead the way, as a model of responsibility, in reducing GHG emissions and urging other jurisdictions to follow suit.

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. The *Exxon Valdez,* for example, 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 production and an array of damage expenditures all added to the GDP and made the economy grow.[3] In the same way, crime, accidents, sickness, resource depletion and natural disasters 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 well-being 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

[3] 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 well-being rather than an improvement. We are indebted to Robert Smith, Assistant Director, Statistics Canada – Environmental Accounting and Statistics Division, for his analysis of the impacts of pollution clean-ups on GDP (personal communication, October 3, 2000).

therefore send misleading signals to policy-makers, economists, journalists and the public on our actual state of well-being and prosperity. This is the principle reason that more than 400 leading economists have publicly urged that the GDP no longer be used as our primary measure of progress.

By contrast to the GDP, the GPI regards crime, pollution, sickness, accidents and natural resource depletion as costs, rather than gains to the economy. The same principle is applied here. The burning of fossil fuels in the human economy has exceeded the capacity of the ecosystem to absorb the emitted GHGs. Canada's commitment under the Kyoto Protocol to reduce GHG emissions to 6% below 1990 levels derives from international recognition that further atmospheric accumulations may produce serious and potentially catastrophic costs to the human economy. Because attainment of the Kyoto targets will not prevent further atmospheric accumulation of GHGs, it should be seen as the first step in a series of emission reductions that will continue until atmospheric concentrations of GHGs are actually reduced.

Like crime and pollution, GHG emissions are counted in the GPI as costs. Unlike the GDP, which always sends the message that *"more"* is *"better,"* the GPI recognizes that *less* crime, *less* pollution and *less* GHG emissions are more accurate indicators of prosperity, well-being, economic sustainability, and "genuine progress" than increased costs in these areas. Unlike the GDP, the GPI goes up when crime rates, pollution and GHG emissions decrease. Cost-benefit analysis, as used in the GPI, therefore corresponds far more closely to common-sense perceptions of well-being than a current accounting system like the GDP that simply counts all expenditures as economic benefits.

In calculating the economic costs of GHG emissions, the GPI does not make its own calculations for the likely impact of climate change on Nova Scotia, for the impact of Nova Scotia emissions on the world, or for potential remediation costs within the province. Instead, the GPI simply uses existing and widely accepted estimates of dollar costs per tonne of carbon emitted and multiplies this unit cost by the quantity of carbon emitted in the province. Because *global* impacts of climate change will affect Nova Scotia just as Nova Scotia emissions affect global climate change, it makes more sense to use such global cost estimates for carbon emissions than to derive separate unit cost estimates for the province.

Finally, cost benefit analyses can help to identify "no regrets" measures that will produce net benefits to society, no matter what the future of climate change may be. For example, reducing the use of fossil fuels will also reduce pollution, maintain a larger non-renewable resource base for future generations and provide other social benefits, whether or not it helps to reduce the rate of climate change. Thus, substituting some automobile use with mass transit can not only reduce GHG emissions and air pollution, but can also reduce accident, policing and road costs, increase mass transit jobs and spur economic growth in a new industry. These total benefits are then compared to costs, which may include reduced economic growth in other sectors. Those measures that produce a net benefit to society, the environment and the economy are then considered "no regrets" measures. The GPI is committed to identifying these "no regrets" measures as the first steps that should be taken in reducing GHG emissions.

Full Cost Accounting

The 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 measurement instrument that can establish benchmarks of progress for Nova Scotia, the GPI method also has practical utility at the micro-policy level. Therefore, this report contains an Appendix applying the GPI accounting principles to a specific GHG reduction scenario – a shift in freight from road to rail. The methods used here can be similarly applied to other specific emission reduction scenarios to determine the most cost-effective policies.

There is a wide range of potential strategies for reduction of GHG 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 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.

"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 can help make this Section of the Act a reality.

The GPI recognizes that there are three stages in the implementation of full cost accounting. The first step, which the GPI attempts to accomplish, 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 the tax and financial structures, 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 to reward sustainable harvesting practices and to penalize unsustainable ones. Similarly, Appendix D to this report would suggest higher road taxes for freight trucking and corresponding financial incentives that encourage rail freight. By quantifying net social benefits in monetary terms, full cost accounting can indicate the appropriate size of subsidy or penalty required to effect such a shift.

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 structure as suggested would reduce the market price of sustainably harvested timber and goods hauled by rail and increase the price of unsustainably produced and transported goods. These steps will not only increase market efficiency by encouraging producers to reduce energy and other costs, but will also decrease the burden on taxpayers and the need for external regulation of the market.

1.3. Public Understanding of the Climate Change Issue

The Climate Change Issues Table on Public Education and Outreach (National Climate Change Secretariat, 1998) summarized the findings of 31 different studies and surveys on Canadian public opinion on climate change as follows:

- The environment and global warming have not been considered as pressing issues, whereas jobs, national unity, health care, education and other economic concerns take priority in the minds of Canadians;
- Two-thirds of Canadian business leaders view climate change as a serious issue;
- Canadians who have taken action on climate change have done so for reasons such as convenience, saving money and conserving energy, rather than to address climate change per se;
- Canadians lack facts and understanding of the issues: they often cannot identify what global warming is, how it is caused, or what is required to stop it;
- Those Canadians who are concerned and prepared to do something about environmental issues don't know what they should do and are looking for examples and advice;
- Canadians think it is government's responsibility to lead and act on this issue and they expect Canada to be a leader with respect to other nations; and
- People are in favour of "soft" approaches (education, advice) as well as public-private partnerships, research and Voluntary Challenge Registries, but are opposed to tax hikes, emissions trading and rationing of gas/oil. They express a willingness to modify their lifestyles if (a) there is evidence that it is necessary; (b) it is clear what society as a whole should be doing; and (c) the government and others are leading by example. They feel that the bigger responsibility rests with manufacturing and industry and do not expect to be asked to act alone.

- Canadians are optimistic that environmental issues can be dealt with through technology and that this may stimulate economic growth, but business leaders believe that the Kyoto Agreement will entail considerable cost to Canadian business and the economy;
- Close to 90% of Canadians think it is somewhat or very likely that within ten years global climate change will have serious negative effects on both the environment and the economy but feel there is not much that they can do about it.

Recent workshops held in Nova Scotia pointed to the need for more education, communication and awareness building of climate change issues in the minds of the general public (Voluntary Planning, 1999).

Even though the vast majority of the world's scientists agree on the extent of climate change and the need for reducing GHG emissions, the public appears to remain confused about the issue. Efforts to take action can be undermined by those who argue that we should not be taking drastic action to reduce GHGs because they believe the science is flawed. Therefore, **GPI***Atlantic* regards it as essential that the public be provided with a basic understanding of climate processes in order to promote informed discussion on climate change.

This study is intended to provide the Nova Scotia public with the information needed to discuss climate change intelligently and to identify GHG reduction options. This report therefore includes a lengthy basic discussion of climate change processes (Chapter 2 and Appendix B) to provide a scientific basis for examining the potential costs and benefits of reducing GHGs and the specific actions that Nova Scotians can take to slow climate change.

2. Climate and Climate Change

As noted, Appendix B provides a detailed explanation of the science of climate change. This Section simply provides a summary of the most recent authoritative statements by the Intergovernmental Panel on Climate Change (IPCC, 2001).

2.1. Climate Change and the Historical Record

In February 2001, the IPCC assessed the degree of climate change in recent history as follows:

> *"The global average surface temperature (the average of near surface air temperature over land, and sea surface temperature) has increased since 1861.*
>
> *"Globally, it is very likely[4] that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record since 1861.*

"New analyses of proxy data for the Northern Hemisphere indicate that the increase in temperature in the 20th century is likely[4] to have been the largest of any century during the past 1,000 years. It is also likely that, in the Northern Hemisphere, the 1990s was the warmest decade and 1998 the warmest year.

"Satellite data show that there are very likely to have been decreases of about 10% in the extent of snow cover since the late 1960s,, and ground based observations show that there is very likely to have been a reduction of about two weeks in the annual duration of lake and river ice cover in the mid- and high latitudes of the Northern Hemisphere over the 20th century

"There has been a widespread retreat of mountain glaciers in non-polar regions during the 20th century.

"Tide gauge data show that global average sea level rose between 0.1 and 0.2 metres during the 20th century."

2.2. Greenhouse Gas Emissions and Evidence for Anthropogenic Influence on Climate Change

Table 1 summarizes the IPCC findings on the increase in atmospheric concentrations of GHGs.

On the likelihood of human influence on observed climate change, the report 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."

2.3. Projections of Future Climate Change

In modeling projections of climate change in response to changes in atmospheric GHG concentrations, the IPCC (2001) outlined six possible scenarios, or story lines, to describe different sets of assumptions about how people will live in the 21st century. These scenarios, described in more detail in Appendix B, reflect different futures based on variations in factors that influence GHG emissions.

[4] In the IPCC documents released in February 2001, the following words have been used to indicate judgmental estimates of confidence: *virtually certain* (greater than 99% chance that a result is true); *very likely* (90-99% chance); *likely* (66-90% chance); *medium likelihood* (33-66% chance); *unlikely* (10-33% chance); *very unlikely* (1-10% chance); *exceptionally unlikely* (less than 1% chance).

Table 1. Changes in Atmospheric Greenhouse Concentrations Since 1750

	Increase in atmospheric concentration since 1750	Present concentration relative to historical values	Estimated radiative forcing[5] from 1750 to 2000 (W/m^2)	Source of anthropogenic emissions
Carbon dioxide (CO_2)	31%	Has not been exceeded in the past 420,000 years or likely in the past 20 million years; rate of increase unprecedented in the past 20,000 years.	1.46	In the past 20 years, about 3/4 from fossil fuel burning; remainder from land use change, especially deforestation.
Methane (CH_4)	151%	Has not been exceeded in the past 420,000 years; rate of increase slowed in 1990s.	0.48	Slightly more than 1/2 of total emissions are anthropogenic from fossil fuel use, cattle farming, rice farming and landfills
Nitrous oxide (N_2O)	17%	Not exceeded in at least the last thousand years.	0.15	About 1/3 of total emissions are anthropogenic from agricultural soils, cattle feed lots and chemical industry.
Tropo-spheric ozone[6]	36%		0.35	Primarily ozone-forming gases from fossil fuel burning.
Strato-spheric ozone	decrease		-0.15	Depletion from ozone-depleting halocarbons which are being phased out.

The factors that will most strongly influence GHG emissions and climate change are:

- Rates of economic and population growth
- Rate of technological change

[5] The IPCC defines radiative forcing as "a simple measure of the importance of a potential climate change mechanism. The perturbation to the energy balance of the Earth-atmosphere system (in Watts per square metre [Wm^{-2}])" (IPCC, 2001).

[6] Increases in emissions of halocarbons have caused depletion of the ozone layer in the stratosphere (the layer that is 12-50km above the earth), while increases in emissions of ozone forming gases (hydrocarbons and nitrogen oxides), primarily from fossil fuel burning, have caused increases in the concentration of ozone in the troposphere (the lower 8-16km of the atmosphere). The Montreal Protocol (signed in 1987 and amended in 1992) regulated internationally the ozone-depleting hydrocarbons, allowing use of substitutes that do not deplete the stratospheric ozone layer. However, some of these substitutes do act as greenhouse gases.

- Degree of use of alternate fuels
- Globalization and degree of societal and cultural homogeneity among regions
- Degree of equalizing of per capita income among regions
- General level of economic, social and environmental sustainability.

Following are some of the statements made by the IPCC about future projections. The low ranges represent scenarios with low rates of population and economic growth and high rates of sustainability and alternative fuel use. The high ranges represent the opposite scenarios:

> *"Concentrations of CO_2 due to fossil fuel burning are virtually certain[4] to be the dominant influence on the trends in atmospheric CO_2 concentrations during the 21st century.*
>
> *"As the CO_2 concentration of the atmosphere increases, ocean and land will take up a decreasing fraction of anthropogenic CO_2 emissions. The net effect of land and ocean climate feedbacks as indicated by models is to further increase projected atmospheric CO_2 emissions, by reducing both the ocean and land uptake of CO_2.*
>
> *"By 2100, carbon cycle models project atmospheric CO_2 concentrations of 540 to 970 ppm for the illustrative scenarios (90% to 250% above the concentration of 280 ppm in the year 1750). These projections include the land and ocean climate feedbacks. Uncertainties, especially about the magnitude of the climate feedback from the terrestrial biosphere, cause a variation of about -10 to +30% around each scenario. The total range is 490 to 1260 ppm (75% to 350 % above the 1750 concentration)."* (Current atmospheric CO_2 concentrations are about 360 ppm.)

On future average temperature, sea level, and precipitation, the IPCC stated:

> *"The globally averaged surface temperature is projected to increase by 1.4-5.8^{o}C over the period 1990 to 2100. These results are for the full range of the scenarios, based on a number of climate models.*
>
> *"The projected rate of warming is much larger than the observed changes during the 20th century and is very likely[4] to be without precedent during at least the last 10,000 years, based on paleoclimate data.*
>
> *"Based on global model simulations and for a wide range of scenarios, global average water vapour concentration and precipitation are projected to increase during the 21st century. By the second half of the 21st century, it is likely[4] that precipitation will have increased over northern mid- to high latitudes and Antarctica in winter.*
>
> *"Global mean sea level is projected to rise by 0.09 to 0.88 metres between 1990 and 2100, for the full range of scenarios."*

Projection of changes in the rate of extreme weather events is a critical aspect of predicting climate change, since these events can be catastrophic and cause enormous environmental, economic and social damage. Table 2, taken from the IPCC report, gives the level of confidence in the statements made by the IPCC.

Table 2. Estimates of Confidence in Observed and Projected Changes in Extreme Weather and Climate Events

Confidence In Observed Changes (Latter Half of 20th Century)[4]	Changes In Phenomenon	Confidence In Projected Changes (During 21st Century)
Likely	Higher maximum temperatures and more hot days over nearly all land areas	Very likely
Very likely	Higher minimum temperatures, fewer cool days and frost days over nearly all land areas	Very likely
Very unlikely	Reduced daily temperature range over most land areas	Very likely
Likely over many areas	Increase of heat index over land areas	Very likely over most areas
Likely over many Northern Hemisphere mid- to high-latitude land areas	More intense precipitation events	Very likely over most areas
Likely in a few areas	Increased summer continental drying and associated risk of drought	Likely over most mid-latitude continental interiors (lack of consistent projections in other areas)
Not observed in the few analyses available	Increase in tropical cyclone peak wind intensities	Likely over some areas
Insufficient data for assessment	Increase in tropical cyclone mean and peak precipitation intensities	Likely over some areas

Finally, the IPCC points out that anthropogenic climate change will persist for many centuries. The following statements serve to illustrate this point:

> *"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 excerpts from the IPCC report illustrate the seriousness of the climate change issues as well as the uncertainties involved. It is clear from the IPCC report, 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 change than has been observed so far.

The IPCC process and conclusions have recently received the strong endorsement of the scientific academies of 17 countries, including the Royal Society of Canada, the Royal Society of the United Kingdom, and the Royal Swedish Academy of Sciences, which awards the Nobel Prizes.

The following joint statement, published in the May 18, 2001, issue of the journal *Science*, is a direct response by these leading national scientific academies to the recent US decision to abrogate its responsibilities under the 1997 Kyoto Protocol which committed industrial countries to reduce their GHG emissions. According to William Leiss, president of the Royal Society of Canada, the statement is intended to keep the Kyoto process alive "and not let the US do it in" (Munro, 2001).

The Science of Climate Change
Editorial (Science, 18 May 2001)

The work of the Intergovernmental Panel on Climate Change (IPCC) represents the consensus of the international scientific community on climate change science. We recognize the IPCC as the world's most reliable source of information on climate change and its causes, and we endorse its method of achieving this consensus. Despite increasing consensus on the science underpinning predictions of global climate change, doubts have been expressed recently about the need to mitigate the risks posed by global climate change. We do not consider such doubts justified.

There will always be some uncertainty surrounding the prediction of changes in such a complex system as the world's climate. Nevertheless, we support the IPCC's conclusion that it is at least 90% certain that temperatures will continue to rise, with average global surface temperature projected to increase by between 1.4^{o} and 5.8^{o}C above 1990 levels by 2100.* This increase will be accompanied by rising sea levels; more intense precipitation events in some countries and increased risk of drought in others; and adverse effects on agriculture, health, and water resources.

In May, 2000, at the InterAcademy Panel (IAP) meeting in Tokyo, 63 academies of science from all parts of the world issued a statement on sustainability in which they noted that "global trends in climate change... are growing concerns" and pledged themselves to work for sustainability – meeting current human needs while preserving the environment and natural resources needed by future generations.[†] It is now evident that human activities are already contributing adversely to global climate change. Business as usual is no longer a viable option.

We urge everyone – individuals, businesses, and governments – to take prompt action to reduce emissions of greenhouse gases. One hundred and eighty-one governments are Parties to the 1992 United Nations Framework Convention on Climate Change, demonstrating a global commitment to "stabilising atmospheric concentrations of greenhouse gases at safe levels." Eighty-four countries have signed the subsequent 1997 Kyoto Protocol, committing developed countries to reducing their annual aggregate emissions by 5.2% from 1990 levels by 2008-2012. The ratification of this protocol represents a small but essential first step toward stabilizing atmospheric concentrations of greenhouse gases. It will help create a base on which to build an equitable agreement between all countries in the developed and developing worlds for the more substantial reductions that will be necessary by the middle of the century.

There is much that can be done now to reduce the emissions of greenhouse gases without excessive cost. We believe that there is also a need for a major coordinated research effort focusing on the science and technology that underpin mitigation and adaptation strategies related to climate change. This effort should be funded principally by the developed countries and should involve scientists from throughout the world.

The balance of the scientific evidence demands effective steps now to avert damaging changes to Earth's climate.

A joint statement issued by the Australian Academy of Sciences, Royal Flemish Academy of Belgium for Sciences and the Arts, Brazilian Academy of Sciences, Royal Society of Canada, Caribbean Academy of Sciences, Chinese Academy of Sciences, French Academy of Sciences, German Academy of Natural Scientists Leopoldina, Indian National Science Academy, Indonesian Academy of Sciences, Royal Irish Academy, Accademia Nazionale dei Lincei (Italy), Academy of Sciences Malaysia, Academy Council of the Royal Society of New Zealand, Royal Swedish Academy of Sciences, Turkish Academy of Sciences, and Royal Society (UK).

* Climate Change 2001: The Scientific Basis [contribution of Working Group 1 to the IPCC Third Assessment Report (www.ipcc.ch)]. The average global surface temperature is predicted to increase by between 1.4° and 3°C above 1990 levels by 2100 for low-emission scenarios and between 2.5° and 5.8°C for higher emission scenarios.† Transition to Sustainability in the 21st Century: The Contribution of Science and Technology [A Statement of the World's Scientific Academies (May 2000) (http://interacademies.net/intracad/tokyo2000.nsf)].

3. Potential Impacts of Climate Change in Atlantic Canada[7]

Global climate change models are not yet regarded as good predictors of particular regional impacts. Economic predictions of climate change impacts, particularly at the regional level, are, therefore, fraught with uncertainties. Nevertheless, the GPI study draws on the best available expert assessments, including Environment Canada's *Canada Country Study* analysis, *Climate Change and Climate Variability in Atlantic Canada,* to indicate potential impacts of global warming on Nova Scotia (Environment Canada, 1997c). In accordance with the approach of the GPI project as a whole, links are drawn between environmental impacts and possible socio-economic effects.

Whereas there has been a global warming trend of 0.3-0.6^{o}C, recorded temperatures in Atlantic Canada have shown a warming trend for the period 1895-1995 overall and a cooling trend of 0.7^{o}C for the period 1948-1995 (Environment Canada, 1997a). This pattern may well be changing with the hotter, drier summers experienced in the late 1990s in some parts of Atlantic Canada. Records for the period 1944-1990 indicate increases of extreme weather events, which are one of the more damaging aspects of climate change (Environment Canada, 1997a).

It is not scientifically possible at this stage to link particular local events with climate change. However, intense floods in the summer of 1999 in Antigonish and in Oxford, Nova Scotia, and flooding in 2000 that caused $3 million in damage to roads in Cumberland County alone, may possibly be an early sign of the increase in storms and extreme events predicted by the IPCC. Similarly, in light of IPCC predictions of an increase in the frequency and intensity of drought worldwide, it would be prudent not to dismiss the possibility that the three straight years of drought experienced by Nova Scotia farmers from 1997-1999 may be linked to climate change. Nova Scotia farm losses related to drought in 1999 were estimated at $50 million (Wooley, 1999).

Even though definitive local links to global climate change cannot be made, lower rates of precipitation and milder winters have certainly had an impact on the agricultural sector in the province. The Nova Scotia Federation of Agriculture newsletter has warned members that climate change may already be a reality for Nova Scotia farmers (Wooley, 1999). In the last three years alone, three seasons in Atlantic Canada have been the hottest on record and two more were the second and fourth warmest ever recorded. The spring of 1999, the warmest on record, was 2.8^{o}C above normal, and summer rainfall in the Annapolis Valley was less than half the seasonal average.

The *Canada Country Study* (Environment Canada, 1997c) outlined six major areas of climate change sensitivity in the Atlantic Region: fisheries, coastal zone, ecosystems and water resources, agriculture, forestry and socio-economic dimensions. Some conclusions from this study and other studies are summarized below.

[7] Research for this Chapter was done by Julia Sable and Jonathan Kay under the supervision of Dr. Larry Hughes, Dalhousie University.

3.1. Precipitation and Extreme Weather Events

Impacts of changes in precipitation were noted above. Snow cover in Atlantic Canada has been decreasing since 1971 and many rivers have reached all-time low levels in recent years. Although temperature and precipitation trends are the most readily available, and possibly, the most important indicators of climate change, the trend that will affect people most directly is probably the rate of occurrence of extreme weather events such as hurricanes and floods (Environment Canada, 1997a). These rates must be considered against the backdrop of great variability over the years in order to assess whether there has been a significant change. Most meteorologists are not willing to say that the trend towards more extreme events can be considered statistically significant.

The insurance industry has expressed particular concern over the economic costs of climate change, particularly due to an increase in extreme weather events, and is therefore also a source for the GPI study. According to the World Disasters Report, natural disasters caused over $72 billion (US$1999) damage worldwide in 1999 (CRED, 2000). The Institute for Catastrophic Loss Reduction (ICLR) in Manitoba has identified hurricanes, erosion and storm surges as the major climate change concerns for Nova Scotia, resulting in potential coastal flooding, sewer backup and flooding at the municipal level.

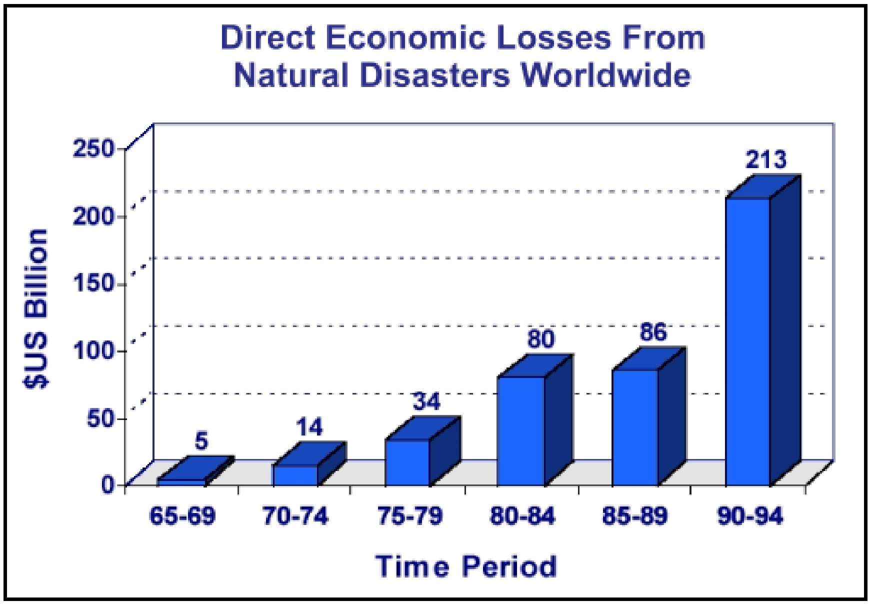
Again, it must be emphasized that the floods, heat waves and drought years recently experienced may well be natural aberrations. But the precautionary principle insists that possible warning signs be taken seriously and that action to forestall potentially catastrophic climate change effects not be delayed. Indeed, 13 large insurance companies have already joined to create a new Risk Prediction Initiative and the ICLR has teamed up with other organizations in a Natural Hazard Risk Assessment Committee to assess potential regional risks due to climate change.

Figure 2 shows the sharp increase in economic losses since the 1960s from natural catastrophes worldwide. While the results are dramatic, they must be interpreted cautiously, as they also reflect population growth, the increase in vulnerability due to intensive construction along coastlines, increased dependence upon electricity for heat, and other factors. Figure 3 shows the US Climate Extremes Index, which indicates a sustained period of extreme weather activity since the mid-1970s.

Of greatest concern for Nova Scotia is possible increased hurricane and cyclone activity. Hurricanes have proven among the costliest natural disasters, both to human life and property, and evacuation costs alone have been estimated at US$660,000 per mile of coastline in the US.

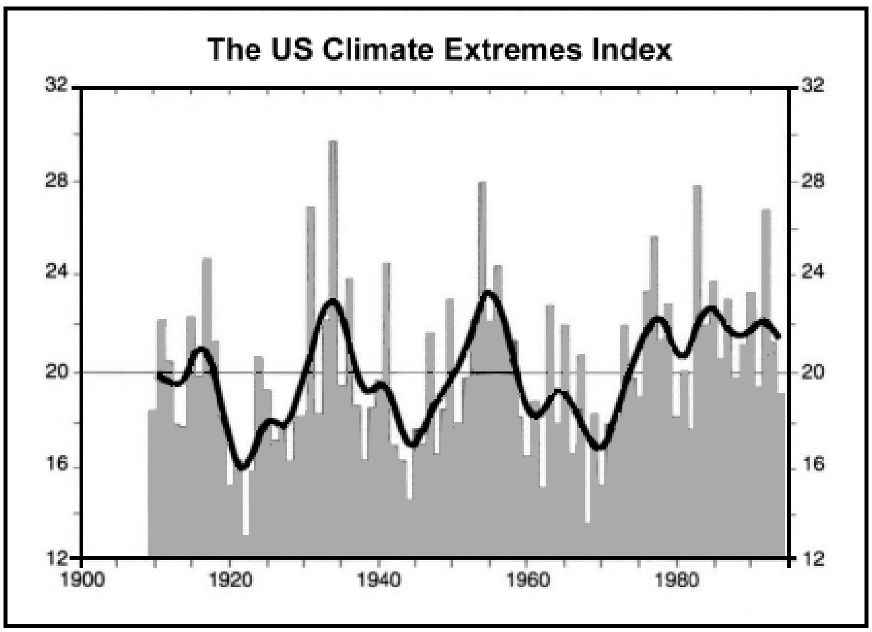
Since Nova Scotians are also Canadian taxpayers and pay insurance premiums to national insurance companies, they share the economic burden of extreme weather events elsewhere in the country. The Quebec ice storm of 1999 alone cost $1.5 billion and insurers in Canada paid over $2.8 billion in 1998 for claims due to natural disasters. An increase in extreme weather events due to global warming, as predicted by the IPCC, will increase insurance premiums and damage costs. Paradoxically, as noted above, an increase in extreme weather events, natural disasters and catastrophic losses may be good for the GDP and economic growth, since cleanup and replacement costs are counted as economic gain.

Figure 2. Direct Economic Losses from Natural Disasters Worldwide, 1965-1994 (C$1998)



Source: Canadian Climate Program Board 1998

Figure 3. The US Climate Extremes Index



Note: The Index combines a variety of measures of temperature and precipitation extremes to give a single annual measure of the frequency of extreme events. Although it does not track all types of extremes – tornadoes, for example, are not included – it does provide a useful approximation of trends in weather extremes on a regional scale. The index shows pronounced but brief peaks in the 1930s and 1950s and a more sustained period of severe weather activity since the mid-1970s.

Source: Francis and Hengeveld, 1998.

The following article (Capella, 2001), published in *The Guardian* of London, illustrates the fact that international aid will not be able to offset the global damages caused by climate change.

Red Cross: Disasters Will Outstrip Aid Effort as World Heats Up
Peter Capella, The Guardian of London, 29 June 2001.

International aid will not be able to keep up with the impact of global warming, the Red Cross said yesterday, after reporting a sharp increase in the late 1990s in the number of weather-induced disasters

In its annual World Disasters Report the International Federation of Red Cross and Red Crescent Societies says that floods, storms, landslides and droughts, which numbered about 200 a year before 1996, rose sharply and steadily to 392 in 2000.

"Recurrent disasters from floods in Asia to drought in the Horn of Africa, to windstorms in Latin America, are sweeping away development gains and calling into question the possibility of recovery," the report says.

Blaming the trend on global warming, Roger Bracke, its head of disaster relief operations, said: "These are also the most deadly events; it is probable that these kind of disasters will increase even more spectacularly.

"There is a natural limit somewhere to what humanitarian assistance can do; we are afraid that there will be a point where we can no longer provide assistance."

Scientists working for the United Nations say that more frequent extreme weather is one of the signs of global warming, and low-lying island states are the first at risk, because of the predicted rise in sea levels and their exposure to harsher tropical storms.

With 41% of its population of about 380,000 killed or affected between 1991 and 2000, the Solomon Islands heads the first league table complied of countries struck by disaster.

Two other island groups in the south-west Pacific, Tonga and Micronesia, are in the top eleven. Floods accounted for more than two-thirds of the 211m people a year on average affected by natural disasters in the past decade.

Famine caused by drought affected nearly a fifth, and accounted for most deaths: about 42% percent of all those caused by natural disasters.

The federation said the impact of climate change in poor countries placed an enormous responsibility on aid-giving states, commenting: "The latter commonly both create the problem and set the terms by which it will be managed."

It suggested that poor countries might seek legal compensation to pay for reconstruction through an "international tort climate court," adding: "Increasingly sophisticated analysis of climate change means that ignorance of the consequences of industrial consumption and pollution can be no defense for inaction".

The report points out that the poor are the most vulnerable to disasters, 88% of those affected and two thirds of those killed in the past 10 years living in the least developed countries.

In short, the costs to Nova Scotia of an increase in extreme weather events due to climate change will not be the result of events within the province alone, but of events throughout the world.

3.2. Coastal Zone and Sea Level Rise

Environment Canada's *Canada Country Study* notes that the potential impacts of climate change on the Atlantic coastal zone include effects of accelerated sea level rise and effects of variable storminess. Increased flood risk in some areas, coastal erosion in others, sediment redistribution, and coastal sedimentation are likely effects of the rise. Variations in storminess may increase erosion, cause storm-surge flooding and increase wave energy. Both types of effects would have serious socio-economic impacts, since the rate of coastal property development in Atlantic Canada is on the rise.

Global sea level has risen by 10 to 25cm over the past 100 years and much of the rise may be related to the increase in global mean temperature. The latest predictions from the IPCC (1996) are for a rise of 20 to 86cm from 1995 to 2100. Relative sea level is now rising along most parts of the Atlantic Canada coast. According to an EPA study (EPA, 2000), sea level along the coast of New York, which typifies the US coast, is likely to rise 26cm by 2050 and 55cm by 2100.

Low-lying regions around Yarmouth, the Bay of Fundy and Halifax Harbour have been identified as particularly vulnerable to a combination of sea level rise, higher tides and changes in storm intensity and frequency (Shaw et al., 1998). The Tantramar Marshes, the Truro flood plain and sections of the southern and eastern shores are also susceptible to flooding, erosion, or increased coastal instability. Saltwater infiltration of groundwater, threats to communication links and overtopping of dykes due to storm surges are also predicted in some areas. The construction of new dykes and the raising of existing ones will be costly. A sea level rise of 75cm has been predicted for Halifax over the next 100 years (Shaw et al., 1998).

3.3. Fisheries

Climate change is expected to have an impact on the distribution of fish species, migration patterns, arrival times, recruitment success, growth rates (through physiological effects), and changes in disease, food availability and predator abundance. Changes in temperature can have effects on fish growth, spawning and reproduction, distribution, abundance, migration, catchability, and availability. Changes in migration patterns and the timing of various aspects of fish life cycles may have a great impact on productivity in the fishing industry. Changes in the vertical temperature gradient of the water may also lead to changes in the ratio of pelagic fish to groundfish.

Paradoxically, global warming is predicted to produce colder, denser, less saline water off Nova Scotia in the long run as Arctic ice caps melt, possibly altering the course of the Gulf Stream and reducing the populations of certain fish species. Extremely limited knowledge of ocean response, fish life-cycles and environmental influences on fish prohibits definitive predictions of the effects of climate change on the fisheries. The importance of the fisheries both to the Nova Scotia economy and to the viability of coastal communities makes further research in this area imperative.

3.4. Ecosystems and Water Resources

Environment Canada's *Canada Country Study* notes that changes in temperature, greater variations in temperature, and shifts in the timing of seasons may change the normal characteristics of the hydrological cycle, creating problems for human and other species. Impacts may include habitat loss and decreases in the quantity and quality of water available for human use. Modifications of the ice regime with temperature increases may provide increased convenience to humans in some areas, but could disrupt some aquatic species that depend on the ice cover for winter survival. Changes in the evapotranspiration balance may lead to lower water tables and to the loss of wetlands. Wetlands, bird migration patterns and wildlife behaviour are all highly sensitive to climate change. Migratory birds will be particularly susceptible to climate change through loss of habitat with sea level rise, disruption of the timing of the birds' life cycle events and changes in migratory boundaries.

Other predicted costs include falling lake and groundwater levels, lower levels of dissolved oxygen in rivers and lakes, stresses on freshwater fish populations, and runoff damage to human infrastructure including dams, bridges and water supply. Predicted benefits include a major reduction in waterway ice jams and therefore a possible extended shipping season.

3.5. Agriculture

Atmospheric warming may have both positive and negative impacts on agriculture in the Atlantic Region. Increased temperatures may expand production of corn, soybeans, tree fruits and specialty crops. If increased precipitation occurs, it would help to offset effects of drought but may increase susceptibility to foliar-type fungal diseases, which thrive under moist conditions. At the same time, it may increase leaching of nutrients from fields, increase soil erosion and decrease the number of days available for fieldwork. Milder winters could improve the potential of alfalfa, clover, winter wheat, strawberries, tree fruits and grapes, in some areas.

In 1997, 1998 and 1999, Nova Scotia experienced unusually dry conditions that led to major economic losses for farmers. The 1998 drought cost between $30 and $50 million in lost crops and livestock and 1999 farm losses were estimated at $50 million (Wooley, 1999).

As noted, global warming could increase some crop yields, weeds and pest populations. Higher carbon dioxide levels will help fertilize plants and weeds, and increased ragweed concentrations may produce difficulties for allergy sufferers. Milder winters will also allow pests currently eliminated by the cold to survive. Pests of particular concern to Nova Scotia if winters become milder are the gypsy moth, the cereal-leaf beetle and the tarnish plant bug. Drier weather would increase the need for irrigation, a costly enterprise.

A range of estimates for Canada as a whole predicts a decrease in agricultural value of between 0.04% to 0.2% of national GDP annually in the event that atmospheric carbon dioxide concentrations double during the next century as predicted (Environment Canada ,1997c). This could mean a decrease of 2% to 10% of the current agricultural GDP in Atlantic Canada, or an annual loss of $20-$88 million (Environment Canada, 1997c).

3.6. Forestry

The IPCC (1996a) predicts that global warming will increase forest fire losses by 140% globally, with $1.8 billion of annual damages to OECD countries alone. It may also lead to changes in the distribution of tree species. One scenario predicts warmer winters and springs but cooler summers for the Maritimes. This could increase the growth rates of conifers, but late frosts or early extended thaws may be more damaging to hardwood species.

Environment Canada predicts that the Canadian forest industry will suffer, as new northern forest ranges will not mature fast enough to compensate for predicted southern range declines. Soil organic matter, an important CO_2 sink, will also decompose faster as temperatures rise, decreasing the carbon sink value of forests and releasing carbon into the atmosphere. Forest productivity in Atlantic Canada may increase under current climate change models, but fire, insect and disease outbreaks, as well as damage from wind-storms, are also expected to increase (Environment Canada, 1997c).

3.7. Socio-Economic Dimensions

While predictions of economic impact have not been made for fisheries, the sensitivity of the Atlantic Canada fishery to environmental factors makes it likely that there will be decreases in productivity and other disruptions to the fishery. Other socio-economic dimensions of climate change include impacts on marine transportation, on offshore oil and gas development, and on energy sources and demand.

Human health impacts of climate change include those caused by temperature extremes, extreme weather events, increase in vector-borne diseases, decreased water quality and quantity, and risks from increased ultraviolet (UV) radiation from the sun. UV radiation from the sun is expected to increase with global warming as warmer climates cool the stratosphere and intensify and increase the stability of the polar vortices. These effects are expected to cause the Antarctic ozone hole to become larger and last longer, to increase the likelihood of arctic ozone holes, and to slow down the recovery of the ozone layer on a global scale (Environment Canada, 2000a).

Environment Canada has issued warnings of up to a 5% greater than usual amount of UV radiation from the sun in the spring and summer months and advised citizens to take extra precautions to prevent unnecessary exposure to the sun (CBC Radio, April 15, 1999). In addition to its indirect impact on human health due to climate change, fossil fuel combustion produces pollution and acid rain, which have adverse impacts on the health of humans and other species.

Nova Scotia's billion dollar tourism industry is largely based on Nova Scotia's natural beauty and its relationship to the ocean. License plates proclaim the province as Canada's "ocean playground." Coastal erosion and the loss of coastline and other features that attract tourists will have a considerable impact upon the tourism industry. Remote travel destinations that depend on the nature of the current natural resources appear to be more at risk than cultural or historical facilities in urban areas. Activities in coastal areas, inland waters, parks and ski areas may all be affected. While Atlantic region data are not available, studies of the length of reliable ski seasons in Quebec suggest climate change impacts ranging from a 28% reduction in ski days to the total collapse of the industry (Environment Canada, 1994). It is reasonable to assume comparable impacts in Atlantic Canada.

Climate change is expected to produce up to 150 million *environmental refugees* world-wide by 2050, forced from their homes by sea level rise, soil degradation, flooding, erosion and drought. Just as Kosovo and East Timor produced costs for Canadian taxpayers, so disaster relief, refugees and other overseas impacts of climate change will produce costs here. In short, since Nova Scotia is not isolated from the world, global warming costs to Nova Scotians cannot be assessed solely by the direct impact of climate change on Nova Scotia alone.

4. Trends in Nova Scotia Greenhouse Gas Emissions

4.1. Trends in Greenhouse Gas Emissions: 1990-1997

Between 1990 and 1997, Canada's GHG emissions (in total CO_2 equivalents) rose by 13.5%, from 601,000 kilotonnes (kt) to 682,000kt. During this same period, Nova Scotia's GHG emissions increased by 3.1%, from 19,400kt to 20,000kt. In 1997, Nova Scotia's GHG emissions contributed 3% of the national emissions. On a per capita basis, Nova Scotians emit an average 21.4 tonnes CO_2 per year, compared with the Canadian average of 22.7 tonnes.[8]

Table 3 shows the kilotonnes (kt) of CO_2 equivalents produced by economic sector for 1997. Energy production and consumption account for 81% of GHG emissions nationally, and 92% in Nova Scotia. This is because Nova Scotia is heavily dependent on fossil fuels for its energy source. Figure 4 shows the major sources of GHG emissions in Nova Scotia in 1997. Electricity and steam generation, transportation and residential energy use together account for 76% of the total emissions.

[8] Based on Neitzert et al. (1999) and Statistics Canada's latest population estimates for Canada (30,750,100) and for Nova Scotia (941,000). Available at http:// www.statcan.ca/english/Pgdb/People/Population/demo02.htm.

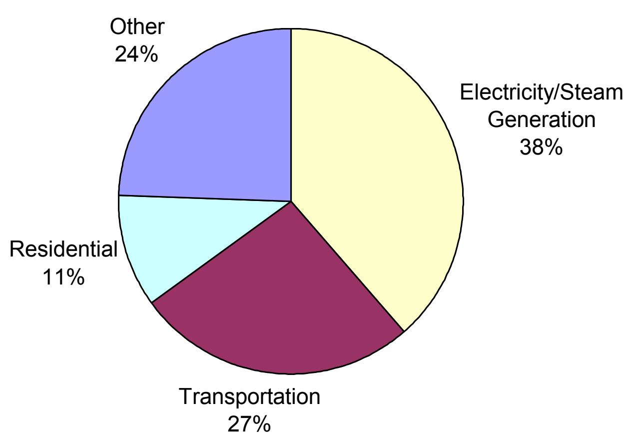
Table 3. Nova Scotia GHG Emissions (1997) by Sector

Greenhouse Gas Source Category	Total CO_2 Equivalent (kilotonnes)	Per Cent of Total
ENERGY:		
Fossil Fuel Industries	649	3.2%
Electricity and Steam Generation	7,720	38.6%
Mining	41	0.2%
Manufacturing	701	3.5%
Construction	30	0.2%
Transportation: Land Vehicles	4,252	21.3%
Transportation: Air/Marine/Rail	1,090	5.5%
Residential	2,100	10.5%
Commercial & Institutional	942	4.7%
Other combustion	250	1.3%
Fugitive Gases	690	3.5%
ENERGY TOTAL	**18,400**	**92.0%**
Industrial Processes	270	1.4%
Solvent & Other Product Use	14	0.1%
Agriculture	580	2.9%
Land Use Change and Forestry	15	0.1%
Waste Total	660	3.3%
TOTAL	**20,000**	**100%**

Notes: Totals may not always reflect sums of numbers in the table, due to rounding. 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 change in household behaviours and a reduction in residential energy use and GHG emissions can also reduce emissions in these other sectors.

Source: Neitzert et al., 1999.

Figure 4. Major Sources of GHG Emissions, Nova Scotia, 1997



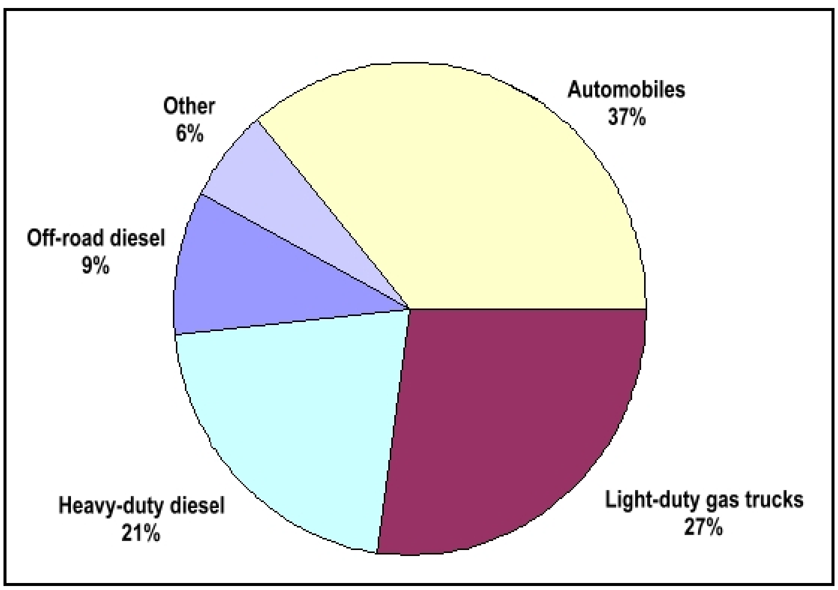
Source: Nietzert et al., 1999.

Within the transportation category, use of vehicles accounts for 80% of the 1997 emissions. Of the emissions from vehicular use, 72.7% is from automobiles, light-duty trucks and off-road diesel vehicles and 21% is from heavy-duty diesel vehicles (Figure 5). Between 1990 and 1997, there was an 8% decrease in GHG emissions from automobiles, a 22% increase in emissions from light duty gasoline trucks [which include vans and sport utility vehicles (SUVs)] and a 20% increase in those from off-road diesel vehicles.

These changes reflect both the increasing energy efficiency of automobiles and a greater use of SUVs, minivans, light trucks, snowmobiles and all-terrain vehicles. Between 1993 and 1997, the percentage of households owning automobiles remained stable at 82%. The percentage of households owning vans or trucks, however, increased from 27.7% in 1993 to 33.5% in 1997 (Nova Scotia Department of Finance, 1999). One SUV has about three times the impact on the environment of a small car (Wilson, 2001, p. 51).

There was a 13% increase in GHG emissions from heavy-duty diesel vehicles, reflecting greater use of trucking for freight. Passenger automobiles accounted for 37% of the emissions, or 1,573kt (Figure 5). Since the total passenger vehicle registrations in Nova Scotia in 1997 were 359,101 (Nova Scotia Department of Finance, 1999), this means that each vehicle is responsible for an **average 4.38 tonnes** of GHG emissions each year.

Figure 5. Nova Scotia's 1997 Emissions From Land Vehicles



Note that light-duty gas trucks include vans and SUVs

Source: Neitzert et al., 1999 and Nova Scotia Department of Finance 1999.

Globally, 25-30% of total human-caused emissions of carbon are the result of deforestation and land use change (Van Kooten et al., 2000). Estimates of emissions due to deforestation and land use change for Canada and Nova Scotia are characterized by a high degree of uncertainty – over 100% in almost every case (Nietzert et al., 1999).

4.2. Trends in GHG Emissions: Predictions to 2020

A recent study for Natural Resources Canada provides an update of projections for economic growth, population growth, energy use and GHG emissions, by province and by economic sector (Natural Resources Canada, 1999). Canada's economy is expected to show an average annual growth rate of 2.3% between 2000 and 2010, whereas the Atlantic provinces are expected to show a 2% annual growth rate, led by natural resource development in Hibernia and Sable Island.

Figures 6 and 7 illustrate the total projected GHG emissions for Canada and for Nova Scotia, projected to the year 2020. These projections take into account the policies and programs established under the Voluntary Challenge Registry and the National Action Program on Climate Change. Otherwise, policies that have not been implemented are not included in the projections. Thus, the projections reflect the "business as usual" (BAU) view, with the exception of the voluntary initiatives already mentioned.

While GHG emissions for Canada are expected to grow to 845 megatonnes (Mt) (million tonnes) by 2020 (a 40.6 % *increase* over 1990 levels), Nova Scotia's emissions are expected to grow to 22Mt by 2015 and then to decrease sharply to 18.5Mt by 2020 (a 4.7% *decrease* from 1990 levels). Nova Scotia's impending conversion to natural gas is primarily responsible for the projected decrease after 2015.[9]

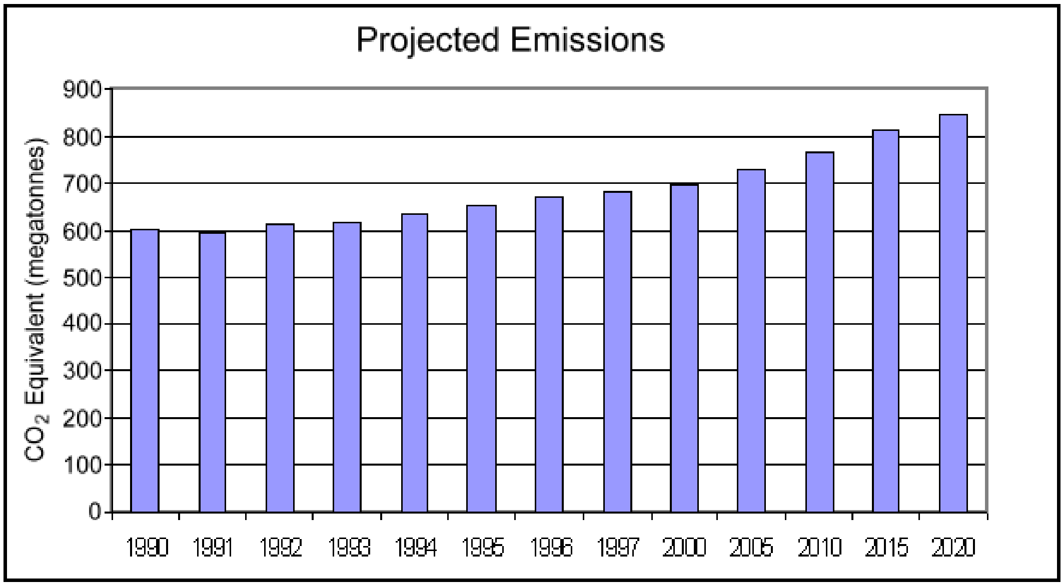
So what does this mean for reduction targets for Nova Scotia? Since we are dealing with projections based on uncertain assumptions about economic growth, fuel prices and other factors, the projections are also highly uncertain. However, they do provide a benchmark against which to assess relative progress. The fact that Nova Scotia emissions are likely to decrease significantly through the fortuitous conversion to natural gas does not mean that Nova Scotia should therefore do nothing about its GHG emissions. Climate change presents a global challenge of such magnitude that no responsible citizenry or government can remain complacent.

Even with widespread conversion to natural gas, Nova Scotia's per capita emissions (Figure 8) will still be among the highest in the world and about twice the Western European level. Per capita emissions for Nova Scotia, Canada and selected countries in 1995 are shown in Figure 9. Instead of assuming that natural gas conversion will absolve the province of responsibility, Nova Scotia has the opportunity to provide leadership in Canada, first by developing innovative ways of estimating the costs and benefits of alternative measures to reduce GHGs and then by taking concrete steps and practical actions based on these estimates.

Looking at our 2010 target year to fulfill the Kyoto agreements, Nova Scotians will still be producing over 20 tonnes of GHGs per person per year under a BAU scenario. This is still twice the West European rate and far short of even the modest Kyoto agreement targets, which would require a 3 tonne per capita reduction by 2008-2012 below the levels currently projected under the BAU scenario (see below).

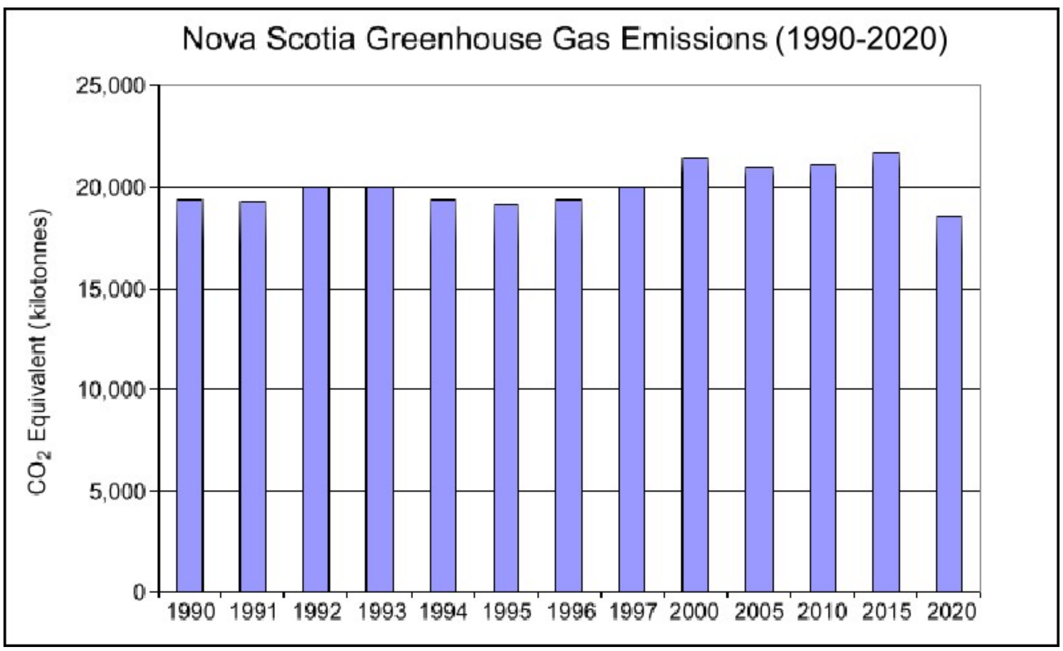
[9] For an analysis of the economics of greenhouse gas emissions associated with the use of Sable Island natural gas for electricity production in Nova Scotia, see Section 6.1 of this report and MacRae, 1997.

Figure 6. Canadian Projected Emissions to 2020



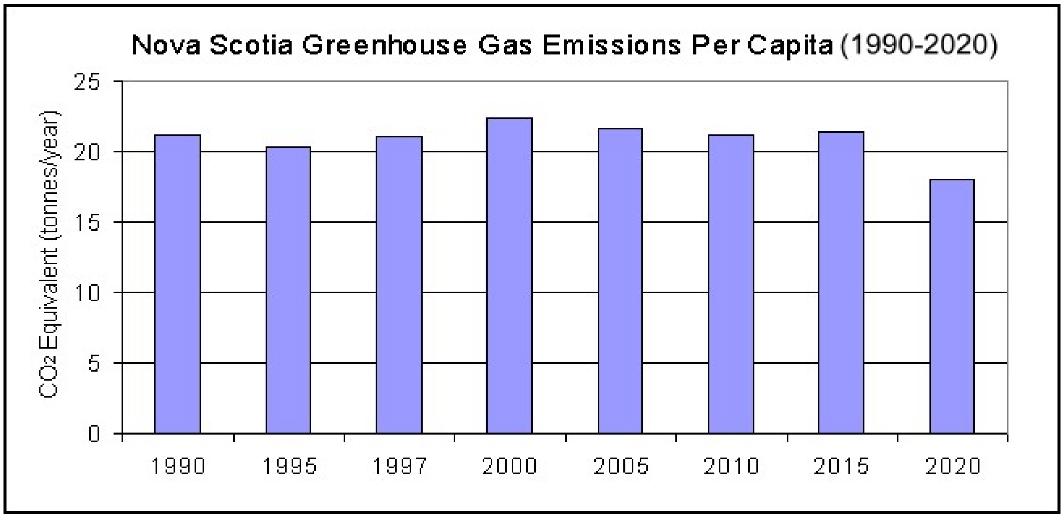
Source: Natural Resources Canada, 1999.

Figure 7. Nova Scotia's GHG Emissions Projected to 2020



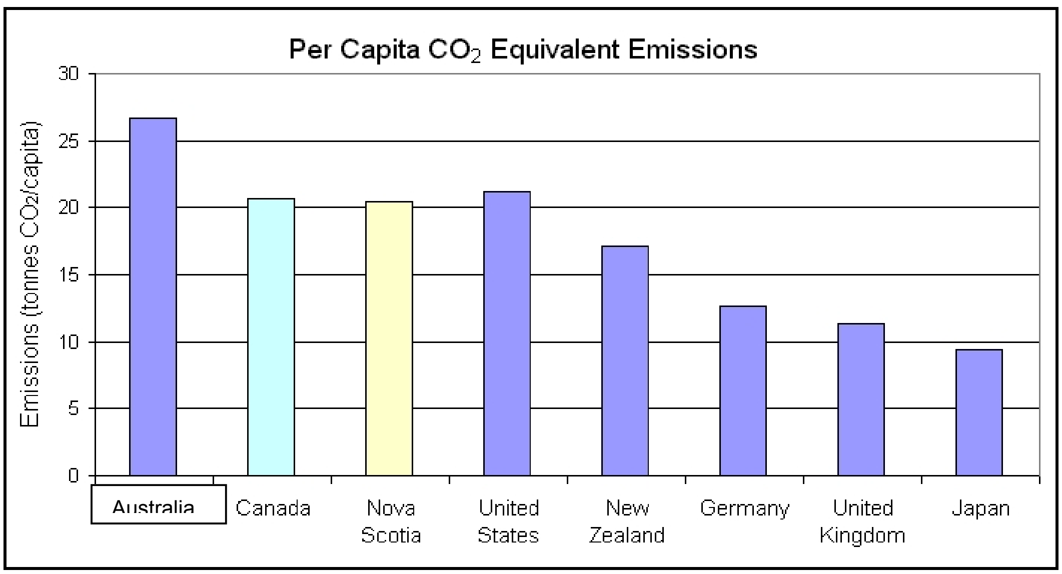
Source: Natural Resources Canada, 1999.

Figure 8. Nova Scotia Per Capita GHG Emissions Projected to 2020



Source: Natural Resources Canada, 1999.

Figure 9. Per Capita CO2 Equivalent Emissions from Selected Countries (1995)



Source: **Data**: Australia Institute, 1999.

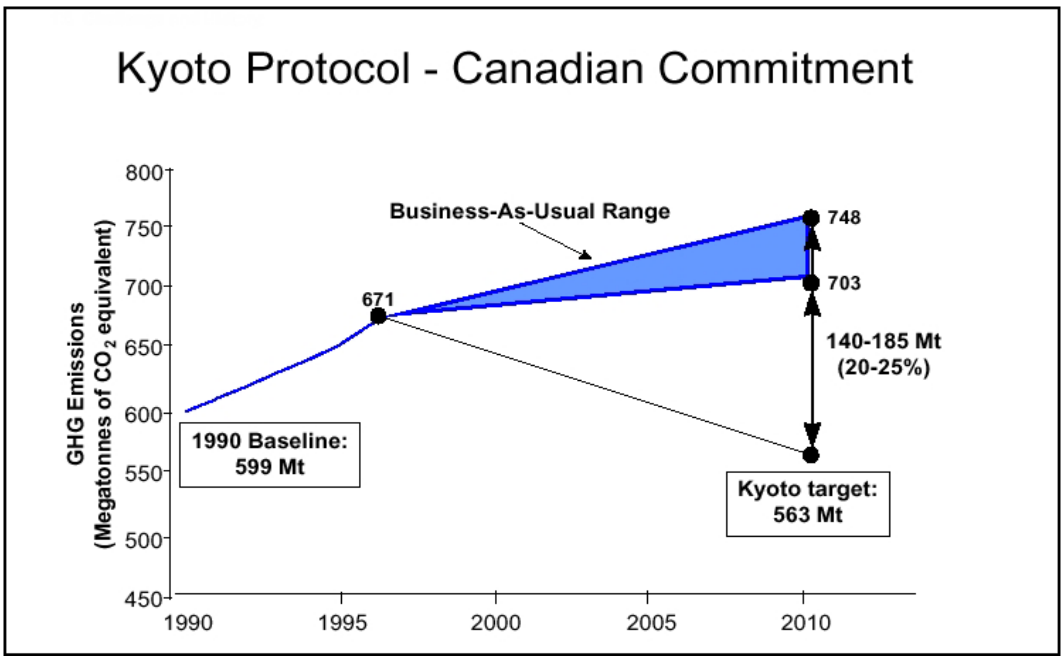
4.3. Targets for Emissions Reductions

Kyoto Targets

On a global scale, in 1990, the United States produced 18.8% of the world's emissions of primary GHGs; the former Soviet Union, 14.2%; Western Europe, 12.9%; China and neighbouring countries, 12.6%; and Canada, 2%. On a per capita basis, the breakdown was United States 25 tonnes per capita; Canada, 22.7; former Soviet Union, 16; Western Europe, 11; and China and neighbouring countries, 3.3 tonnes per capita (Neitzert et al., 1999). From these figures it is clear that the industrialized G8 nations with 12% of the world's population produce almost half of the world's GHG emissions. As the developing countries of the world become more developed, their GHG emissions will increase proportionately, if development continues along traditional lines.

In 1992, Canada and more than 150 other nations signed the UN Framework Convention on Climate Change (FCCC), which had as its objective that developed countries reduce their gross GHG emissions to 1990 levels by the year 2000. In December 1997 in Kyoto, Canada and 160 other countries agreed to a protocol in which the industrialized countries undertook to reduce their collective emissions of GHGs. Canada agreed to reduce its GHG emissions to 6% below 1990 levels by 2008-2012. If emissions continue unabated, and accounting for predicted economic growth, Canada will need to reduce its emissions by up to 25% by 2010 in order to meet this target (Figure 10). In other words, the longer the problem goes unabated, the greater the reduction that will be required.

Figure 10. Canadian Kyoto Targets



Source: Environment Canada, 1999.

It should be noted that these emission reduction targets will not reduce, nor even stabilize atmospheric CO_2 concentrations because of the persistence of GHGs in the atmosphere, because developing countries will continue to increase their GHG emissions sharply, and because the Kyoto levels for industrialized nations are still far in excess of sustainable historic emissions levels. In fact, under the Kyoto reduction targets, CO_2 concentrations in the atmosphere will continue to rise.

What the Kyoto targets can do is begin to slow that rate of GHG accumulation in the atmosphere and to postpone marginally some of the more drastic potential long-term impacts of climate change. Therefore, the Kyoto targets must be seen as interim measures designed to initiate a long-term process of reducing GHG emissions considerably further in succeeding years.

In early 1998 the Canadian federal, provincial and territorial Ministers of Energy and the Environment met and approved a process to engage governments and stakeholders in examining the impacts, costs and benefits of GHG reduction. The process by which allocation of reduction requirements will be made has not been established.

At a conference held in April 1998, this issue was examined in depth by Canadian non-governmental organizations, industry and government (Pembina Institute, 1998). Generally it was felt that an allocation by province on a proportional basis may not turn out to be fair or effective, and that allocation of reduction targets by industry may be more reasonable and less political. Some combination of the two may eventually be necessary. Another mechanism proposed was a per capita reduction, and allocation to the provinces on that basis.

Several guiding principles were established by the conference for allocating reduction targets:

- No source or region will be expected to bear an unfair burden;
- Every source and region will be expected to bear a fair share of the burden; and
- The allocation of responsibility will change over time as the structure of the economy changes.

The conference further recommended that early action be recognized; that government deal with the adverse impacts of mitigation on specific industries, communities and sectors of the society; and that an effective negotiating process be established that allows Canada to meet its Kyoto target and that constitutes a realistic deadline (within the framework of the 2008-2012 deadline). Concerns by stakeholders at the conference included maintaining Canada's economic competitiveness and ensuring that the approach is flexible, effective, efficient and equitable.

Recently, David Suzuki (2000) demonstrated that Canada could reduce GHG emissions by 50% in the next 30 years, using available technologies to increase energy efficiency and decrease dependence on fossil fuels. He demonstrates that this new "low carbon future" is the key to our national prosperity, rather than a burden to our economy. Indeed this proposition is supported by research in both Canada and the United States (Hawken et al., 1999 and Lovins, 1997).

What the national reduction target means for Nova Scotia is unclear. It is possible that Nova Scotia will be required to reduce its emissions to this level proportionately. It is also quite possible that the required reductions may be greater as Nova Scotia converts energy sources to natural gas. This means that there will be greater opportunities for reducing emissions in this province than in some other provinces, which already have natural gas in operation but have much higher emissions. It may be that per capita reductions, averaged over the nation, could be more equitable in the long run.

The recent US abrogation of its Kyoto Protocol commitment and responsibilities has made the need for responsible leadership more urgent than ever. If Canada, or Nova Scotia, can demonstrate in practice that sharp cuts in GHG emissions are compatible with economic prosperity, as Suzuki, Hawken, Lovins and others have argued, that example can provide a powerful alternative model for the world at this critical historical juncture.

Nova Scotia Targets

In the absence of provincial allocations of responsibility for reducing GHGs, this study uses a range of reduction targets to determine what might be feasible for Nova Scotia (Table 4). The minimum target to meet the Kyoto agreement is 6% below 1990 levels. Suzuki (2000) proposes a reduction of 50% from 1995 levels by the year 2030. When prorated to 10 years rather than 30, this amounts to roughly a 17% reduction from 1995 levels.

According to the latest figures, Nova Scotia's emissions are actually projected to decrease by the year 2020 due to natural gas conversion, but to increase in the intervening years under a BAU scenario (National Climate Change Process, 1999). Therefore, we compare targeted emissions with projected emissions for the year 2010 in order to determine the reduction required. Based on the range shown in Table 4, we chose a low reduction target of 2.9 million tonnes and a high one of 5.2 million tonnes, by the year 2010.

Table 4. Range of Reduction Targets for GHG Reduction in Nova Scotia by 2010

Reduction Target	Reason	Result: Total Emissions in 2010 (megatonnes)	Projected for 2010 – BAU (megatonnes)	Total Reduction Required in Year 2010 (megatonnes)
6% below 1990	Minimum Kyoto	18.2	21.1	2.9
17% below 1995	50% by 2030, prorated to 2010 (Suzuki, 2000)	15.9	21.1	5.2

5. Cost Estimates of Nova Scotia's Greenhouse Gas Emissions

The three main cost categories commonly associated with climate change are (Rothman et al., 1999):

1) control or mitigation costs – the costs of reducing the impact of climate change through actual reduction of GHG emissions;

2) adaptation costs – the costs of adapting to the impacts of climate change that are not avoided by mitigation; and
3) residual (or damage) costs – the cost of residual climate change impacts after adaptation.

Control costs, adaptation costs and residual (damage) costs are all examples of what the United Nations (1993) *Handbook of National Accounting: Integrated Environmental and Economic Accounts* defines as defensive expenditures:

> *"The actual environmental protection costs involved in preventing or neutralizing a decrease in environmental quality, as well as the actual expenditures that are necessary to compensate for or repair the negative impacts of an actually deteriorated environment."*

Separating out such expenditures (which contribute to the GDP and are conventionally and mistakenly interpreted as enhancing welfare) is a fundamental principle of the GPI.[10]

In this Chapter, we are interested in comparing the costs that would be incurred if no mitigation or adaptation took place to the costs of controlling or mitigating climate change through reducing GHG emissions. Therefore, we will compare only these two categories of costs:

1) damage costs (costs of impacts of climate change assuming no mitigation measures) and
2) control costs (costs of reducing or controlling GHGs).

In each case, the important parameter and common metric is the marginal cost of one tonne of CO_2 emissions. Adaptation costs are not quantified in this analysis, although their implications are briefly considered in Section 5.7.

The authors acknowledge that this very simple comparison of damage and control costs cannot assess actual economic impacts within a particular region nor the net benefits and costs, primarily because all significant co-benefits of GHG reductions are not included in the equation. Indeed, it is a fundamental principle in the GPI that a full range of social, economic and environmental benefits and costs must be considered in any policy analysis. In the case of GHG emissions, studies have shown that emission reductions produce a wide range of concomitant savings that substantially reduce gross mitigation or control costs.

For example, GHG reductions in the transportation sector have been shown to produce a wide range of savings in avoided energy costs and air pollution impacts, and reduced accident, road maintenance, capital and policing expenditures. Indeed, the use of gross mitigation costs without consideration of such savings and co-benefits can be conceptually misleading because it implies that a preventive policy measure with wide-ranging social, economic and environmental impacts is analogous to an end-of-pipe site-specific control measure like scrubbers on smoke-stacks which have the sole purpose of reducing pollutant emissions.

For this reason, and in order to demonstrate an economic impact analysis that *does* include co-benefits, this study includes a full-cost accounting application of the GPI methodology to an

[10] For more details on "defensive expenditures," see **GPI***Atlantic*, 1998.

actual GHG emission reduction scenario (Appendix D). That case study shows that a 10% switch from road to rail in the freight transport sector will produce a *net* saving or benefit of $10 million a year to Nova Scotia, even when "control costs" are included. **GPI***Atlantic* strongly recommends that this methodology, including the GMI described in Appendix D, be applied to other GHG emission reduction scenarios.

Financial constraints did not permit more such policy applications for this report, and so it is important to stress that the gross control cost estimates adapted from the economic literature on GHG reductions should *not* be interpreted as reflecting actual net costs or benefits to society, *nor* as reflecting the GPI full-cost accounting methodology. A limited set of co-benefits has been included, as specified, in some of the estimates given below, but Appendix D demonstrates the need for expanding that important part of the equation. Beyond the very general range of estimates in this Chapter, therefore, policy makers will definitely require more specific cost-benefit studies of proposed GHG reduction measures of the type demonstrated in Appendix D, in order to make informed decisions.

In this Chapter, accounting for gross damage and control costs according to standard economic estimates to date allows for at least a crude, preliminary estimate of the potential economic benefits of emission reductions. Understanding the potential long-term costs of damages caused by climate change can at least help policy makers balance short-term reduction costs (often the *sole* policy consideration) against the long-term benefits of damage avoidance.

Though this study does not assess the costs of adapting to a changing climate and avoiding potential damage, it should be noted that some such costs can be enormous. Such costs might include construction of dykes; water course diversions; engineering works to protect coastlines from sea level rise and low lying lands from flooding; and irrigation projects to prepare for droughts and drier summers. These costs would be justified in economic terms if they prevented higher damage costs such as storm and flood losses, clean-up and restoration costs, disaster relief, or subsidies to drought-stricken farmers. However, the high capital costs of many adaptation measures put them out of the reach of any but the wealthiest nations.

At some future point, when GHG emissions have been reduced to a reasonable level, the question of what an environmentally sustainable level of emissions is must ultimately be addressed. Currently, however, because of the long lifetime of some GHGs in the atmosphere, even the most drastic conceivable reductions in global GHG emissions would only begin to stabilize atmospheric concentrations of GHGs. It would take many centuries to return to pre-industrial levels.[11] Because global warming has *already* begun, every additional tonne of GHGs emitted must therefore be considered a cost to society. For that reason, in determining costs of GHG emissions to the global economy, 100% of emissions are considered a cost. (If we were still at pre-industrial GHG concentrations, we could count only *excess* emissions as a cost.)

[11] Because methane has a far shorter atmospheric life span (9-15 years) than carbon dioxide (100-200 years), a reduction in atmospheric concentrations of methane could begin very quickly, even though it would take much longer to reduce overall levels of GHG concentrations. See Table 1 and Appendix Table 1 for characteristics of major greenhouse gases.

In other words, there is at present no environmentally sustainable level of GHG emissions. It is clearly not feasible to have zero emissions in the foreseeable future. Nevertheless, a cost-benefit analysis from the perspective of environmental sustainability must currently count every reduction in emissions as a benefit, an assessment that can then be balanced against the economic impacts of alternative reduction scenarios. Another way of explaining this perspective is simply that the cost-benefit equation at this historical juncture answers the question of *which* reduction option can achieve the greatest reduction at the least cost. Acceptance of the IPCC assessment, of the science of climate change and of the precautionary principle precludes the misuse of cost-benefit analysis to assess *whether* GHG reduction is a viable option. An apt analogy is that cost-benefit analysis can be properly used to assess the cost-effectiveness of alternative health care delivery mechanisms but not to assess *whether* health care should or should not be available to the ill.

Attaching a cost to total GHG emissions can usefully serve to demonstrate the potential benefits of reducing emissions. It must also be noted that the cost estimates are based on global climate change and therefore assess impacts on the global economy rather than on the Nova Scotia economy in particular.

Since we are placing values on both the control and damage costs for GHG emissions, we must state clearly the principles upon which these values are based. In the case of the GPI, the values are based on sustainability, the well-being of future generations, and on the precautionary principle. These principles have a significant impact on the choice of assumptions used in deriving dollar values, as will be discussed later.

5.1. A Note on Discounting

One assumption that strongly affects results is the choice of a discount rate, which, in assessing the cost of climate change, is the ratio of present value to future value. Discounting is the process by which total social costs and benefits in different years are 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 show the costs of a changing climate over time in present day dollars.

Two generally 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 resources can be used now to increase wealth through *investment*, the resources have greater value now than in the future. This type of measure works well with manufactured capital and short-term (20-30 year) projects, but is generally not appropriate when assessing damages to natural capital over longer time periods. The SRTP is based simply on the idea that individuals prefer *consumption* now rather than in the future and therefore a particular resource would have greater value to the 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 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 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 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, 1997b).

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 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 well-being of the present generation.

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.

Despite the philosophical and scientific arguments that favour a zero discount rate, monetary valuations that compare natural resource values with produced capital values nevertheless require that some discount rate be used. Without discounting, no meaningful assessment of trade-offs with goods and services traded in the market economy is possible. Therefore, even Bein and Rintoul's (1999) high-end $1000/tonne damage cost estimate (see below) is derived using a 1.5% SRTP discount rate.

Applying the view of sustainable development to debates over long-term environmental issues, such as global climate change, inevitably requires focus on intergenerational equity and the rights of future generations. That perspective is particularly appropriate when project impacts may lead to irreversible outcomes.

At the same time, because future generations are expected to continue to experience economic growth, application of some discount rate is also generally deemed appropriate. Assuming a future growth rate in per capita income of 1% to 2% annually, a discount rate of 1.5% to 3% has been suggested (National Center for Environmental Decision-Making Research, 2000). In the transportation study (Appendix D), a range of discount rates was used because specific pricing was being examined. In deriving cost estimates for overall GHG emissions, however, we have chosen estimates that use a low discount rate (1.5%), in accordance with the reasoning described.

5.2. Damage Costs: Methodology

Note to readers: Unless otherwise specified, all monetary values in this report are in Canadian constant 1997 dollars. However, first citations of monetary estimates from the literature generally specify both the particular year and currency used by the author.

Estimating the costs of climate change to the world economy is fraught with difficulties. The first difficulty is determining the time frame over which the damages will be estimated. A second challenge is to decide on a projection of likely GHG emissions for that time frame and the associated projected rise in temperature and increase in climate variability. Obviously, estimates of potential damage costs depend on the baseline emissions used and the time frame examined.

Even when these parameters have been set, the valuation of non-market benefits and costs, such as changes in the services provided by natural ecosystems, typically produces a very wide range of estimates. National and regional differences must also be accounted for and appropriate discount rates must be chosen. With all these considerations, it is not surprising that estimates of climate change damage vary by several orders of magnitude.

Damage costs of emissions, called "shadow prices," are based on estimates of the cost of the wide range of potential effects of global warming (Bein, 1997) and can be as high as $1,000 per tonne of CO_2 emitted (C$1995). At the lower end of the scale, Cline (1995) gives a range of $20-$50 per tonne of CO_2 emitted (US$1990) as the cost of environmental damage from climate change.

A brief review of pertinent literature is provided here, to demonstrate the range of damage cost estimates which provide the basis for the values used in this report.

The IPCC (1996) presented a range of monetized damage estimates based on a doubling of atmospheric CO_2. Table 5, taken from the IPCC report, provides a summary of the estimates of potential climate change damages to the US economy, both in billions of US dollars (1990) and as a percentage loss in GDP.

All authors looked at the potential results of a doubling of atmospheric CO_2 concentrations from pre-industrial levels but assumed varying increases in temperature as a result of the doubling. The estimates do not indicate a particular year in which the doubling is anticipated, although it is generally estimated the actual doubling of atmospheric CO_2 concentrations will occur around 2050-2060. Thus, these estimates are based on a relatively short time frame.

Estimates of economic losses for developing countries run as high as 8.6% of GDP for Africa and Southeast Asia. It should be noted that these estimates refer to the mid range of warming expectations (increase in temperature of 2.5^o-4^oC) and that the corresponding damages for upper limits of warming predictions would be much higher. Cline (1992) estimated a reduction of 6.1% in world GDP based on a 10^oC warming. The upper limit warming prediction of the IPCC (2001) is 5.8^oC. Application of the precautionary principle argues for the use of upper limit temperature estimates and correspondingly higher damage cost estimates than the middle range values in

Table 5. This is the same logic used to argue that public health policy should be based on the upper limits of disease risk estimates to ensure public safety.

Table 5. Monetized Damage to Present US Economy From Doubling of CO_2

Damage Category	Monetized Damage (US$1990 billions annual damage)				
	Cline, 1992 (2.5°C)	Fankhauser, 1995 (2.5°C)	Nordhaus, 1991 (3.0°C)	Titus, 1992 (4.0°C)	Tol, 1995 (2.5°C)
Agriculture	17.5	8.4	1.1	1.2	10
Forest Loss	3.3	0.7	Small	43.6	
Species Loss	4.0	8.4			5.0
Sea Level Rise	7.0	9.0	12.2	5.7	8.5
Electricity	11.2	7.9	1.1	5.6	
Non-electric heating	-1.3				
Human amenity					12.0
Human morbidity					
Human life	5.8	11.4		9.4	37.4
Migration	0.5	0.6			1.0
Hurricanes	0.8	0.2			0.3
Construction					
Leisure Activities	1.7				
Water Supply: - availability - pollution	7.0	15.6		11.4 32.6	
Urban infrastructure	0.1				
Air Pollution -Trophospheric ozone	3.5	7.3		27.2	
Mobile Air conditioning				2.5	
TOTAL	**61.1**	**69.5**	**55.5**	**139.2**	**74.2**
Loss as % of GDP	**1.1**	**1.3**	**1.0**	**2.5**	**1.5**

Note: Billion US $1990 of annual damage based on the estimated size of the US economy in 1998, but referring to the year in which a doubling of CO_2 actually occurs. Doubling refers to a doubling of pre-industrial atmospheric CO_2 concentrations.

Source: Adapted from IPCC, 1996a.

Several criticisms of the IPCC damage cost estimates have focused on the work of individual authors whose work was included in the assessment. Meyer and Cooper (1995) have pointed out that damage costs of global climate change are long-term, highly uncertain and include both tangible and intangible costs. They comment that the IPCC figures are based on several flawed assumptions:

- that the global economy will have progressed from the present to the year 2050 in a BAU manner;
- that the global temperature will have risen by a mean figure of only 2.5°C, and
- that a "snap-shot" of a single year's damages (the year that CO_2 doubling occurs), has utility without showing the cumulative assessment of damages for the intervening years.

Using Fankhauser's raw damage estimates as a starting point, the authors derive a damage cost figure for the year 2050 in a range of 12% to 130% of Gross World Product. The loss for OECD countries is in the range of 0.6% to 17% of Gross Regional Product (GRP), while for countries outside the OECD, the range is from 25% to 250% of GRP. Accumulated losses between 1990 and 2050 would then be between $50 and $600 trillion. The calculations are based on several assumptions concerning (a) the range of temperatures which may plausibly occur in 2050, and (b) the fact that costs are expected to rise very slowly with the first increment of temperature change and to rise more quickly as the temperature continues to rise.

With respect to the IPCC figures, Meyer and Cooper point out the following:

- "Willingness to Accept Compensation" for damages might be a more appropriate estimation tool than "Willingness to Pay" surveys;
- It is possible that by 2050, GHG concentrations in the atmosphere may have more than doubled, and thus the temperature increases and climate variability might be higher;
- No climate sensitivity, feedbacks or uncertainties were included in the calculations; and
- Deaths due to malaria and malnutrition should not be omitted from the calculations.

Nordhaus' (1991) estimates are based on the Dynamic Integrated Climate and the Economy Model (DICE). Costanza (1996) comments on several deficiencies in this model:

- The model assumes that economic growth is not limited by natural resource capacity or environmental changes;
- Natural capital values are missing from the model;
- The relationship between global mean temperature change and damage is oversimplified and does not include feedbacks between climate change and ecosystem changes or between ecosystem changes and economic performance;
- Results from the DICE model are globally averaged and do not allow for climatic surprises in particular locations; and
- The model assumes that consumption equates with general welfare.

Bein and Rintoul (1999) have adjusted previous estimates of damage costs (Cline, 1995) to bring them into line with the precautionary principle. According to the precautionary principle, when the precise impact is uncertain but potentially serious or irreversible, high rather than low estimates of damage help to avoid unreasonable risks.

Bein and Rintoul describe the consequences of climate change as first, second and third order impacts. First order impacts are the direct consequences for environmental processes linked to the atmosphere, affecting virtually all natural processes and conditions. The largest first order impacts are non-monetary. Second order impacts occur in those economic sectors most dependent upon natural resources, such as forestry and fisheries. Third order impacts are ripple effects from the first and second order impacts, such as employment and production losses, loss in recreational and amenity values, and impacts on suppliers to the resource sectors.

Bein and Rintoul (1999) have shown that adjusting previous damage estimates by correcting two basic values – the service value of wetlands (SVOW) and the value of statistical life (VOSL) can result in values that differ from the original by several orders of magnitude. The authors point out that if other habitats lost or degraded by climate change were evaluated, the total monetized damages would increase even more. The authors estimate that the service value of habitats currently preserved in developed countries by law is comparable to their national product. Canada, for example, protects 70 million hectares by law. Assuming a value of $10,000 per hectares in annual economic benefits from an average habitat being preserved (Bein and Rintoul, 1999), the annual worth of these reserves would be $700 billion, or about the order of Canada's GDP. Much of this value could be lost or altered by climate change, but is currently excluded from many damage cost models.

According to Bein and Rintoul, the wide variation in estimates of climate change damage are largely due to the following practices:

- Ignoring or arbitrarily valuing externalities, non-market values, and some of the values of natural resources;
- Measuring willingness to pay for saving existing natural assets, instead of the higher willingness to accept compensation for their loss;
- Using the values of present society to represent future values;
- Using the opportunity cost of capital instead of the social rate of time preference in discounting of long-range impacts; and
- Conducting analysis for "best guesses," which in fact may only be samples from a large set of possibilities.

In deriving a shadow price, the common measure is the marginal damage of one tonne of carbon emitted into the atmosphere. The values are very sensitive to the choice of discount rate, with lower discount rates producing higher shadow prices. Bein and Rintoul (1999) have adjusted the calculations of Cline (1995), which were based on a moderate damage case. The authors expanded Cline's assumptions as follows:

- The horizon year for climate change damages was extended from 2276 to 2500;
- The range for the climate sensitivity parameter (expected mean global temperature rise from a doubling of pre-industrial CO_2 equivalent concentration of all GHGs) was extended from the central estimate of 2.5^{o}C to a range of 2.5-4.5^o In light of the latest IPCC (2001) assessment of a 5.8^{o}C upper limit, even Bein and Rintoul's 4.5^{o}C upper limit may be conservative;
- It was assumed that 2.5^{o}C warming occurs by the year 2060 (unchanged from Cline).
- Benchmark damage up to 4% of GDP for developed countries and up to 8% of GDP for developing countries, as compared with Cline's assumptions of 1.4-2.5% for developed countries and 1.8-4.0% for developing countries;

- Discount rate (SRTP) is allowed to vary around 1.5%, whereas Cline assumed a point estimate of 1.5%;
- The damage function exponent has a range of 1.3-3.2, which means that the damage increases by a bit more than the cube of the temperature increase over pre-industrial levels, whereas Cline's range was 1.3-3.0; and
- No constraint is put on the size of the impact, whereas Cline put an upper limit on the GDP-based measure of impacts.

These assumptions produce a dramatically higher shadow price estimate of potential damage costs of about $1000 (C$1995) per tonne of CO_2 compared to Cline's estimate of just $20 to $50 (US$1990) per tonne. This value corresponds to a high damage estimate and relatively high climate sensitivity at a discount rate (SRTP) of 1.5%. **GPI***Atlantic* uses this value of $1,000 per tonne (C$1995) to represent an upper limit for the potential damage cost of emissions. According to Bein and Rintoul, such an estimate most nearly approximates the application of the precautionary principle to the derivation of shadow prices, because higher prices account for the possibility of severe and irreversible damage from climate change.

Although the precautionary principle does imply adherence to the higher estimate, this Chapter nevertheless provides a range illustrating both low and high cost estimates for the potential damage caused by one tonne of CO_2 equivalent emissions. For the low-end cost, we use Cline's (1995) low value of $20/tonne (US$1990) and for the high value, Bein and Rintoul's (1999) estimate of $1,000 per tonne (C$1995). Although these are rough estimates, they are converted here to 1997 Canadian dollars in order to be consistent with the rest of the report. In 1997 Canadian dollars, these low and high end estimates become $38 and $1,040 respectively.

5.3. Damage Costs of Nova Scotia's GHG Emissions

It must be emphasized that in calculating damage costs, we are not implying that Nova Scotia's GHG emissions cost the Nova Scotia economy a certain amount per year. First, climate change is a global phenomenon. The impacts of Nova Scotia's GHG emissions are therefore of a global nature. Secondly, carbon dioxide emitted today remains in the atmosphere for 100-200 years, continuing to warm the planet and create potential damage generations from now. Damage costs are therefore long-term and are estimated, in the case of the $1,040/tonne estimate, over a 500-year time span. Thus the marginal cost of one tonne of carbon emitted in Nova Scotia today may reflect damage a hundred years hence by virtue of its contribution to the ongoing accumulation of GHGs in the atmosphere.

Table 6 shows the calculation of potential damage costs of Nova Scotia's 1997 GHG emissions based both on Bein and Rintoul's (1999) estimate of C$1,040/tonne and on Cline's C$38/tonne estimate. As Table 6 demonstrates, Nova Scotia's 1997 emissions will cost the global economy over $20 billion dollars at the high end, or more than $3 for each person alive on the planet today. At the low end, the damages will cost $760 million. It is also clear from Table 6 that 92% of these damages are due to energy-related uses.

Table 6. Global Damage Costs of Nova Scotia 1997 GHG Emissions and Costs Estimates by Sector

Greenhouse Gas Source	Total CO_2 Equivalent (kilotonnes)	Cost (C$1997 millions)	
		$1,040 per tonne	$38 per tonne
ENERGY:			
Fossil Fuel Industries	649	$675	$25
Electricity and Steam Generation	7,720	$8,029	$293
Mining	41	$43	$2
Manufacturing	701	$729	$27
Construction	30	$31	$1
Transportation: Land Vehicles	4,252	$4,422	$162
Transportation: Air/Marine/Rail	1,090	$1,134	$41
Residential	2,100	$2,184	$80
Commercial & Institutional	942	$980	$36
Other combustion	250	$260	$10
Fugitive Gases	690	$718	$26
ENERGY TOTAL	**18,465**	**$19,204**	**$702**
Industrial Processes	270	$281	$10
Solvent & Other Product Use	14	$15	$1
Agriculture	580	$603	$22
Land Use Change and Forestry	15	$16	$1
Waste Total	660	$686	$25
TOTAL	**20,000**	**$20,804**	**$760**

Note: Totals may not always reflect sums of numbers in the table, due to rounding.

Figure 11 shows the relative costs of Nova Scotia's GHG emissions by sector using the low estimate and Figure 12 shows the costs using the high estimate. From these figures, it is seen that the greatest global damage costs are from electricity and steam generation, followed by transportation and residential energy use.

Per capita emissions for 1997 in Nova Scotia were 21.4 tonnes CO_2 equivalent per year, (based on population estimates released by Statistics Canada, September 2000), translating into a global damage cost per Nova Scotian of $813-$21,400. Cumulative GHG emissions in Nova Scotia over the past ten years add up to 260,300kt CO_2 equivalents, which produces a cost range of $9.9 billion to over $260 billion in long-term global damages, or up to $43 for each global citizen. The enormity of these cost estimates reflects the fact that they refer to *long-term, global, asset losses* and thus cannot be reasonably compared to current domestic income assessments.[12]

[12] For an interpretation of the enormity of these costs, the magnitude of potential climate change damages and the problems in comparing these costs with GDP and per capita income, please see Section 5.3.

Figure 11. Global Damage Costs of Nova Scotia GHG Emissions by Sector, Based on Cost of $38/tonne (C$1997 millions)

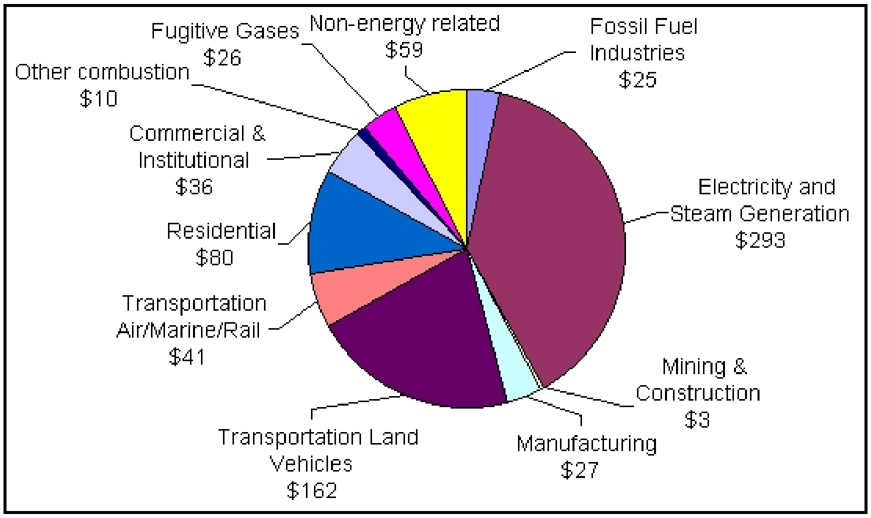


Figure 12. Global Damage Costs of Nova Scotia GHG Emissions by Sector, Based on Cost of $1,040/tonne (C$1997 millions)

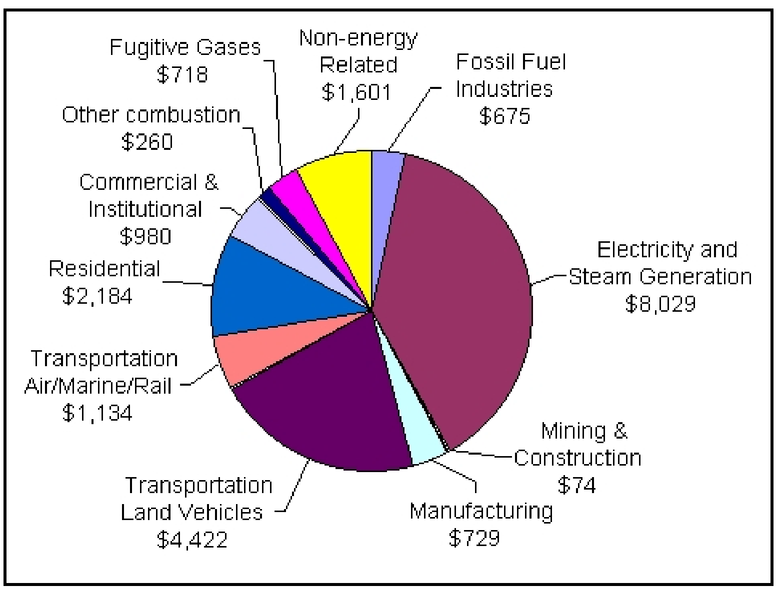
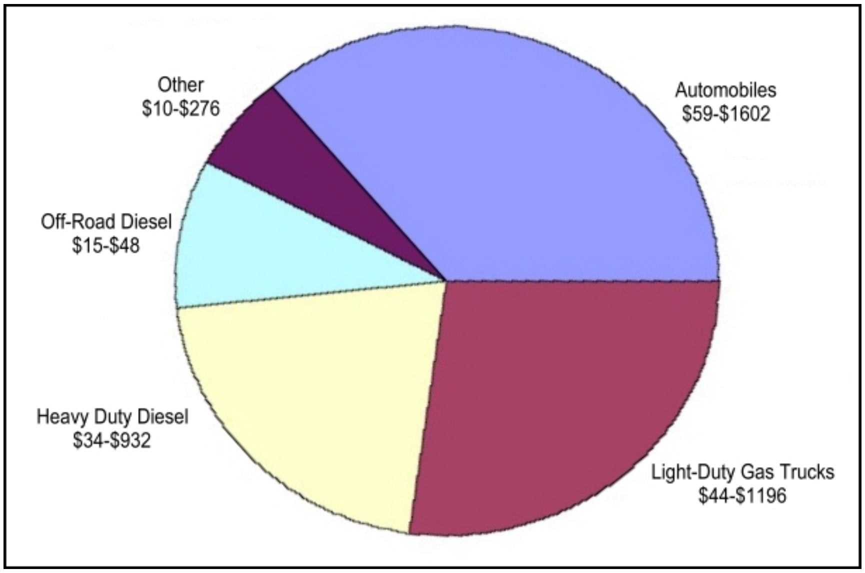


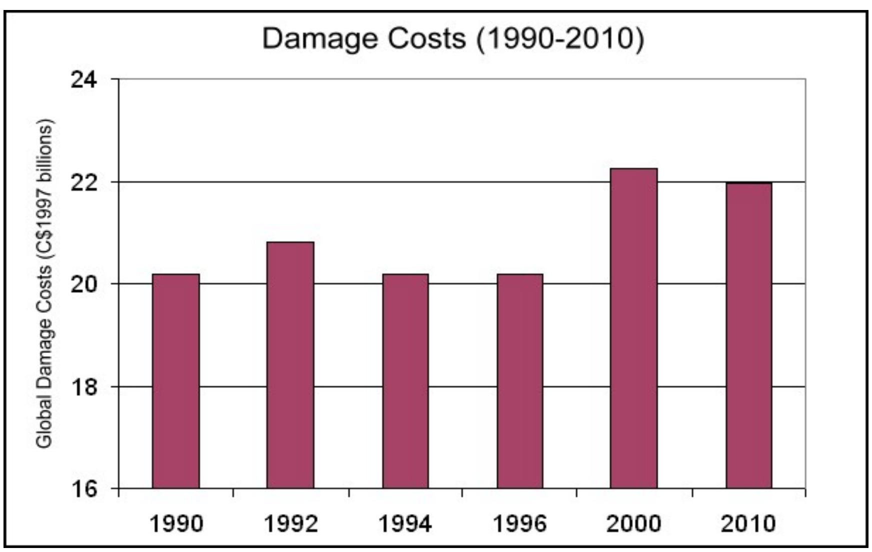
Figure 13 presents damage costs of emissions from land transportation vehicles, which account for over 80% of Nova Scotia's GHG transportation emissions. By far the heaviest cumulative damages come from automobiles, followed closely by light duty gasoline trucks. On a per vehicle basis, however, minivans, SUVs and light trucks produce considerably greater GHG damage costs than small fuel-efficient cars. Total emissions from Nova Scotia's land vehicles in 1997 will produce damage costs estimated at $162 million to $4.4 billion.

Figure 13. Global Damage Costs of Nova Scotia (1997) GHG Emissions From Land Vehicles (C$1997 millions)



Projections into the future (Figure 14) show the increasing trend of global damage costs of Nova Scotia's GHG emissions. By the year 2010, using Bein and Rintoul's $1,040/tonne high-end estimate, global damage costs will have risen to 22 billion dollars. With conversion to natural gas, the damage costs due to Nova Scotia's GHG emissions in 2020 are projected to decline to $19.4 billion for that year's emissions. On a per capita basis, that is still twice the estimate for Western Europe and thus gives no reason for complacency.

Figure 14. Estimated Global Damage Costs of Actual and Projected GHG Emissions for Nova Scotia, 1990-2010, Based on $1,040/tonne



Note: C$1997 billions.

Local Emissions and Global Impacts

It must be repeated here that these damage costs do not reflect damage to Nova Scotia. This point may be confusing. Because we are looking at *global* impacts of *local* emissions, we cannot compare damage cost estimates attributable to any one jurisdiction with the GDP of that same jurisdiction. The high-end estimate of $22 billion in potential global damage attributable to Nova Scotia's projected GHG emissions therefore cannot be compared to the Nova Scotia GDP (a measure of economic activity over one year), because the damages are inflicted on the world and over a very long period of time.

Climate change damage attributable to Nova Scotia is the result of Nova Scotia's contribution to global emissions. Per capita, Nova Scotians, like other North Americans, contribute much higher emissions than the average global citizen. The much smaller per capita GHG emissions in developing countries mean that climate change due to *their* present emissions will take a correspondingly smaller toll on Nova Scotia's economy compared to per capita damage contributions from high emitters of GHGs. Another way to think of this is that we are presently ***exporting*** climate change damage costs from Nova Scotia to developing countries with much smaller per capita emissions. This concept is explored in more detail in the GPI Ecological Footprint analysis (Wilson, 2001).

Future material development and population growth in developing nations will, however, dramatically increase their GHG emissions and, therefore, their contribution to climate change and to potential damage costs. Even if per capita emissions in developing countries were to remain low, the high population growth rates of these countries will ensure an increasingly significant impact on climate change. Ultimately, it is not per capita emissions but total global emissions that will change the earth's climate, and an increasingly large proportion of those total emissions in the coming decades will come from developing countries.

The massive size of potential GHG emission damage costs prompts consideration of a very interesting issue of principle and ethics: Do we as Nova Scotians take responsibility for the potential damage caused *globally* by our emissions here? Or do we concern ourselves only with the potential *local* damages caused here by global emissions, including our own? The high-end damage cost presented in this Chapter ($22 billion based on estimated year 2000 emissions) clearly reflects the former assumption and is in line with basic GPI principles, which include equity as a core component of the index. Taking full responsibility for the potential $22 billion in global damages caused by our year 2000 emissions means that we value human life and property in other parts of the world equally to our own, now as well as over the centuries-long horizon of GHG damage cost analyses.

The more parochial and self-centred view considers damage costs at a much lower level – up to 4% of GDP in developed countries (Section 5.1), or $800 million for Nova Scotia. That view is problematic not only because of its failure to take responsibility for the high proportion of global damages caused by emissions in developed countries, but also because it does not account for the process of climate change itself.

The lower damage cost estimate (up to 4% of GDP) used by some analysts is a hypothetical "snap-shot" conceived for a "scenario" of expected damages at a time when atmospheric GHG concentrations reach about twice the pre-industrial level, probably between 2050 and 2100. *But* climate change will go on *after* that "snap-shot" moment and even if atmospheric GHG concentrations are stabilized at that very high level. Just as a rock let loose keeps rolling down a slope, the GHGs *already* in the atmosphere will continue to warm the planet year after year in addition to those emitted in succeeding years.

Though still massive, *local* Nova Scotian damages from *global* emissions are a very small portion of the *global* damages inflicted by *local* emissions. To account for this huge difference, it would be necessary to have a *spatial* discount rate to assess the importance we assign to Canadian interests as opposed to the needs of other global citizens, just as we currently have a *temporal* discount rate (OCC and STRP) to reflect the precedence we give to our own welfare over that of future generations. The notion of "net present value" in conventional discounting, becomes "net local value" from a spatial or geographic perspective.

From an ethical perspective, high *spatial* discount rates can be considered a measure of narrowness or selfishness, while lower ones reflect a commitment to greater geographical equity. Similarly lower *temporal* discount rates reflect a greater commitment to inter-generational equity. A zero spatial discount rate reflects a high degree of global consciousness that values distant global citizens as our own neighbours, just as a zero temporal discount rate puts our children's well-being on an equal footing with our own.

Both measures of equity are cited as specific characteristics of sustainability in the Brundtland Commission's seminal definition of sustainable development (WCED, 1987):

> *"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."*

Statistics Canada (1997) 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."*

The notion of spatial discounting already exists in the tendency to assign a higher economic value to human life in western countries than in poor countries, when that value is calculated according to earnings or productivity. Transport Canada, for example, assigns a $1.56 million monetary cost valuation to each road fatality, while cost valuations of human life globally are frequently several orders of magnitude lower. As noted above, Bein and Rintoul's (1999) adjustment of the value of statistical life (VOSL) alone sharply increases most damage cost estimates.

Understanding Damage Costs as Asset Losses

The $22 billion annual damage cost estimate, based on year 2000 emissions, seems enormous even as a high-end estimate and is difficult to grasp from a conventional perspective. We have seen (Section 5.3) that comparisons to provincial GDP are invalid, because the $22 billion reflects long-term global impacts rather than local damage in one year. But there is a second reason that such comparisons are invalid – they also mix up stocks and flows (assets and income). GDP measures *income*, calculated as an annual flow of goods and services. Climate-induced damage from a severe storm, however, could destroy in a single moment assets that represent both the embodied accumulation of many years of past GDP value and the future loss of goods and services that would have contributed to the GDP for many years to come.

For example, if lightning strikes a cow or a person, or a flash flood destroys a factory, we lose far more than the productive services supplied by that capital over a year. The full productive life-span of the cow's milk-giving potential (several more years) is destroyed in that one moment and the remaining productive work years of the person are lost. Similarly the embodied GDP value of many years investment in the factory and equipment, plus the consequent loss of productive services from that factory for many succeeding years, are lost. Such cost estimates cannot account for the non-monetary value of human, social and natural capital, such as the costs of human grief, unemployment and lost ecosystem services.

In other words, the loss incurred by the destruction of wealth and of capital assets can far exceed a single year's income flows. Peter Bein points out that 78 days of NATO bombing in Yugoslavia caused physical damage far in excess of that country's annual GDP (pers. comm., September 2000). If human casualties were valued at Transport Canada's $1.56 million estimate per road fatality, several billion dollars more would be added to Balkan war costs.

From that perspective it makes sense that climate-induced damages to stock values and assets (cumulative embodied GDP values) due to Nova Scotia's GHG emissions in a single year may be larger than the total *annual* output of goods and services produced by the province's economic activities. Ironically, the GDP counts all the provincial damage clean-up and repair costs due to climate change as contributions to economic growth and prosperity. By GDP accounting standards, human-induced damage and natural disasters may be "good" for the economy, because they generate more spending on goods and services! The real comparison of damage costs is not, therefore, with current GDP values, but with the accumulated asset wealth (manufactured, human, natural and social capital) of a given society.

From that perspective the $22 billion damage cost (high-end estimate) based on Nova Scotia's annual CO_2 emissions does not seem as unbelievable as a comparison with annual GDP would imply. Indeed, the damage cost would be considerably higher if climate change produces catastrophic "surprises," as some scientists predict, as these surprises and catastrophes are not accounted for in the climate change models from which damage costs are estimated.

Damage Costs are Long-Term Assessments

There is yet another basic reason that comparisons of damage cost estimates with *current* GDP can be confusing and misleading. The time span over which damages are assessed (500 years in Bein and Rintoul's $1,040/tonne estimate) takes into account that damages will start out relatively mildly and become much more serious the more the climate warms over time. Therefore the $1,040/tonne estimate (or $22 billion a year based on current Nova Scotia annual emissions) is based on the damages anticipated over a 500 year period and accounts for the increasingly serious projected damages centuries from now. It should be pointed out that, because of the discounting process, almost all of the projected damage costs are accounted for in the first 100 years (see below).

The comparison with *current* GDP is therefore invalid, because the aggregate of increasing future damages over centuries could be many times greater than current GDP. A shrinking natural and man-made capital base, due to climate change damages, can mean that assets are lost at a much faster rate than nature and new production can replace them. Therefore the damage estimate of $1040/tonne is a sum of damages inflicted by a present emission of one tonne of carbon dioxide (or CO_2 equivalent mass of other GHGs) over 500 years. Since a single tonne of CO_2 emitted now remains in the atmosphere for 100-200 years, even the high-end $1,040/tonne estimate indicates that this single tonne causes just $5-$10 a year in damages.

Comparing an estimated damage cost of $22 billion with current GDP in effect compares the impact of cumulative future global market *and* non-market damages with current Nova Scotia market output only. To compare a current year's domestic output with 500-year global estimated climate change damages is therefore illogical and inappropriate.

In order to make any kind of meaningful temporal comparison at all in monetary terms, discounting is used, as described above. Annual GDP is an un-discounted current value, while long-term damage costs are discounted over time (at 1.5% annually in the case of Bein and Rintoul's $1,040/tonne estimate.) The discounting procedure, used to obtain a "net present value" for future damage costs, effectively and substantially dilutes the effect of distant damages in proportion to their distance from the present. Thus, in Bein and Rintoul's 500-year damage cost horizon, the last few hundred years are effectively valued at a very much lower rate than the first one hundred, even though actual damages are likely to be much higher as climate continues to warm.

In sum, the enormity of potential climate change damage costs due to Nova Scotia's GHG emissions is difficult to grasp in conventional terms, for the three main reasons described:

1) Global climate change damage cost estimates include the much smaller per capita impacts of developing nations' GHG emissions, and thus enable us to avoid responsibility

for the much higher *proportion* of global damage costs attributable to our own high emissions.

2) We are accustomed to assessing prosperity and well-being based on GDP and current income valuations. But climate change damage costs are based on loss of accumulated human-made wealth (capital) and production as well as loss of nature's stocks and flows of services. Lost assets include not only many years of past embodied productive value, but also the potential for future production of goods and services by man as well as nature.
3) Global damage costs are estimated over a long time period and increase as climate warms. GHGs emitted now remain in the atmosphere and continue to cause damage together with more GHGs that will be emitted in future years.

Therefore damage cost estimates are *global* damages caused by all *local* emissions; they are *future* damages attributable to *present* emissions; and they are *asset* losses as well as service flow losses that can far exceed *income*. Understanding these concepts can clarify the use and size of damage cost estimates.

Nevertheless, Peter Bein of Environment Canada's Adaptation and Impacts Group points out that there *is* one useful purpose in comparing damage costs to current GDP (pers. comm., September, 2000). The comparison tells us how much harder we would have to work now in order to compensate for the future damages with increased economic output, assuming that losses of natural assets could be replaced at all. Nova Scotia would have to double its GDP, according to Bein and Rintoul's $1,040/tonne damage cost estimate, in order to compensate for future climate change damages due to current GHG emissions.

The following Section on control costs illustrates another useful purpose served by comparing climate change damage costs with current expenditures. **The enormity of potential damage costs makes current control measures a "very good deal."** When responsibility is taken for global damages from local emissions, the ratio of damage costs to control costs is more than 30:1, using high-end estimates of both types of costs from 2000 to 2010. The value of controlling GHG emissions is therefore demonstrated even without taking into account other concomitant economic, social and environmental benefits of GHG reductions, such as reduced road accidents and air pollution. When such benefits deriving from potential "no regrets" measures are taken into account, as seen in the next Section, this ratio can become even larger.

5.4. Cumulative Damage Cost Avoidance

The minimum GHG emission reduction necessary to meet the Kyoto Protocol commitment is 6% below 1990 levels. If this is applied at a provincial level, Nova Scotia's total GHG emissions in 2010 must be 18.2 million tonnes (see Table 4). If Nova Scotia were to meet the more ambitious reduction of 50% of 1995 levels by 2030 (Suzuki, 2001) (prorated to 2010 as 17% below 1995 emissions), then total GHG emissions in the province must be 15.9 million tonnes in 2010. It is projected that under a BAU scenario, even accounting for a gradual switch to natural gas, Nova Scotia's emissions will be 21.1 million tonnes in the year 2010 (see Section 5.3). That means that Nova Scotia must achieve a reduction of between 2.9 and 5.2 million tonnes a year by 2010.

It is unlikely that a cut of this magnitude will be accomplished by waiting until the year 2010 to take action and by then achieving a 3 to 5.2 million tonne reduction in a single year. Therefore, there will have to be a gradual reduction over the 10-year period. Let us assume that, in the current political climate and absence of a coherent strategy, and based on ongoing high emissions levels, no action will be taken between 2000 and 2004. Let us also assume that a coordinated national emissions reduction strategy is in place by the year 2004. Then a graduated annual reduction in each of the years 2005 through 2010 will produce the cumulative emission reductions presented in Table 7.

Table 7. Cumulative Damage Cost Avoidance Achieved by Meeting Kyoto and Suzuki Targets (based on graduated emission reductions from 2005 to 2010.)

Year	Kyoto Target (6% below 1990)			Suzuki Target (17% below 1995)		
	Emission Reduction (tonnes)	Damage Cost Avoidance (C$1997 millions)		Emission Reduction (tonnes)	Damage Cost Avoidance (C$1997 millions)	
		$38 per tonne	$1,040 per tonne		$38 per tonne	$1,040 per tonne
2000-2004	0	$0	$0	0	$0	$0
2005	483,334	$18.4	$502.7	866,667	$32.9	$901.3
2006	966,668	$36.7	$1,005	1,733,334	$65.9	$1,803
2007	1,450,002	$55.1	$1,508	2,600,001	$98.8	$2,704
2008	1,933,336	$73.5	$2,010	3,466,668	$131.7	$3,605
2009	2,416,670	$91.8	$2,513	4,333,335	$164.7	$4,507
2010	2,900,004	$110.2	$3,016	5,200,002	$197.6	$5,408
TOTAL	**10,150,014**	**$385.7**	**$10,566**	**18,200,007**	**$691.6**	**$18,928**

Note: Totals are cumulative emissions reduced and associated damages avoided over the ten-year period. Totals may not add due to rounding. All dollar values are C$1997 millions.

Table 7 presents estimates of decreases in damage costs resulting from reducing GHG emissions by 2.9 million tonnes and 5.2 million tonnes, respectively, by 2010. Achieving the 2.9 million tonne reduction would save between $110 million and $3 billion in avoided climate change global damages due to lower 2010 emissions alone compared to the BAU scenario for that year. Achieving the 5.2 million tonne reduction would save between $198 million and $5.4 billion due to lower 2010 emissions compared to BAU.

If Nova Scotia begins to implement the Kyoto agreement targets gradually starting in 2005, the *cumulative* savings associated with meeting the 2.9 million tonne reduction would be $386 million to $10.6 billion over 2000-2010 in avoided damage costs. If Nova Scotia begins to implement the Suzuki targets gradually starting in 2005, then the *cumulative* savings associated with meeting the 5.2 million tonne reduction would be $692 million to $18.9 billion.

The logic behind the cumulative cost estimates is simply that GHGs have a long life and continue to cause damage for many years after they enter the atmosphere. Thus GHGs emitted in

2005 are still causing damage in 2010. Likewise, each year's GHG emission reduction continues to produce savings in avoided damages. In other words, if the gradual, phased reduction shown in Table 7 takes place, there will be 10-18 million less tonnes of GHGs in the atmosphere than there would have been under a BAU scenario. For that reason, in addition to a point estimate of avoided damages in the year 2010 it is also necessary to account for *cumulative* reductions and avoided damages to that date.

5.5. Co-Benefits of Reducing Nova Scotia's GHG Emissions

There are two kinds of benefits that result from taking action to reduce GHG emissions: the primary benefits (climate change damage cost avoidance) and the secondary, or co-benefits. Damage costs in the literature and the damage avoidance costs summarized in the previous Section are based on climate change models. However reducing fossil fuel combustion also avoids damages and produces cost savings of a different kind.

These "co-benefits" include the impact of proposed GHG reduction initiatives on conventional pollutants, including reductions in levels of sulphur and nitrogen oxides, particulate matter and volatile organic compounds, all of which produce health and economic costs. Similarly, a reduction in automobile usage can also produce savings in reduced accident costs, road building and maintenance expenditures, policing and so on. The economic costs of reducing fossil fuel combustion are examined in the next Section on "control costs," but here it is important to note that damage avoidance benefits extend beyond climate change impacts.

As pointed out by Caton and Constable (2000, p. 1), co-benefits of reduced fossil fuel combustion may include any or all of the following:

- Associated emission reductions of common (criteria) air contaminants (CACs), leading to improved air quality. Selected examples include:
  - Reduced smog precursors (avoided human health, crop and forest damage)
  - Reduced acid rain precursors (avoided ecosystem damage)
  - Improved visibility (longer visual range, clearer atmosphere, positive impact on tourism)
- Reduced materials damage from air contaminants (soiling and deterioration of buildings, ozone damage to vehicle tires and other rubber products).
- Reduced human exposure to toxic air contaminants (possibly related to lung cancer).
- Avoided flooding and other land requirements (lower demand for hydroelectricity and other generating facilities).
- Avoided community impacts (lower demand for transportation infrastructure, developed land use).
- Improved energy efficiency of the economy generally (job creation in existing industries due to improved efficiency and in new energy efficiency industries, recycling of dollars formerly spent on fossil fuels).

Inclusion of these and other co-benefits suggested by Suzuki, Hawken, Lovins and others would substantially increase savings estimates and correspondingly reduce the marginal abatement cost estimates. From a practical policy perspective, it would be expected that priority can be given to the zero or lowest-cost reduction options first, thus obviating or reducing the transition costs to a low-carbon economy.

In a study on the environmental and health impacts associated with reducing GHG emissions, the Analysis and Modeling Group (AMG, 2000b) determined that these co-benefits are in the range of $11 to $17 per tonne of elemental carbon.[13] The co-benefit estimates are conservative, since they do not cover all of the pollutants, omit the contribution of sulphate reductions in western Canada, and do not include many of the savings that can accrue from changes in transportation and land use planning options .

AMG noted that the co-benefits of GHG reductions are "immediate, accrue directly to Canadians, and are fairly certain" (AMG, 2001b). This makes them different in nature from the damage avoidance costs associated with climate change, which are global, long-term and subject to a wide range of potential variability. Unlike the previous Section, therefore, the following estimates for Nova Scotia, based on the AMG study, are short-term savings that will accrue directly to Nova Scotians.

Table 8 shows both the single year co-benefits of achieving the Kyoto 2.9 million tonne target in 2010 and the cumulative co-benefits over the 2000-2010 period. Achieving the 2.9 million tonne reduction target will result in co-benefits of $32 million to $49 million in the year 2010 alone. If Nova Scotia begins to implement the Kyoto agreement targets gradually starting in 2005, the *cumulative* co-benefits associated with meeting the 2.9 million tonne reduction by 2010 would be $112 million to $173 million over the 2000-2010 period.

Table 8 also shows both the single year co-benefits of achieving the Suzuki 5.2 million tonne target in 2010 and the cumulative co-benefits over the 2000-2010 period. Achieving the 5.2 million tonne reduction target will result in co-benefits of $57 million to $88 million in the year 2010 alone. If Nova Scotia begins to implement the Suzuki targets gradually starting in 2005, the *cumulative* co-benefits associated with meeting the 5.2 million tonne reduction would be $200 million to $309 million over the 2000-2010 period.

It is important to note again that the $11-$17 figure does not include all co-benefits and avoided damages. Nevertheless, the figure does serve as a convenient proxy to highlight the fact that climate change damages are not the only costs avoided by reducing GHG emissions. Chapter 6 of this report notes some specific reduction options that can produce a wide range of co-benefits and cost savings, and Appendix D describes and values some of these co-benefits more explicitly. In Section 5.7, these co-benefits as well as the potential decreases in climate change damage costs are compared with the control costs required to achieve these reduction targets.

[13] For a detailed explanation concerning the four alternate control cost pathways and scenarios examined in the AMG study, as well as the assumptions underlying each of them, and the methodologies used in the calculations, please see AMG, 2001a-c.

Table 8. Cumulative Co-Benefits Achieved by Meeting Kyoto and Suzuki Targets

Year	Kyoto Target			Suzuki Target		
	Emission Reduction (tonnes)	Co-Benefits (C$1997 millions)		Emission Reduction (tonnes)	Co-Benefits (C$1997 millions)	
		$11 per tonne	$17 per tonne		$11 per tonne	$17 per tonne
2000-2004	0	$0	$0	0	$0	$0
2005	483,334	$5.3	$8.2	866,667	$9.5	$14.7
2006	966,668	$10.6	$16.4	1,733,334	$19.1	$29.5
2007	1,450,002	$15.9	$24.7	2,600,001	$28.6	$44.2
2008	1,933,336	$21.3	$32.9	3,466,668	$38.1	$58.9
2009	2,416,670	$26.6	$41.1	4,333,335	$47.7	$73.7
2010	2,900,004	$31.9	$49.3	5,200,002	$57.2	$88.4
TOTAL	**10,150,014**	**$111.7**	**$172.6**	**18,200,007**	**$200.2**	**$309.4**

Note: Totals are cumulative emissions reduced and associated co-benefits over the ten-year period. Totals may not add due to rounding. All dollar values are C$1997 millions.

5.6. Control Costs: Concepts and Methodology

The second major area to be explored in costing, and the one most apparent to policy makers, is the cost of controlling or mitigating GHG emissions. As noted earlier, these "control costs" are generally considered in isolation from (a) the damage costs they are designed to obviate and (b) the concomitant social, economic and environmental benefits they may produce.

For example, the US decision to abrogate the Kyoto agreement has been justified by US policy makers almost entirely on the grounds of excessive control costs or losses to the US economy. These estimates do not consider either long-term global climate change impacts nor the potential for emission reductions to increase income through savings in other areas (e.g. reduced fuel use, reduced road accidents, reduced air pollution costs, etc.) It is highly misleading to represent only one element of a complex equation.

One specific case study that includes *all* three elements of the equation (control costs, climate change damage avoidance, and co-benefits) is given in Appendix D. When all these elements are included, control costs are properly seen as "investments" that can yield long-term returns.

Another flaw in treating "control costs" in conventional accounting mechanisms is that adjustment investments are frequently attributed solely to climate change rather than to energy efficiency innovations that can end up producing major cost savings. There may be sound economic reasons for improving energy efficiency that may enhance the overall health of the economy and which have, as their by-product, the reduction of GHG emissions. In such cases, which affect the design of new power plants for example, it is misleading to attribute the entire investment cost to climate change and GHG mitigation.

Subtle changes in the macroeconomic structure of an entire economy, such as a shift in the tax structure from taxing income and wages to taxing carbon and pollution, can dramatically enhance the incentives for energy efficiency and change the equations generally used to assess cost-effectiveness. In such circumstances, in the economic climate produced by GPI-type full-cost accounting mechanisms, ratifying the Kyoto Accord can literally be seen as creating economic benefits and advantages rather than "costs."

It should be remembered that a primary purpose of including social and environmental benefits and costs in accounting systems is to enhance economic efficiency. The exclusion of "externalities" from accounting mechanisms literally encourages the inefficient use of resources by displacing the full or "true" costs of economic activity onto taxpayers and future generations. This is not a matter of ideology but of simple market efficiency. In a July 28, 2001, editorial, the *Financial Post* noted:

> *"But if these natural resources really are precious and scarce, then we should be charging Canadians – including farmers and petrochemical barons – a lot for using them. Water use should be universally metred, and natural gas should be taxed heavily. If we want to hand over this planet to our children with a full tank of resources – much as rental cars have to be returned with a full tank of gas – then we should be pricing all our resources at their true cost, with all costs in, including production costs, environmental costs and depletion costs…*
>
> *If worry about our kids' future needs doesn't cause us to price our resources at their true costs, then the simple stupidity of pricing them at levels that encourage us to use them frivolously…should make us think twice"* (Watson, 2001).

This editorial does not even mention climate change or GHG emissions. But the macroeconomic shift it envisions would create independent incentives for a reduction in fossil fuel combustion, for energy conservation, and for genuine long-term economic savings that would render the concept of "control costs" almost meaningless. Needless to say, precautions must be taken to ensure that such a shift is not regressive and remains revenue-neutral. Tax shifting from income and wages to carbon, pollution and resource use, along with adequate income supports for lower income groups can create such a shift without penalizing any income group.

In such circumstances, utility companies would design power plants for economic and efficiency reasons that would sharply reduce GHG emissions, and households would have sound economic reasons for conserving energy, buying smaller cars, and reducing single-occupancy automobile travel. The technological changes spurred by such a shift in incentives could create significant macroeconomic benefit. This perspective again renders the concept of "control costs" an artifact of the "old"economy.

There are two clear circumstances in which the concept of "control costs" could be justifiably used. First, if an investment were made for *no other purpose* than reducing carbon emissions, it could justifiably be called a control cost attributable to climate change. For example, installing technology to capture CO_2 from a coal-fired plant and injecting it underground in order to sequester the carbon in geological formations is a "control cost." There is no other purpose served by such an investment than the avoidance of damage due to climate change. Certainly there is no obvious business advantage, and it is justifiable to consider it a "cost."

Secondly, if macroeconomic adjustments aimed at de-carbonizing the economy are made very quickly, and in such a way as to leave assets like working coal-fired power plants "stranded" before the end of their useful economic life, then the lost asset value can justifiably be considered a "control cost" attributable to climate change. For example, if six years of a plant's estimated 35-year working life were lost due to climate change adjustments, then those six years of lost value are a control cost.

However, macroeconomic change can be introduced gradually, and timed to coincide with the end of a coal-fired plant's useful economic life or at a point where major refurbishments would be required in any case. In such a case, a business investment in a new plant with reduced GHG emissions may not produce costs in excess of normally required business expenditures, and the adjustment would not be considered a "control cost" attributable to climate change.

For example, the phased introduction of carbon taxes may make the construction of a highly efficient plant reliant on local natural gas an excellent business investment compared to building a new coal-fired plant dependent on imported coal. In such a case a tax shift from labour to carbon provides a business incentive for a change that can also reduce GHGs, simply because coal is now paying its true cost and therefore more expensive than less damaging alternatives.

It is noted below that Nova Scotia Power's decision to burn natural gas at Tufts Cove rather than oil will be based on the comparative market prices of the two fuels, not on comparative GHG emissions. In such a case, too, the reduction of GHGs is clearly not a "control cost." Tax shifting is probably the most efficient way to create a business climate in which taxes on high-carbon fuels rather than labour change the cost-benefit equation for businesses, so that they are prompted to make investments (for reasons of business cost-efficiency and savings) in technologies that reduce GHG emissions.

In sum, it is incorrect to apply the concept of "control costs" to all business decisions that reduce greenhouse gas emissions. The concept should be restricted only to those cases where the investment or stranded asset value is clearly attributable to climate change alone. The more that macroeconomic changes like tax shifting change the business climate, the less relevant control costs become, provided that the changes remain revenue-neutral and that business expenses simply shift from taxes on labour and income to taxes on carbon and pollution. Overall business costs may not increase, but investments in energy-efficient plants become more attractive for economic reasons.

Nevertheless, the concept of "control costs" is pervasive in the literature on climate change economics, and it is, as noted above, generally the only cost to which politicians and others relate. Statements by the leaders of the US, Alberta, and other jurisdictions in opposition to the Kyoto Accord are based entirely on the notion of "control costs," which are assumed to be excessive. Despite the fundamental flaws in the use of the concept, **GPI***Atlantic* does refer here to the conventional control cost estimates in the traditional literature and recognizes the necessity of speaking the economic language in current use at this point in history.

De-carbonizing the economy by reducing fossil fuel combustion is currently seen as producing major adjustments for economies, like Nova Scotia's, that are currently highly dependent on fossil fuel-based energy sources. Because transition costs to alternative energy sources, transportation options and land use planning scenarios are more immediate than the long-term damages that will be caused by business as usual, they are also more apparent to policy makers. In the absence of carbon taxes, transitions to more efficient economies and to investments that will yield significant long-term benefits do produce initial costs that must be considered in order to identify the most cost-effective emission reduction options.

For this reason, and with all the caveats described above, this GPI study does account for the concept of "control costs" that is so widespread in the literature on the economics of climate change. Ultimately, from the GPI perspective, the concept of control costs should have less and less meaning for the reasons described above. It should be seen here simply as a transitional tool that acknowledges both its pervasive use in the literature on climate change economics and the common perspective of policy makers operating within the framework of a conventional accounting system that fails to value or fully price natural resources.

When carefully used, the concept of "control costs" should point beyond itself. It is reasonable to acknowledge the up-front transitional costs of a macroeconomic shift that values resources fully, and shifts the tax burden from productive activities like wages to unproductive activities like resource depletion, pollution and environmental damage. As these changes take root, investments that reduce GHG emissions are no longer attributable to climate change but are seen as means to enhance macroeconomic and market efficiency, even without consideration of the benefits that accrue to future generations.

Properly used, control cost estimates for alternative GHG reduction strategies may facilitate a comparison of different options for controlling emissions on the basis of total costs and benefits. Concomitant benefits that accompany GHG reductions are clearly different for different options. For example, reduced automobile use, in addition to reducing GHGs, would decrease air pollution, road maintenance costs, road accidents, and, indirectly, health care costs for the province, while district heating and conservation measures can reduce air pollution and produce significant energy savings and reduced home heating costs. Each of these alternative strategies clearly requires different kinds of investments which will affect the final cost-benefit equation.

Repetto and Austin (1997) analyzed 16 leading simulation models that estimate the cost of controlling GHGs as a percentage of the Gross Domestic Product (US). Included were top-down models and bottom-up models. The top-down models are aggregate pictures of the whole economy, based on the sale of goods and services by producers and the flow of labour and investment funds from households to industries. They include "computable general equilibrium" models that are based on market supply and demand and on the assumption that consumers and producers allocate their resources to maximize their welfare or profits. Top-down models also include optimizing models that are based on statistical behaviour in the past. The top-down models are useful for predicting long-term effects of policy options.

"Bottom-Up" models analyze the technological options for energy savings and fuel switching by industrial sector and then aggregate them to calculate the overall cost to the economy of reducing

GHG emissions. The bottom-up models tend to be more optimistic, partly because they may overlook barriers to implementation, such as management and retraining time, risk-aversion and household preferences.

Arguments for a zero cost of reducing emissions are based on the offsetting benefits of the measures. Energy efficiency measures, in particular, are likely to produce "negative costs" or actual financial savings at the same time that they reduce greenhouse emissions. Lovins and Lovins (1997) provide many examples in which energy savings produce financial benefits and improve business competitiveness and profits, while dramatically reducing GHG emissions:

- Dupont projected that simple measures to reduce GHG emissions by the equivalent of 18 million tonnes of CO_2 by the year 2000 would also save the company $31 million each year in reduced energy costs.
- Energy saving projects at Dow Chemical in Louisiana sharply reduced GHG emissions and produced returns on investment of 204%.
- A process innovation at Blandin Paper Company saved 37,000 tonnes of CO_2 per year and more than $1.8 million.

While these examples tend to promote optimism about the cost of reducing CO_2 emissions, other studies have identified significant transition costs. A top-down study that helped establish Canada's negotiating position at the Kyoto conference (Standard and Poor's DRI study, discussed in: Holling and Somerville, 1998), showed that measures to stabilize emissions at 1990 levels by 2010 would depress the GDP by about 2% for the first decade, after which it would recover to BAU levels. Several scenarios have indicated that there would be short-term transition costs to the economy but that the long-term productive capacity of the economy would not be significantly affected.

Recently the Analysis and Modeling Group (AMG) of the National Climate Change Process has released an assessment of the economic and environmental implications for Canada of the Kyoto Protocol (AMG, 2000a).[14] The analysis used three sets of models: a micro model to evaluate the direct impacts of future GHG reduction scenarios; and two energy-technology models – one that is market-based and predicts the lowest financial cost solution to a given emissions target, and a second that takes into consideration consumer and producer behaviours and other non-financial considerations.

These models were applied to a number of scenarios for reducing emissions. The studies predicted that at the national level, attainment of the Kyoto targets would result in a decrease in GDP of 0-3%, relative to BAU predictions. A 3% reduction in GDP in the year 2010 would mean that over the 2000-2010 decade the economy will grow by about 26% rather than the predicted 30%. While the provincial impacts are generally within 1.5 percentage points of this national average, the predictions for Nova Scotia are ambiguous. One study for Nova Scotia indicated impacts greater than the national average and another indicated the opposite. The models predicted that if Canada acts alone (i.e., assuming other nations do not), the marginal cost of GHG abatement in 2010 could range from $40-$120 per tonne of CO_2.

[14] For more details on the methodologies and assumptions of the Analysis and Modeling Group, see AMG, 2000a, 2000b and 2000c.

The marginal cost is the net cost of removing the last tonne of CO_2, in this case the cost of abatement in the year 2010. Marginal cost can also be interpreted as the price of an emissions permit in an emissions-trading system. It should be noted that this marginal cost of $40-$120 per tonne of CO_2 is very conservative since it is the cost of the *last* and therefore *most expensive* tonne, rather than an average cost. Earlier reductions would likely be considerably less expensive than later ones.

This $40-$120 per tonne of CO_2 estimate is also high because it is based on the following assumptions:

(a) Least-cost sharing of the national target among sectors (electricity, industry and upstream, residential and commercial, and transportation);
(b) Canada will have to meet its Kyoto commitment for GHG emission reductions by acting alone and without any international instruments; and
(c) Consumer behavior will increase control costs.

The assumption that consumer behavior necessarily increases control costs is not explained in the AMG report and is clearly highly pessimistic. Consumer behaviour may well be *highly* responsive to GHG reduction initiatives, especially if accompanied by an effective public education program. Nova Scotia's solid waste management strategy, which succeeded in diverting 50% of solid waste from landfills in just 10 years, indicates that consumers *can* respond quickly and effectively to environmental protection initiatives and change their habitual behaviour quite drastically even when it involves added inconvenience.

Nevertheless, the control cost estimate of $120 per tonne of CO_2 will be used in this study as the high estimate in order to provide a conservative upper limit.

In order to identify these zero or low-cost strategies, **GPI***Atlantic* has developed a "bottom-up" standard for comparing GHG emission reduction options – the GMI. This index uses full cost accounting mechanisms to include consideration of a wide range of social, environmental and economic impacts of various potential GHG reduction measures. The index can thereby indicate the net costs or benefits to society of alternative options for reducing GHG emissions.

An example of the application of this index can be found in Appendix D, which is a study of options for reducing GHGs in the Nova Scotia freight transportation industry. In that study, the GMI was -$715 per tonne, which means that the measures proposed produced a net social benefit of $715 for every tonne of CO_2 emissions reduced. The specific benefits of the measure proposed (a 10% shift from road to rail) produced a net annual social benefit of $10 million, when reduced accident, infrastructure, air pollution and other costs were considered and when a corresponding range of social, economic and environmental benefits were included.

This type of study required detailed research into the costs and benefits of specific scenarios in a specific sector of the economy. The present study, in attempting to present an overview of the damage and control costs of GHG emissions in Nova Scotia, simply uses values derived from the existing literature for the cost of one tonne CO_2 and applies those estimates to the Nova Scotia situation. While this is a rather crude method, it does at least give some estimate of the order of magnitude of costs. Even this type of estimate will improve in accuracy as more adequate indicators of the cost of mitigating one tonne of CO_2 emissions are developed.

GPI*Atlantic* recommends further detailed sector-specific studies along the lines of the freight study in Appendix D to assess the full costs and benefits of alternative emission reduction scenarios. In the freight transportation study, a value of $35/tonne CO_2 was used as the cost of reducing emissions. Since that case study was completed, the AMG has estimated that the marginal cost of GHG abatement in 2010 could be as high as $120 per tonne of CO_2 under a worst case scenario. Because that figure is based on the Canadian economy and does include some co-benefits, this present study uses AMG's $120 estimate as the upper bound of control costs in the following Section.

The same lower bound estimate as in the freight study in Appendix D ($10 per tonne of CO_2) is also used here (Klein, 1997). That estimate is based on electric power generation. An intermediate estimate by the IBI group, based on the transportation sector, uses a control cost estimate of $35 per tonne (1997 $Cdn.) Sector control cost estimates are generally lower than those for the economy as a whole. However, they are considered more useful from a practical policy perspective both because they encourage each sector to assess how it can make reductions in the most cost-effective way and because they facilitate cost-benefit comparisons between different sectoral initiatives. These cost estimates are summarized in Table 9.

Table 9. Estimates of Costs of Reducing GHG Emissions by One Tonne of CO_2 Equivalent

Source of Estimate	Amount per tonne CO_2
Klein (1997)	$10 (1997 $Cdn)
IBI (1995)	$34 (1995 $Cdn)
AMG (2000)	$40-$120 ($Cdn)[15]

5.7. Estimated Costs of Reducing GHG Emissions in Nova Scotia

Control costs imply an initial outlay of funds, just as any investment does. However, it is important to remember both that control costs obviate future damage costs and that mitigation strategies can be chosen which will both reduce GHGs *and* improve economic performance and generate savings. In other words, they are not simply "costs," as implied by conventional accounting systems, but *investments* designed to produce a positive rate of return both in avoided damages and in substantive co-benefits, including direct energy cost savings.

[15] Although comparative estimates in this study use 1997 dollars, the $120 upper bound estimate is not adjusted to 1997 dollars since information on dollar year was not available in the AMG report. The effect this has on calculated estimates is assumed to be minimal.

An examination of policy tools and financial mechanisms that could be used to finance investments in reducing GHG emissions is beyond the scope of this study. However, it should be noted that one of the most promising approaches, already being used by some European countries, is a shift in the tax structure from wages and income to "green taxes" or "carbon taxes." This may be particularly helpful in achieving large reductions in GHG emissions across the entire economy, rather than more limited sectoral reductions through piecemeal policy initiatives in different sectors. In this Section, however, we focus simply on the targets rather than on the mechanisms for achieving them.

Since control costs will vary with the option chosen, we use a wide range of control costs, ranging from $10 per tonne of CO_2 (Klein, 1997) to $120 per tonne (AMG, 2000a), as discussed in the previous Section. Table 10 summarizes the costs of reducing Nova Scotia's GHG emissions to reach the targets recommended in Table 4 by the year 2010. The investment required to reach the Kyoto target by 2010 is between $29 and $348 million over six years. To reach the Suzuki target of a 5.2 million tonne reduction by 2010 will require an investment of $52 – $624 million spread over six years.

Table 10. Control Cost Estimates for Kyoto and Suzuki Targets (C$1997 millions)

Year	Kyoto Target			Suzuki Target		
	Emission Reduction (tonnes)	Control Costs (C$1997 millions)		Emission Reduction (tonnes)	Control Costs (C$1997 millions)	
		$10 per tonne	$120 per tonne		$10 per tonne	$120 per tonne
2000-2004	0	$0	$0	0	$0	$0
2005	483,334	$4.8	$58.0	866,667	$8.7	$104
2006	966,668	$4.8	$58.0	1,733,334	$9.5	$104
2007	1,450,002	$4.8	$58.0	2,600,001	$9.5	$104
2008	1,933,336	$4.8	$58.0	3,466,668	$9.5	$104
2009	2,416,670	$4.8	$58.0	4,333,335	$9.5	$104
2010	2,900,004	$4.8	$58.0	5,200,002	$9.5	$104
TOTAL	**10,150,014**	**$28.8**	**$348.0**	**18,200,007**	**$52.2**	**$624**

Notes: Control costs are not calculated on a cumulative basis. Rather, they are calculated on an additive basis, assuming that whatever investment is made in control technology will continue to reduce GHG emissions in subsequent years. For example, $4.8 million invested in equipment in 2005 will reduce emissions by 483kt in 2005; 483kt in 2006; 483kt in 2007 and so on. The additional $4.8 million investment in 2006 will reduce emissions by a *further* 483kt, and so on. Although the high-end $120/tonne estimate is the "marginal cost" of reducing the last tonne of CO_2 in the year 2010, and although earlier reductions are likely to be cheaper, the same $120/tonne estimate is applied in each year to produce a considerably more conservative and pessimistic estimate than would likely be the case in practice.

In Chapter 6, we elucidate specific reduction options that can produce a wide range of co-benefits and cost savings. Here we are simply presenting a general range of costs for controlling emissions in the economy as a whole. Table 11 presents a summary of the control costs and damage avoidance benefits from these two scenarios

Table 11 indicates that in the year 2010, using the low estimates of both control and damage costs, every $1 invested in reducing GHG emissions will produce $27 to $30 in savings due to avoided primary and secondary damage costs. Using the high estimates from the literature, every $1 invested in reducing emissions will produce $53 in savings. Using a ten-year estimate from 2000-2010, rather than a single year snap-shot, every $1 invested in reducing GHG emissions will save $17 in avoided damages using low-end estimates and $31 using high-end estimates. When control costs are subtracted from damage costs, the net benefit to society of a concerted six-year effort to meet the Kyoto targets is between $469 million and $10.4 billion. Meeting the Suzuki target will produce a net benefit of $840 million to $18.6 billion.

Even more significantly, the cost effectiveness of reducing GHG emissions is shown in Table 11 *not* to be dependent on the differing assumptions of the climate change economists who have calculated both the 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 damages exceed the cost of reducing GHG emissions. In short, ***greenhouse gas 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***.

It should be noted again that both ratios assume control costs with very incomplete co-benefits included. When the additional social, economic and environmental benefits of curbing GHG emissions are factored in (for example, energy savings, and reduced road accidents), there is a very clear case for immediate action to reduce emissions. As Chapter 6 demonstrates, the concomitant benefits of GHG reductions can dramatically dilute control costs, increase savings, and strengthen the economic case for GHG reductions.

Furthermore, as noted in Section 5.5, a revenue-neutral tax shift from labour to carbon taxes would create business and personal incentives to reduce GHG emissions that produce no net adjustment cost, particularly if tax shifting is introduced gradually to coincide with needed investment in new infrastructure. Indeed, such a macroeconomic change would render the notion of "control costs" obsolete and effectively create a "zero" or negative value to replace the current $10-$120 estimate of mitigation costs used in the ratios that follow.

On the other side of the equation, it was also noted earlier that climate change damage costs are predicted to increase in severity over a long time horizon as global temperatures warm, and that they apply globally. Therefore, both in Table 10 and in Chapter 6, the 2000-2010 time horizon refers to an initial recommended period of GHG emission reductions corresponding to the time frame of the Kyoto Protocol. The actual benefits in avoided climate change costs would be realized globally and by future generations rather than by Nova Scotians in the next ten years. To avoid misinterpretation of Table 10 and the equations in Chapter 6, please refer to Sections 5.2 and 5.5 on damage cost and control cost concepts and methodology.

Table 11. Summary of Damage Avoidance Benefits and Control Costs – in Year 2010 and Cumulative Over 2000-2010 (C$1997 millions)

CO_2 Equivalent Reduction	In Year 2010		Cumulative Over 2000-2010	
	Low Estimate	High Estimate	Low Estimate	High Estimate
Minimum Kyoto (2.9 million tonnes)				
Damage Avoidance				
Climate Change Mitigation	$110	$3,016	$386	$10,556
Co-Benefits	$32	$49	$112	$173
Total Damage Avoidance	$142	$3,065	$498	$10,729
Control Costs	$4.8	$58	$29	$348
Ratio of Damage Avoidance to Control Costs	**30:1**	**53:1**	**17:1**	**31:1**
Net Benefits	**$137**	**$3,007**	**$469**	**$10,381**
Minimum Suzuki (5.2 million tonnes)				
Damage Avoidance				
Climate Change Mitigation	$198	$5,408	$692	$18,928
Co-Benefits	$57	$88	$200	$309
Total Damage Avoidance	$255	$5,496	$892	$19,237
Control Costs	$9.5	$104	$52	$624
Ratio of Damage Avoidance to Control Costs	**27:1**	**53:1**	**17:1**	**31:1**
Net Benefits	**$246**	**$5,392**	**$840**	**$18,613**

Note: Low estimates are based on $10/tonne for control costs (Klein, 1998), $38/tonne for damage costs (Cline, 1995) and $11/tonne for co-benefits (AMG, 2000b). High estimates are based on $120/tonne for control costs (AMG, 2000c), $1,040/tonne for damage costs (Bein and Rintoul, 1999), and $17/tonne for co-benefits (AMG, 2000b). Net benefits are total damage cost avoidance less control costs.

5.8. Conclusion and Recommendation

Because climate change is universally acknowledged as the most serious environmental challenge of the century, the clear conclusion of this economic costing exercise and the principal recommendation of this study as a whole, is that reduction of greenhouse emissions must be a top priority on the policy agenda at this time. No regrets measures to reduce GHG emissions can be undertaken without delay.

Even without factoring in wider potential social, economic and environmental benefits, investments in emission reductions today are, in themselves, highly cost-effective by comparison to later damage costs. That conclusion is reached here even using the conventional and seriously flawed concept of control costs that is common today. When we consider the potential to encourage GHG reductions for reasons of efficiency, savings, and sound business investment through instruments like tax shifting, then emission reductions are seen as even more cost-effective.

Perhaps most importantly, a concerted education and public awareness campaign is necessary if ordinary citizens, public officials and opinion leaders are to undertake the actions today that can protect the welfare of future generations. Awareness of potential future damage costs and of the potential for macroeconomic changes that can encourage investments in GHG reductions is an essential element of such a campaign. Above all, such an educational effort can help explain to ordinary citizens the rationale behind a shift from income taxes to carbon taxes.

If Nova Scotia chooses to take a leadership role in this global effort (and the province is well-positioned to make that responsible choice), there is no doubt that others will come here to study and learn from our experience. There is even an economic opportunity here that can benefit the provincial GDP!

Some concrete emission reduction options are considered in Chapter 6; and Appendix D provides a specific example of the costing method and analysis that can be used to identify the most cost-effective emission reduction options.

5.9. A Note on Adaptation Costs

Though no estimates are given in this study for adaptation costs, it is acknowledged that they are increasingly important in climate change cost estimates and therefore deserve mention here. This brief note focuses on the markedly different ethical and practical implications of the alternative responses to climate change denoted by these different costing approaches.

There is a growing trend in Canada to put more money and human resources into adaptation research and action, based on an acceptance of the reality of a warming climate and the need to respond to it. While that trend seems eminently reasonable given the scientific evidence, it reflects an ethical and policy choice that is quite different from the emphasis on emission reductions in this study. The policy choice relates directly to the choice of "spatial discount rate" discussed previously.

At the beginning of this Chapter it was noted that some of the costs of adapting to a changing climate and thereby avoiding potential damage can be enormous. Construction of dykes; water course diversions; engineering works to protect coastlines from sea level rise and low lying lands from flooding; and irrigation projects to prepare for droughts and drier summers would be justified in economic terms if they prevented higher damage costs such as storm and flood losses, clean-up and restoration costs, disaster relief, or subsidies to drought-stricken farmers. However, the high capital costs of many adaptation measures put them out of the reach of any but the wealthiest nations.

Rich countries like Canada may have the luxury of choosing how to allocate resources to respond to climate change. But even rich countries have limited resources, a growing emphasis on adaptation will almost certainly reduce expenditures on emission reductions. In practice, adaptation generally reflects a commitment to protect one's own citizens and communities from the consequences of a warming climate. Reducing emissions, on the other hand, reflects a greater commitment to geographical equity because it embodies the understanding that high emissions here can cause far more devastating damages in distant places. Emission reductions therefore have global benefits that may be greatest in developing countries and low-lying island states that are at greatest risk from climate change but do not have the resources for adaptive responses.

In short, an emphasis on adaptation reflects a higher spatial discount rate in which the future of Canadians is valued highly over that of distant global citizens, while an emphasis on emission reductions recognizes that benefits flow to all parts of the globe and most particularly to those at greatest risk in developing countries.

The dimensions of this ethical choice become apparent in the light of current adaptation research results that show potential benefits to Canada from a warming climate in some sectors. For example, some analysts predict possible higher yields for Prairie farmers in the event that precipitation increases and growing seasons become longer, and they are already examining crop types and growing methods that can potentially take advantage of global warming trends.[16]

Localized adaptation research and adjustment schemes, already under way and rapidly gathering momentum in Canada, can gradually and subtly blunt policy initiatives to slow climate change, create constituencies that see personal benefit in a warming climate, and shift resources from emission reductions to climate change management and adaptation techniques. Canada's Climate Change Action Fund is devoting increasing resources to adaptation research and has indicated that adaptation will gradually occupy an ever larger portion of the Fund's budget in coming years.

Perhaps more dangerously, this growing body of adaptation research implies an assumption that we can somehow "manage" the consequences of climate change. It subtly assumes, by virtue of omission of such externalities from localized adaptation costing procedures, that distant sea level rise, flooding and other natural disasters will not have any impact on Canadians. It implies a predictability that is probably unreal. For practical and scientific as well as ethical reasons, the implicit premise that local adaptation can shelter us from global impacts and that the consequences of climate change can be successfully managed, is likely illusory.

The integrative perspective of the GPI, which includes equity as a core measure of progress, demands continued emphasis on and priority for emission reductions as a clear and genuine measure of progress. For the reasons described here, successful adaptation to climate change is regarded in the GPI as a "defensive expenditure," as described above, but not as a core indicator of progress in this component of the GPI.

[16] This analysis and the discussion in this Section is based on **GPI***Atlantic*'s participation in an international workshop for climate change economists sponsored by Environment Canada and the Climate Change Action Fund on "Costing Canadian Climate Change: Impacts and Adaptations," September 27-29, 2000, University of British Columbia, Vancouver. At that conference, it was emphasized that Canada's Climate Change Action Fund is devoting increasing resources to adaptation research and that adaptation will gradually occupy an ever larger portion of the Fund's budget in coming years.

6. Options for Reducing Greenhouse Gases

This Chapter examines a few potential emission reduction opportunities for Nova Scotia in a general way. A considered evaluation of each option requires the more detailed cost-benefit analysis demonstrated in Appendix D. This Chapter, therefore, constitutes a proposal for replications of the Freight Transport case study (Appendix D) for each of the options identified here.

Two key factors in reducing GHG emissions are technology development and, at the same time, a marked change in attitude by governments and the general public. With appropriate attitudes, technologies can be identified that will increase resource productivity by a factor of four (Hawken et al., 1999). At the same time, attitudinal changes are necessary to help individuals examine their consumption patterns and learn how to use less fossil fuel energy while at the same time improving their quality of life (Wilson, 2001).

For example, heightened awareness about the potential impact of GHG emissions on climate change may persuade a household to buy an energy efficient smaller car rather than a sport utility vehicle. Heightened awareness on the part of governments may provide financial incentives for the former and tax penalties for the latter, as is currently the case in the UK. Clearly a combination of financial instruments, including full-cost accounting and shifts from income to carbon taxes, along with a concerted public education campaign has the highest likelihood of success in reducing emissions and effectively combating climate change.

The David Suzuki Foundation has recently produced evidence that emissions in Canada can be cut by 50% by the year 2030, with many examples of measures that decrease *both* GHG emissions *and* costs (Suzuki, 2000). That target can also be achieved in Nova Scotia and is used in this study as the "high end" objective. However, we must look at specific situations in Nova Scotia in order to determine which particular emission reduction scenarios will work best here.

As is true for Canada as a whole, opportunities for GHG reduction in Nova Scotia are mainly related to energy production and use. Nova Scotia is heavily dependent on fossil fuels – electricity in the province is currently produced almost entirely by coal and oil, 79.5% and 9.7%, respectively (National Energy Board, 1999). In comparison, the national breakdown of electricity sources is: 66% hydroelectricity, 16% coal, 16% nuclear energy and 2% other (Neitzert et al., 1999). This particular profile for Nova Scotia, including impending conversions to natural gas, indicates that different opportunities for GHG emission reductions exist here than in other parts of the country.

Although emissions from electricity production are treated separately from residential emissions, it must be remembered that the two are closely related and that decreasing GHG emissions in Nova Scotia will require more efficient energy use in both production and consumption of electricity.

In addition, Nova Scotia still has a significant rural population, and the headquarters of many suppliers for businesses are located outside the province. Therefore, transportation is another major source of GHG emissions. Because energy production, transportation, and residential energy use together account for 76% of all GHG emissions in this province (Table 3, Figure 4), these sectors present the greatest opportunity for substantial emission reductions. While there are other important emission reduction opportunities (in farming methods for example), this Chapter focuses on what corporations, governments and individuals can do in the three sectors that account for the highest proportion of emissions. This study also does not address the issue of governmental regulations and incentives that will promote GHG reductions, although that it is a vital area for exploration.

6.1. Opportunities for Reduction in Steam and Electricity Generation

Table 12 summarizes Nova Scotia Power Inc.'s (NSPI) planned/in-place projects and projects under investigation to reduce GHG emissions. By far the most cost-effective short-term GHG reduction action for NSPI will be conversion to natural gas. This includes planned conversions at Trenton 5 and 6 on Nova Scotia's north shore and Tufts Cove 1, 2 and 3 in Dartmouth. At some locations, use of gas in combined facilities will be considered. In fact, 75% of total GHG reductions envisioned by NSPI for 2012 can be accounted for by conversion to natural gas.

The second most effective GHG reduction plan is increased energy efficiency in thermal and hydroplants and in the transmission and distribution system. According to NSPI, use of renewable energy is the third most effective action. However, NSPI's flat rate estimate for renewables (Table 12) appears to be based on the assumption that there will be no further investment in renewables.

NSPI's GHG emissions in 1990 were 6.8Mt. The target reduction for NSPI is based on a baseline that is higher than actual 1990 emissions in order to include two additional generating units (Point Aconi and Trenton 6), which were approved prior to 1990 but came on line after 1990. The approved NSPI baseline for 1990 is 9.6Mt, so that a 6% reduction would be 576kt, producing emissions of 9Mt in 2012. A target of 6% below *actual* 1990 emissions, would require a reduction of 389kt, resulting in total annual emissions of 6.5Mt in 2010.

NSPI's projection for GHG emissions without abatement procedures is 10.5Mt in 2012 (Table 12). NSPI's projected emissions for 2012, with abatement procedures in place, is 7Mt. This amount constitutes a 27% decrease from the 1990 baseline, but a 3% increase over actual 1990 emissions. If NSPI accomplishes its own reduction target, it will still mean an increase in overall emissions from power generation in Nova Scotia of 168kt over the actual emissions in 1990.

These estimates include programs for emission reductions that are still under investigation by NSPI, including increased thermal energy efficiency; cogeneration projects (Halifax district heating) and additional fuel switching. Further options for emission reductions and associated co-benefits are discussed in the next Sections. Opportunities for emission reductions through energy conservation measures in the residential sector are discussed in Section 6.2.

Fully 75% of the proposed NSPI emission reductions rely on conversion to natural gas, 62% are still under investigation, and none envision a reduction in energy demand through conservation measures. David Suzuki advocates conversion of coal and oil fired plants to natural gas but also proposes measures that would allow consumers to decrease their energy demand by one-third by the year 2030 (Suzuki, 2000). The modest reductions envisioned in the NSPI reduction plan and the fact that planned GHG emissions in 2012 exceed actual 1990 power generation emissions indicate that the existing NSPI plan will make little substantive contribution to needed GHG reduction targets for the province as a whole.

Table 12. Projected Greenhouse Gas Emission Reductions from Nova Scotia Power Inc.'s Emission Reduction Plan

Source/Reduction	CO2 Equivalent (kilotonnes)		
	2005	2010	2012
Projected Emissions (BAU)	9,862	10,338	10,517
Projected Emission Reductions			
Planned/In-Place Projects			
Conversion to Natural Gas (Tufts Cove 1-3)	691	691	691
Internal Efficiency Improvements	380	394	398
Renewables and other projects	178	178	178
Offset Projects	59	59	59
TOTAL: Planned/In-Place Projects	1,308	1,322	1,326
Projects Under Investigation			
Internal Efficiency	93	93	93
Cogeneration	118	145	150
Conversion to Natural Gas at Trenton 5 and 6 and Conversion of Trenton 5 to Combined Cycle	444	444	1,933
TOTAL: Projects Under Investigation	655	682	2,176
TOTAL PROJECTED EMISSION REDUCTIONS	**1,963**	**2,004**	**3,502**
NSPI Net CO_2 Equivalent Contribution to Atmosphere	7,899	8,334	7,015
Actual CO_2 Equivalent Emissions in 1990: **6.8Mt**			
Approved 1990 Baseline CO_2 Equivalent Emissions: **9.6Mt**			
Target Reduction 6% Below 1990 CO_2 Equivalent Baseline: **9.0Mt**			

Source: Voluntary Challenge and Registry Inc., 2000, Tables 6-8.

The fact that 75% of NSPI's proposed reductions are dependent on conversion to natural gas (a fortuitous historical circumstance) indicates that opportunities for more substantial and proactive reductions in GHG emissions must be explored in this sector if Nova Scotia is to assume any kind of leadership role. Since power generation is responsible for fully 39% of the province's total GHG emissions, advances in this sector are clearly central to any overall provincial strategy.

In particular, it is clear that greater attention must be paid both to conservation and to long-term investments in renewable energy sources, which currently account for only 5% of NSPI's proposed emission reductions and only 2.5% of projected emissions. In these areas, there are important innovations under way outside the NSPI framework that should be considered in any cost-benefit analysis of GHG reduction options in power generation.

For example, the Western Valley Development Authority (WVDA) has begun to explore the potential for wind-based power generation in the Annapolis Valley. As the world's leader in wind technology, Denmark has demonstrated that innovations in the field of renewable energy can produce substantial economic benefits to market leaders in the field. This example provides an important model for Nova Scotia.

As noted previously, Suzuki, Hawken, Lovins and others have provided concrete and practical examples of major conservation measures that can sharply cut GHG emissions and save money in avoided energy costs. While such conservation initiatives may not come from a power generation company whose revenues are tied to consumption expenditures, there is clearly a strong case for government, business and consumer interests, all of which stand to benefit financially in energy savings, to explore such conservation options further (see Section 6.2).

In sum, given the very modest assumptions in the NSPI plan and the potential for deeper and more innovative GHG emission reductions in this sector, it is clearly necessary to look beyond the NSPI plan if Nova Scotia is to make substantive progress in this sector.

In particular, **GPI***Atlantic* recommends that any cost-benefit analysis of potential GHG reductions in the important power generation sector include a full evaluation of tried and tested conservation options and of investments in renewable energy sources. The promising advances in wind technology, already under investigation in Nova Scotia both by the WVDA and by business interests, may be particularly viable for conditions in this province.

Co-Benefits of Fuel Switching for GHG Emission Reductions and Improved Ambient Air Quality

As noted in the Chapter 5, the notion of "control costs" can be confusing and even misleading, because these apparent up-front "costs" of reducing emissions are generally not compared to future savings from avoided climate change damages and because they may exclude other concomitant social, economic and environmental benefits of GHG reductions. Even when compared to avoided damage costs, gross control costs are highly likely to understate the cost-effectiveness of emission reductions unless these co-benefits are considered.

Even conceptually, "control costs" imply site-specific end-of-pipe solutions comparable to installing scrubbers on smoke stacks, rather than systemic preventive measures like energy conservation that may result in productivity and efficiency gains, cost savings and net benefits, rather than "costs." From the GPI perspective, control costs may be more appropriately labeled as "investments" with a rate of return realized not only in avoided climate change damages, but also in other less apparent or longer-term co-benefits.

Appendix D of this study demonstrates the GPI full-cost accounting method in some detail applied to a wide range of potential social, economic and environmental benefits and costs in a specific GHG reduction scenario – a freight shift of 10% from road to rail. In less detail, this Section demonstrates the applicability of such an analysis to just one potential co-benefit of fuel switching – an improvement in ambient air quality.

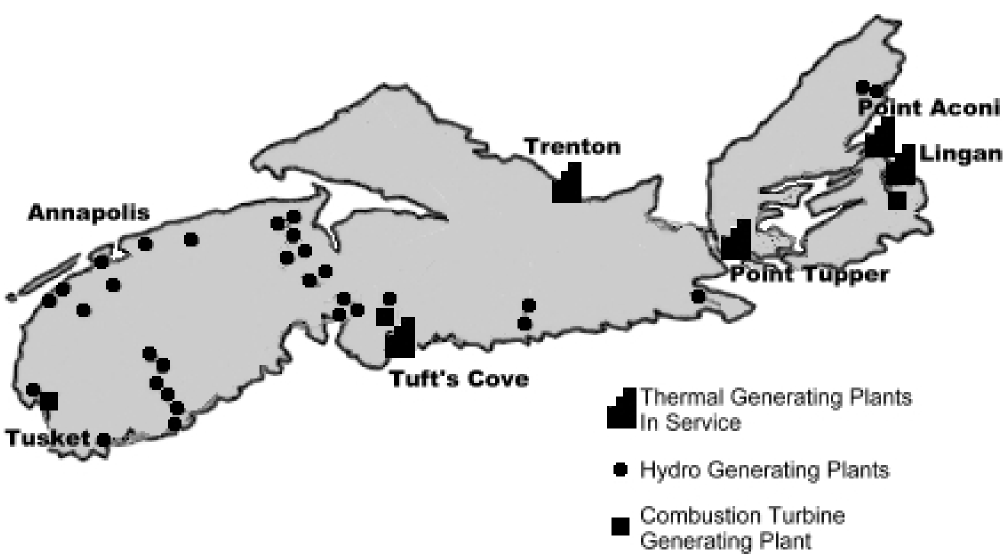
From the perspective of Nova Scotia Power Inc., the potential for GHG reductions in power generation may be measured literally as a gross "control cost," or expense – "How much is it going to cost us to reduce emissions by a certain amount?" But from the perspective of society at large, there are other benefits that will be gained from such reductions, benefits that can significantly modify the costs of mitigation in the long term, and that can ameliorate any additional expenses passed on by NSPI to its customers.

Here we look briefly at the potential of fuel-switching to improve ambient air quality at the same time that it reduces GHG emissions. It is presented here in order to point towards the type of analysis that should be conducted for all emission reduction scenarios, and that can qualify dramatically the notion of "control costs."

NSPI generates 97% of the energy used by Nova Scotians (NSPI, 2001b). Five thermal generating plants located throughout the province are responsible for 90% of the power produced: Lingan, Point Aconi, Point Tupper, Trenton and Tufts Cove (Figure 15). Coal is currently the primary source of energy in these stations, with the exception of Tufts Cove which has used oil. The fuel types and capacities of these plants are summarized in Table 13.

The remaining 10% of NSPI's energy is generated by 33 small hydroelectric plants, one tidal plant and three combustion turbines across Nova Scotia (NSPI, 2001b). In other words, 90% of electricity in Nova Scotia is generated by non-renewable fossil fuels (coal, oil and natural gas), with only 10% of electricity generated by renewable energy sources.

Figure 15. Location of Electrical Power Generating Stations Operated by NSPI



Source: Adapted from NSPI, 2001a.

Table 13. Nova Scotia Electric Generating Stations (1997): Capacity, Start Date and Estimated Year of Retirement

Station	Fuel	Capacity (MW)	Start Date	Estimated Retirement
Tufts Cove 1	Oil	100	1965	2000
Trenton 5	Coal/Oil	150	1969	2004
Tufts Cove 2	Oil	100	1972	2007
Tufts Cove 3	Oil	150	1976	2011
Lingan 1	Coal/Oil	150	1979	2014
Lingan 2	Coal/Oil	150	1980	2015
Lingan 3	Coal/Oil	150	1983	2018
Lingan 4	Coal/Oil	150	1984	2019
Point Tupper 2	Coal	150	1988	2023
Trenton 6	Coal/Oil	150	1991	2026
Point Aconi 1	Coal with limestone additive	185	1994	2029

Notes: Assumes a retirement after 35 years of serviceable life. MW = megawatts.

Source: Adapted from MacRae (1997) with additional information from NSPI, 2001a.

Table 14 summarizes the estimated damage costs per tonne of the main pollutants generated through fossil fuel combustion. These pollutants are sulphur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOC) and total particulate matter (TPM). Costs include estimated damages to human health, forests, crops, and other material and environmental assets. In order to present a range of values, both low and high cost estimates are given from the literature.

Table 14. Damage Costs of Emissions Used in Present Study (C$ 1997 per tonne)

Pollutant	Cost Per Tonne (C $1997)		References
	Low	High	
CO_2	$38	$1,040	Cline 1995, Bein and Rintoul 1999
SO_2	$1,000	$6,240	Klein 1997, IBI 1995
NOx	$1,000	$7,280	Klein 1997, IBI 1995
VOC	$3,161	$5,200	Tellus Institute 1994, IBI 1995
TPM	$2,000	$4,160	Klein 1997, IBI 1995

In addition to contributing GHG-related damage costs of $293-$8,029 million, the electrical power generation sector in Nova Scotia contributes between $164-$1,027 million in damage costs due to non-GHG emissions (Table 15). The majority of these damage costs can be attributed to sulphur dioxide (SO_2) emissions ($135-$842 million) which cause acid rain, respiratory irritation, reduced crop yields and materials damage.

Table 15. Electrical Power Generation (Utilities) Sector: Estimated Emissions (1995) and Estimated Damage Costs

Pollutant	Nova Scotia Emissions (Tonnes)	Damage Costs (C$ 1997 millions)	
		Low	High
CO_2 equivalent	7,720,000	\$293	\$8,029
SOx	134,883	\$135	\$842
NOx	24,330	\$24	\$177
VOC	126	\$0.4	\$0.7
TPM	1,910	\$4	\$8
TOTAL		\$457	\$9,056
TOTAL (non-GHG damage costs)		\$164	\$1,027

Note: All emissions are estimated for the year 1995 with the exception of CO_2 equivalent emissions which are estimated for 1997. Since the emissions data are for sulphur oxides and the damage cost estimate is for sulphur dioxide, SOx and SO_2 are assumed to be equivalent for the purposes of these calculations.

Sources: **kt CO_2 equivalent emissions:** Neitzert et al, 1999 (see Table 3); **TPM, SOx, NOx, and VOC emissions:** Pollution Data Branch, 2001.

Damage costs due to nitrogen oxide emissions are also significant (\$24-\$177 million), since these compounds contribute to the formation of ground-level ozone (smog) which can cause respiratory irritation and increased susceptibility to respiratory infection.[17]

Particulate matter in the atmosphere consists of particles ranging in diameter from 0.005 to 100µm. Only particles with a diameter of 10µm or less (PM_{10}) enter the thoracic region. Particles of 2.5µm or less ($PM_{2.5}$) can penetrate deep into the lungs. Both PM_{10} and $PM_{2.5}$ can elicit a toxic response in humans. Damage costs due to total particulate matter emissions range from \$4 million to \$8 million.

The term volatile organic compounds refers collectively to organic gases and vapours in the atmosphere, excluding methane. VOCs contribute to the formation of photochemical smog and can be toxic to humans. Benzene, for example, is a known human carcinogen. VOCs damage costs are estimated to be between \$400,000 and \$700,000.

In sum, fossil fuel combustion causes serious air pollution problems that produce environmental and health costs above and beyond the damage due to GHG emissions and climate change. Therefore, reductions in fossil fuel combustion that have the goal of reducing GHG emissions will also improve ambient air quality and generate significant additional savings in avoided health and environmental damage costs due to other pollutants.

[17] The damage costs associated with air pollution in Nova Scotia will be more fully explored in the forthcoming GPI Air Quality Accounts (2001).

Fuel Switching at Tufts Cove Thermal Generating Plant

In the summer of 2000, Tufts Cove Generating Station in Dartmouth completed a $24 million project to modify the station's three units. Previously, the three Tufts Cove units were oil-fired steam boiler/turbine units. The boilers were modified so that they are now capable of switching between Bunker "C" oil and natural gas, allowing more flexibility within NSPI's fuel mix. The latest technology burners have been installed, which will help reduce nitrogen oxides, whether the plant is burning natural gas or oil. Depending on fuel pricing, Tufts Cove will burn the less expensive of the two fuels. Unfortunately, information on the exact amounts of natural gas and oil used since the commissioning of the new boilers is not publicly available.

This NSPI strategy is based solely on market prices for natural gas and oil and does not include the costs of "externalities" associated with electrical power generation. These externalities include the climate change effects caused by GHG emissions as well as the health and environmental impacts of emissions of SOx, NOx, VOCs and TPM on ambient air quality.

Another option available to NSPI when the Tufts Cove units were nearing retirement was a straightforward replacement of the existing boiler systems with a gas turbine/heat recovery steam generator combination (combined cycle). This option would have required a much greater up-front investment than the fuel-switching option NSPI chose – as much as $315 million (Klein, 1997), but would have produced substantially greater benefits, because the combined cycle operates at a much higher efficiency which in turn results in fewer GHG and non-GHG emissions. The higher efficiency would also result in substantial fuel savings.

Further, the combined cycle operates at a much higher capacity [420 megawatts (MW) per unit] than the simple-cycle gas turbines (100 to 150 MW per unit) (MacRae, 1997). Upgrading only the #3 unit at Tufts Cove to combined cycle would provide enough energy so that there would be no need to run Tufts Cove 1, Tufts Cove 2, Trenton 5 and Point Tupper 2 (MacRae, 1997). This would have resulted in an additional substantial reduction in GHG and non-GHG emissions and substantial savings that must be subtracted from the large initial investment expense.

When a wider range of "externalities" is considered, we see that strategies to reduce GHG emissions have the added effect of reducing damage costs associated with non-GHG emissions as well (Table 16 and Figure 16). Internalizing these costs in the GPI full-cost accounting approach indicates that the decision to use natural gas or oil should depend not only on comparative market prices, according to NSPI's current plan, but also on the potential savings in damage costs associated with *both* reduced GHG *and* non-GHG emissions.

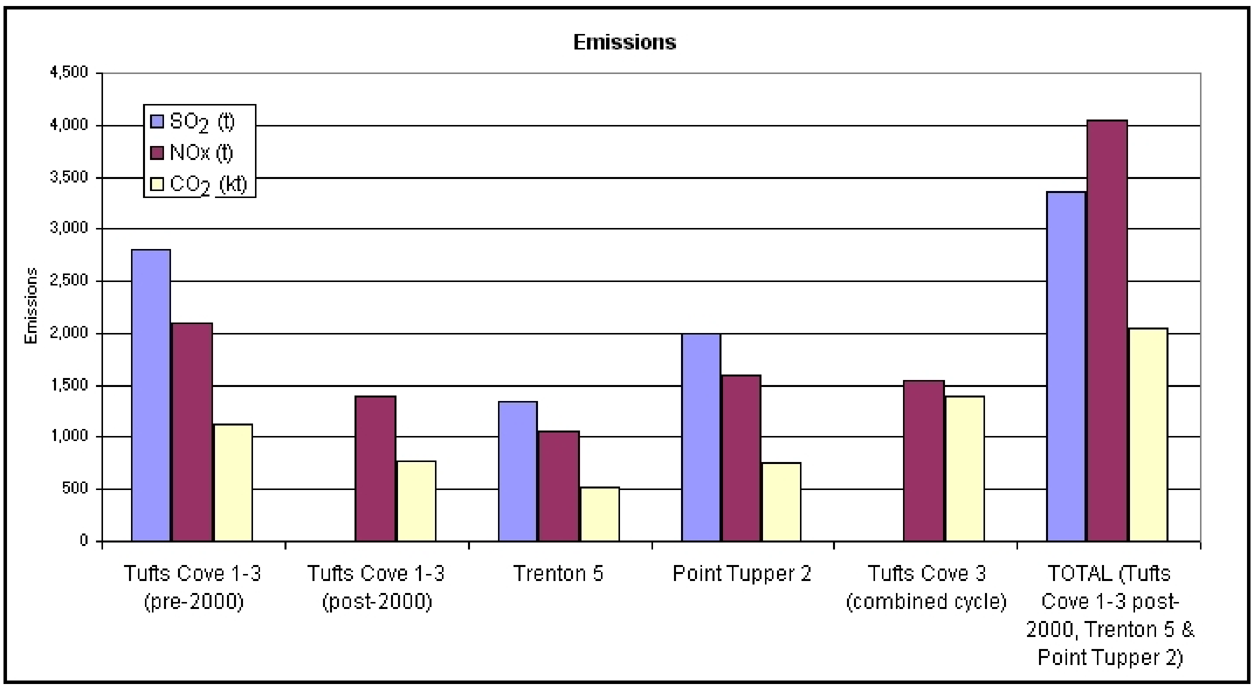
A significant difference in emissions is seen between the pre-2000 oil-fired boilers and the new gas-fired boilers installed in 2000 (Figure 16). In particular, sulphur dioxide emissions are reduced to zero, carbon dioxide emissions are reduced by 31%, and nitrogen oxides are reduced by 33% when natural gas is used. It may appear from Figure 16 that the combined cycle upgrade creates more emissions than gas-fired steam, but it should be noted that upgrading to combined cycle would eliminate the emissions for Tufts Cove 1-3 (post-2000), Trenton 5 and Point Tupper 2.

Table 16. Approximate Comparison of Air Pollutants Emitted from Various Electricity Generating Plants

	Efficiency (%)	Emissions (kg/MW·h)		
		SO_2	NOx	CO_2
Coal-Fired Steam (with low-NOx burner, SO_2 scrubber)	36	2.5	2.0	950
Oil-Fired Steam (1% sulphur #6 oil, scrubber)	36	2.0	1.5	800
Gas-Fired Steam (with low-NOx burner)	36	0	1.0	550
Combined Cycle (gas fuel, steam injection)	45	0	0.5	450

Source: MacRae, 1997.

Figure 16. Sulphur Dioxide, Nitrogen Oxides and Carbon Dioxide Emissions from Various Boiler Types



Notes: Because of the much higher capacity of a Tufts Cove 3 combined cycle operation, total emissions from Tufts Cove 3 must be compared to the combined total emissions of the post-2000 Tufts Cove 1-3 units, Trenton 5 and Point Tupper two units. Suphur dioxide and nitrogen oxide emissions are in tonnes; carbon dioxide emissions are in kilotonnes.

Assuming that all three Tufts Cove units use either 100% oil or 100% natural gas, then the emissions profile for the Tufts Cove plant is that presented in Table 17. There are two possible scenarios for oil-fired steam boilers, depending on the specific fuel oil used (1% sulphur and

2.6% sulphur). Since information on the percentage sulphur is not publicly available, the 1% sulphur type fuel is used for the purposes of this analysis. The lower-sulphur fuel type results in smaller emissions of SO_2 and NOx, producing a more conservative estimate than if use of 2.6% sulphur oil were assumed.

It should also be noted that the modified boilers are capable of switching between oil and natural gas and that the calculations in Table 17 are based on the assumption that natural gas only is used in the gas-fired boiler.

Since upgrading the #3 Tufts Cove unit to combined cycle would provide enough energy so that there would be no need to run Tufts Cove 1, Tufts Cove 2, Trenton 5 and Point Tupper 2, annual emissions estimates for those stations are also shown in Table 17. There are two possible scenarios for coal-fired boilers as well (coal fired steam with 2.5% sulphur and coal fired steam with low-NOx burner with SO_2 scrubber). Since information on the sulphur content of the coal fuel used by Trenton 5 and Point Tupper 2 is not publicly available, the calculations in Table 17 assume the latter. Trenton 5 is capable of using both coal and oil. The calculations for Trenton 5 in Table 17 are based on the assumption that oil is used 50% of the time and coal is used the remaining 50% of the time. Point Tupper 2 is capable of burning only coal, so the calculations are based on coal being used 100% of the time.

GPI*Atlantic* urges NSPI to make information publicly available both on the sulphur content of its fuel and on the proportion of fuels actually used, so that more accurate estimates of actual emissions can be made. Both factors significantly impact total emissions. Since GHG and air pollutant emissions are a matter of public interest and concern, this information should be in the public domain. Table 17 calculations give the benefit of doubt to NSPI and assume the lowest possible emissions, but greater accuracy depends on the utility providing this basic information on actual fuel use.

By undergoing $24 million in modifications at Tufts Cove, annual damage costs associated with sulphur dioxide emissions are reduced from between $2.8-$17.5 million to zero (assuming that natural gas is used 100% of the time) (Table 18). By upgrading a single unit at Tufts Cove to combined cycle instead of the modifications made by NSPI, the initial outlay of funds would have been much greater than $24 million, but the other two Tufts Cove units, the Trenton 5 unit and the Point Tupper unit would no longer be needed, producing substantial savings in operating costs to NSPI. This conversion to combined cycle would have resulted in an additional annual savings in SO_2 damage costs of $6.2-$38.5 million – a decrease of 55%. This damage cost savings would occur each year over the 35-year servicable life of the unit.

If Tuft's Cove uses natural gas 100% of the time, annual nitrogen oxide damage costs after the 2000 Tufts Cove modifications are reduced from $2.3-$15.3 million to $1.4-$10.2 million dollars – a decrease of 33%-39%. If a single Tufts Cove unit had been upgraded to combined cycle, $4.8-$33.4 million dollars in NOx damage costs could have been avoided annually – a decrease of 52%-54%.

Carbon dioxide damage costs after the 2000 Tufts Cove modifications are reduced from $42.6-$1,165 million to $29.3-$801 million dollars per year – a decrease of 31%. If a single Tufts Cove unit had been upgraded to combined cycle, \$67.8-\$1,851 million dollars in CO_2 damage costs would have been avoided – a decrease of 37%.

Table 17. Sulphur Dioxide, Nitrogen Oxides and Carbon Dioxide Emissions for Various Boiler Types used by and available to NSPI

Station, Type of Boiler and Type of Fuel	Generating Capacity (GW·h/year)	Annual Emissions		
		SO_2 (t)	NOx (t)	CO_2 (kt)
Tufts Cove 1, 2 and 3 (pre-2000 modifications) Oil-Fired Steam (1% sulphur #6 oil, scrubber)	1,400	2,800	2,100	1,120
Tufts Cove 1, 2 and 3 (post-2000 modifications) Gas-Fired Steam (with low-NOx burner)	1,400	0	1,400	770
Trenton 5 50% Coal-fired Steam (with low-NOx burner, SO_2 scrubber) and 50% Oil-Fired Steam (1% sulphur #6 oil, scrubber)	600	1,350	1,050	525
Point Tupper 2 Coal-Fired Steam (with low-NOx burner, SO_2 scrubber)	800	2,000	1,600	760
Tufts Cove 3 Combined Cycle (gas fuel, steam injection)	3,100	0	1,550	1,395
Reduced emissions due to modifications in 2000		2,800	700	350
Reduced emissions if Tufts Cove 3 had been converted to combined cycle instead of the modifications in 2000 (emissions from Tufts Cove 1-3 *Pre*-2000, Trenton 5 and Point Tupper 2 minus Tufts Cove 3 combined cycle emissions)		6,150	3,200	1,010
Reduced emissions if Tufts Cove 3 or another 150MW unit is converted to combined cycle (emissions from Tufts Cove 1-3 *Post*-2000, Trenton 5 and Point Tupper 2 minus Tufts Cove 3 combined cycle emissions)		3,350	4,050	660

Notes:

1) Calculations for Tufts Cove units are based on the assumption that oil was used 100% of the time prior to the 2000 modifications and that natural gas has been used 100% of the time since the 2000 modifications.
2) Calculations for Tufts Cove 3 ***if*** it were converted to combined cycle (potential scenario). This serves as a proxy for any 150MW unit in the NSPI system being converted to combined cycle.
3) Calculations for Trenton 5 are based on the use of coal 50% of the time and oil for the other 50%.
4) Because of the much higher capacity of a Tufts Cove 3 combined cycle operation, total emissions from Tufts Cove 3 must be compared to the combined total emissions of either the pre- or post-2000 Tufts Cove 1-3 units, Trenton 5 and Point Tupper two units.

Source: **Generating Capacity:** MacRae, 1997.

Table 18. Damage Costs of Emissions from Various Types of Electrical Power Generating Units (C $1997 millions)

Station, Type of Boiler and Type of Fuel	SO_2		NOx		CO_2		TOTALS	
	Low	High	Low	High	Low	High	Low	High
Tufts Cove 1, 2 and 3 (pre-2000)	$2.8	$17.5	$2.1	$15.3	$42.6	$1,165	$47	$1,198
Tufts Cove 1, 2 and 3 (post-2000)	$0.0	$0.0	$1.4	$10.2	$29.3	$801	$31	$811
Trenton 5 Coal- and Oil-Fired	$1.4	$8.4	$1.1	$7.6	$20.0	$546	$22	$562
Point Tupper 2 Coal-Fired	$2.0	$12.5	$1.6	$11.6	$28.9	$790	$32	$815
Tufts Cove 3 Combined Cycle	$0.0	$0.0	$1.6	$11.3	$53.0	$1,451	$55	$1,462
Damage costs avoided due to modifications in 2000	$2.8	$17.5	$0.7	$5.1	$13.3	$364	$16	$387
Damage costs avoided if Tufts Cove 3 had been converted to combined cycle instead of the modifications in 2000 (Tufts Cove 1-3 *Pre*-2000, Trenton 5 & Point Tupper 2 minus Tufts Cove 3 combined cycle emissions)	$6.2	$38.4	$3.2	$23.2	$38.5	$1,050	$46	$1,113
Damage costs avoided if Tufts Cove 3 or another 150MW unit is converted to combined cycle (Tufts Cove 1-3 *Post*-2000, Trenton 5 & Point Tupper 2 minus Tufts Cove 3 combined cycle emissions)	$3.4	$20.9	$2.5	$18.1	$25.2	$686	$30	$726

Note: Totals may not always reflect sums due to rounding.

By using natural gas-fired steam generation at Tufts Cove, a total of $47-$1,198 million in annual damage costs due to SO_2, NOx and CO_2 emissions are reduced to $31-$811 million – a 32%-34% decrease. Even if natural gas is only used 50% of the time, damage costs are still reduced by 16%-17%. Total non-GHG damage costs avoided are $4.9-$32.8 million assuming 100% use of natural gas at Tufts Cove. Total annual damages avoided as a result of NSPI's $24 million investment therefore range between $16 million (low estimate) and $387 million (high estimate).

It should be noted that these are single year savings estimates. When cumulative estimates are made over a number of years, accounting for the long atmospheric life of CO_2 in particular, these savings are significantly multiplied. A single investment in emission reductions continues to avoid climate change and pollutant damages for the estimated 35-year operating life-span of the refurbished generating units. In sum, NSPI's $24 million investment in gas-fired boilers is highly cost-effective from a full-cost accounting perspective at both the low end and the high end of damage estimates when viewed over the operating life-span of the generating units.

If, however, NSPI had chosen to upgrade Tufts Cove 3 to combined cycle, $77-$1,924 million dollars in CO_2 damage costs would have been avoided. Compared to an estimated capital investment of $315 million (which is not adjusted to reflect fuel and efficiency savings due to replacement of *five* existing generating units) combined cycle is an even more cost-effective investment than installation of gas-fired boilers. This is true at both the high and low ends of the scale when viewed over the estimated 35-year operating life span of the combined cycle unit.

Since Tufts Cove modifications were completed in 2000 and since the units have an estimated 35 years of serviceable life, it is unlikely that NSPI will choose to upgrade any of the Tufts Cove units to combined cycle. The hypothetical scenario described above is used for illustrative purposes only, but it should be noted that comparable results could be obtained by converting any 150MW unit in NSPI's current system (i.e., Lingan 1-4, Trenton 5 and 6, and Point Tupper 2). The estimated retirement date for Trenton 5 is 2004 and converting this unit to combined cycle is listed by NSPI as a project under investigation (Voluntary Challenge and Registry Inc., 1999). The initial investment in combined cycle may appear expensive compared to other options. However, conversion to combined cycle at Trenton 5 in 2004 would significantly reduce GHG and non-GHG emissions and their associated damage costs, in addition to producing major savings for the utility in replacing existing lower-capacity generating units. Cost-effectiveness in the longer term is definitively demonstrated when all these factors are taken into account over the life-span of a new combined cycle unit.

It should be noted that these total emission reductions and economic savings do not include estimates of damage costs avoided for VOC and TPM emissions. Also, the estimates likely err on the conservative side since the lower-emitting coal and oil types were selected for use in the analysis. As noted earlier, NSPI generates 90% of the energy used by Nova Scotians in five thermal generating plants. The preceding analysis did not include scenarios involving all plants and all units, so the analysis is not exhaustive.

In addition, emissions from the full fuel cycle, including extraction, processing, transmission, distribution, storage and end use must be considered in a true full-cost accounting analysis, whereas this study has examined only the electricity generation process itself. For that fuller analysis, the GHG and non-GHG emissions from the full fuel cycle for coal, oil and natural gas need to be estimated. Jacques-Whitford Environmental Consultants, the Clean Nova Scotia Foundation and **GPI***Atlantic* have jointly made a proposal to conduct such a life-cycle analysis and to estimate comparative costs and benefits for alternative energy generation scenarios from a full-cost accounting perspective.

GHG emissions from natural gas operations are expected to decrease as new control measures are put in place (CGA, 1997). Because of the increase in demand for natural gas, it is unlikely that there will be a decline in absolute emission volumes from natural gas. However the total emissions from natural gas will be considerably less than if more polluting fuels were used to meet energy demands.

The use of natural gas should not be considered as the solution to Nova Scotia's GHG and non-GHG emissions problems. Natural gas use still results in a net increase in atmospheric GHG concentrations, in depletion of a non-renewable resource, and in other indirect costs. The use of natural gas should therefore be considered a temporary or transitional measure to begin reducing emissions in the short term, while allowing alternate forms of renewable energy to be developed in the interim.

6.2. Opportunities for GHG Reductions in the Residential Sector

Annual electric costs for Nova Scotian households average $1921.09 (Voluntary Challenge and Registry Inc., 2000).[18] That is an average for all households in the province, regardless of heating source.

For those households that use electric heat, electrical energy use breakdown and costs are as follows:

- Heat: 50% ($960.55)
- Hot Water: 30% ($576.33)
- Appliances: 14% ($268.95)
- Lights: 6% ($115.27)

The **GPI***Atlantic* study "*The Nova Scotia Ecological Footprint*" recommends a number of measures by which Nova Scotians could reduce their energy use and costs by nearly 50% (Wilson, 2001). Table 19, based on Nova Scotia Power estimates, presents some of the GHG reduction measures that would be available to most Nova Scotians, along with the potential cost savings and savings in kilowatt hours.

Table 19 is based on households with electric heat. But, for the purposes of this exercise, it is assumed that other residential energy sources, such as furnace oil for home heating and propane, could be reduced proportionately. For example, turning down one's thermostat will produce energy savings and GHG reductions no matter what the heat source. Although the following savings are based on an all-electric household, they can therefore be used as a proxy measure for all households, regardless of heating fuel.

[18] George Foote, NS Department of Natural Resources (October 2000), correctly points out that this average masks significant disparities among houses with and without electric heat. Time did not permit a more detailed breakdown at this stage, but future updates of this report should make distinctions on electricity and energy use according to household facilities. Household members who wish to calculate their own fuel and heating costs should refer to fuel prices and fuel and heating costs provided by the NS Department of Natural Resources at the NS Department of Natural Resources web site, www.gov.ns.ca/natr/energy/homeheat/default.htm (NS Department of Natural Resources, 2001). For more details on residential energy costs, and potential cost savings and emission reductions, see **GPI***Atlantic*'s "*The Nova Scotia Ecological Footprint*" (Wilson, 2001).

Table 19. Reduction Opportunities in the Residential Sector & Savings

Energy Saving Measure	Economic Savings (Cdn$2000)	Energy Savings[i] (KWH)
Switch to a time based-programmable thermostat (from a standard non-programmable thermostat)	$288.16[ii]	3,002
Turn down the thermostat at night to 17 degrees (based on a household temperature of 21 degrees)	$76.84[ii]	800
Switch from standard incandescent bulbs to		
a) Halogen bulbs	$63.40	660
b) compact fluorescent bulbs (assumes 150 operating hours/month)	$86.45	901
Install a low flow shower head (assumes a household of four)[iii]	$60.83	634
Clothes Washer (assumes 34 loads per month)		
a) Switch to energy efficient model	$29.94	312
b) Wash clothes in cold water vs. hot water	$107.14	1,116
Clothes dryer (assumes 34 loads per month)		
a) Switch to energy efficient model	$35.70	372
b) Hang dry	$115.20	1,200
Dish washer (assumes 34 loads per month)		
a) Switch to energy efficient model	$49.56	516
Refrigerator (responsible for 15% of household energy use)		
a) switch to energy efficient model	$62.76	654
Air Conditioner (assumes 3 month use period)		
a) Switch to an energy efficient model	$32.40	338
b) Switch to a fan	$25.92	270
c) Open windows	$64.80	675
Add an insulating blanket to hot water heater (Assumes an average use of 355 kwh/month = approximate use for household of three)[ii]	$20.40	213
Clean furnace filter regularly	$144.01	1,500

Notes:

[i] Annual savings estimates are in KWH and are based on NS Power estimates of typical electrical costs and assume the year 2000 rate of $0.096 per kilowatt hour including taxes (NSPI, 2000.)

[ii] These dollar costs and savings are based on electric heat costs, as detailed on the Nova Scotia Power web site. Actual costs and savings will vary significantly according to household and fuel source. Whatever one's home heating fuel source, however, switching to a time based programmable thermostat or turning down the thermostat at night to 17 degrees will reduce one's household energy footprint and produce comparable overall energy savings. For more information on household heating costs and savings, please visit the NS Department of Natural Resources web site, www.gov.ns.ca/natr/energy/homeheat/default.htm (NS Department of Natural Resources, 2001)

[iii] Due to different data sources, some proposed actions refer to a household size of three individuals, while others are based on a household size of four.

Source: Adapted from Wilson, 2001.

Another caveat, mentioned earlier, is that official GHG emission statistics separate out electricity generation, transportation and residential energy use. Thus, in the provincial emissions statistics, furnace oil use for home heating is attributed to households while electric heat use is attributed to the utility company. As well, household use of gasoline for automobiles, SUVs and minivans is attributed to the transportation sector not to the residential energy use sector.

As a proportion of total provincial GHG emissions, therefore, the 10.5% attributed to "residential energy use" is therefore very much understated. Conversely, this means that changes in household behaviour that produce reductions in GHG emissions will reduce emissions in the electric generation and transportation sectors in addition to the residential sector. Nova Scotia Power's projected reductions in GHG emissions described above, for example, do not include reductions to energy savings and conservation by households.

In the end, these accounting details and categories do not materially affect the tables that follow. The savings described here can accrue to households within their homes regardless of home heating source, and Section 6.3 on transportation offers further opportunities for households to reduce their GHG emissions through changes in their travel habits.

With residential energy use contributing 2,100kt CO_2 equivalent emissions annually, and with a conservative 30% of Nova Scotian households participating in the full range of energy reduction measures described above, emissions savings of 315kt CO_2 equivalent would result. With 50% participation, emissions savings rise to 525kt and with 60% participating, the total reduction would be 630kt CO_2 equivalent (or 30% of current residential emissions.)

This is a "no regrets" measure, since each household saves an average of more than $800 a year in electrical energy costs and it would also more than accomplish the Kyoto target to reduce emissions to 6% below 1990 levels for the residential sector.

In another more modest scenario, if total residential emissions were reduced by 1% each year, from 2000 to 2010, a reduction of 184kt would be accomplished. NSPI and the Clean Nova Scotia Foundation energy audit program have both shown that it is possible to reduce GHG emissions through education and public campaigns. The 1999-2000 NSPI campaign alone was expected to produce a decrease in GHG emissions of 1.3% in one year. So the residential emission reduction goals outlined above are quite achievable, with the right mix of education and incentives, just as Nova Scotians have already markedly changed their behaviour to divert 50% of their solid waste from landfills.

6.3. Opportunities for Reduction in the Transportation Sector

Opportunities for GHG emission reductions in the transportation sector will be explored in more detail in **GPI***Atlantic*'s forthcoming transportation module (anticipated release: Winter 2001-2002). For more details on reducing GHG emissions in the transportation sector, please see Chapters 12 and 13 on Nova Scotia's Transportation Footprint in **GPI***Atlantic*'s *Nova Scotia Ecological Footprint* report (Wilson, 2001, pages 46-53).

In 1997, transportation accounted for nearly 27% of all GHG emissions in Nova Scotia, so opportunities must be found to reduce this amount significantly. In addition, the transportation sector is experiencing a particularly rapid and troubling increase in GHG emissions, fueled in part by consumer appetites for SUVs and minivans. The 5.3 million tonnes of GHGs emitted by transportation in Nova Scotia are expected to rise to 6.4 million tonnes by 2010 and to 7.1 million tonnes by the year 2020 (National Climate Change Process, 1999). For Canada as a whole, emissions from transportation are expected to increase by 24% from 124 million tonnes in 1990 to 155 million tonnes in 2010.

As shown in Figure 5, automobiles, minivans, SUVs and light-duty trucks account for 64% of GHG emissions and heavy-duty diesel trucks for 21%. Therefore these two sub-sectors (private passenger transportation and freight) offer the greatest opportunities for substantial GHG emission reductions. From the sources used to derive these figures, it is not known what percentage of light-duty gasoline trucks are used for freight or other commercial purposes.

Appendix D contains a study on opportunities for GHG emission reductions in the freight transportation sector in Nova Scotia. This study found that a 10% shift in freight from truck to rail along the Halifax-Amherst corridor could result in a reduction of 14.9kt in GHG emissions by 2010, as compared with the projected emissions for a BAU scenario. That move would save Nova Scotians $10 million a year when a full range of benefits and costs are included in the equation.

Even this kind of modest shift would require that the federal government begin to level the playing field between the railway and the trucking industries by ending subsidies to private trucking, assessing fairer taxes that correspond to actual costs, and counting the full social and environmental costs of different modes of transportation (Suzuki, 2000).

In terms of personal transportation, five factors determine the GHG emissions from personal travel:

- the number of trips
- the length of trips
- the mode of travel
- the fuel efficiency of the vehicle
- the type of fuel being used.

Measures that affect any one of these factors will, therefore, affect the amount of GHG emissions that result from personal travel. These issues are examined in more detail in the GPI Transportation and Ecological Footprint components.

Length and Number of Trips

Nova Scotians own, on average, 1.5 vehicles per household and travel over 19,000km per vehicle each year. Each vehicle in Nova Scotia currently produces an average of 4.4 tonnes of GHG emissions annually (see Section 4.1).

In order to reduce the length and number of passenger transportation trips substantially, attention must ultimately be paid to integrated land use/transportation planning. Neighborhoods can be designed to include businesses, shopping and amenities close to residential areas and thus to decrease the need for travel. In the 1970s, Portland, Oregon, estimated it could cut gasoline consumption by 5% just by adding neighbourhood grocery stores to communities.

The average commuting distance for Nova Scotians is 5,300km per year (Colman, 1998). For Canadians, commuting accounts for 28% of travel time; shopping for 21%; and entertainment for 19%. Changes in travel patterns in these areas can significantly reduce the length and number of trips and the consequent GHG emissions.

It has been suggested that increasing use of the internet and electronic communications for work and shopping can potentially replace some travel to and from work and shopping trips by allowing more home-based work opportunities and shopping. Health education campaigns (such as the former *Participaction* program) that encourage people to walk or ride bikes, along with provision of walking and bike trails (as on the Dartmouth-Halifax bridge), can also help reduce automobile travel kilometres.

Mode of Travel

Replacing a significant portion of private automobile use with urban and rural mass transit systems can have a major impact on emissions. This requires making public transit more convenient and less expensive and perhaps providing other incentives. Urban design to promote public transportation is critical in this effort. Halifax, as the major urban centre in Nova Scotia, has seen significant fare price increases and route reductions in its public transit system, leading to potential declines in usage. In more rural areas, incentives could be provided for car pools. Computerized car pool systems, such as that in Maine, can provide excellent models for Nova Scotia.

Incentives for use should be a major part of any public transit or car pool system, because under-use will undermine any system that can be devised. Dedicated lanes, road pricing systems and toll remissions have all been successfully used in different jurisdictions to encourage modal shifts from automobiles to mass transit and car pool use.

By including social and environmental costs in transportation pricing, genuine competition could be fostered among different modes of transportation, with the mode that produces the most convenience for the least cost generally being chosen. Currently, the costs of roads, parking, emissions and other elements of automobile travel are subsidized to such an extent that virtually no other mode of travel can compete fairly.

Implementing alternative transportation initiatives aimed at reducing single occupant automobile use from 73% of commuter trips at present to 50% (a 32% reduction) in the year 2010 will reduce GHG emissions by 4.7Mt in Canada from projected levels in the year 2010 (Hornung, 1998). By applying Nova Scotia's population percentage of 3.1% of the Canadian total,[19] that means a 32% reduction in single occupant automobile use will result in a GHG emission reduction of 146kt in Nova Scotia. A 50% reduction in single occupant automobile commuting would result in a GHG emission reduction of 228kt. That single step would reduce GHG emissions from total automobile travel by 14% and achieve the Kyoto target for that sector.

Using estimates of $38 and $1,040 per tonne CO_2 emissions, the 32% reduction in single occupancy commuting trips would result in damage avoidance of $5.5 million to $152 million. Associated co-benefits of single occupant automobile use reduced by 32% (at $11 and $17 per tonne) would be $1.6 million to 2.5 million. The 50% reduction would result in damage avoidance of $8.7 million to $237 million with associated co-benefits of $2.5 million to $3.9 million.

Fuel Efficiency and Type of Fuel Used

David Suzuki (2000) predicts that fuel efficiency could triple by the year 2030. He also predicts that a new generation of vehicles powered by hybrid gasoline/electric engines will increase vehicle efficiency. Hawken et al. (1999) propose three changes in current automobile design to increase efficiency and decrease emissions:

1) making the vehicle ultralight (2-3 times less than the weight of steel cars);
2) making it ultra low-drag (i.e. low resistance); and
3) making the propulsion system "hybrid-electric."

If the federal government were to implement mandatory fuel economy standards for new automobile fuel efficiency requiring an average achievement of 5 L/100km for automobiles and 7 L/100km for light trucks beginning in 2005, it would result in a national GHG emission reduction of 25.8Mt from projected levels in the year 2010 (Hornung, 1998). This equates to a reduction of about 800kt in Nova Scotia, or nearly 30% of the GHG emissions currently attributable to automobiles and light trucks in the province. The damage costs avoided by implementing such a fuel efficiency standard would be $30 million to $832 million, with additional co-benefits of $8.8 million to $13.6 million.

In the meantime, steps can be taken to discourage the current trend towards fuel-inefficient SUVs, minivans and light trucks, a market that has grown dramatically in recent years. The UK currently provides a useful model of financial incentives and tax penalties designed to encourage use of smaller, more fuel-efficient cars.

While it is beyond the scope of the present study to develop detailed scenarios for reduction of GHG emissions based on all of the above measures, this should be done in the very near future and should include provincial conditions and statistics. The transportation freight study in Appendix D could provide a template for cost-benefit studies in each of the areas outlined above.

[19] Statistics Canada's latest population estimates for Canada (30,750,100) and for Nova Scotia (941,000). Available at http:// www.statcan.ca/english/Pgdb/People/Population/demo02.htm.

In the transportation industry, emission reductions to 6% below 1990 levels (which were 5.2 million tonnes of CO_2 equivalent emissions) would mean a reduction to 4.8 million tonnes. Compared with the projected emissions in 2010 of 6.4 million tonnes, this would mean a total required reduction of 1.6 million tonnes based on current trends.

6.4. Summary of Potential Nova Scotia GHG Reduction Opportunities

Table 20 shows the potential for emission reduction opportunities in the three sectors just described.

If NSPI were to implement all of its planned/in-place and under investigation projects (excluding the hypothetical scenario of Tufts Cove 3 being converted to combined cycle), and if the other modest measures in Table 20 were implemented, Nova Scotia's GHG emissions could be reduced by between 2.9 and 3.7 million tonnes in 2010. The low estimate meets the minimum reduction required to achieve the Kyoto target of 6% below 1990 levels (2.9 million tonnes) and the high estimate amounts to 71% of the Suzuki target of 50% below 1995 levels by 2030 prorated to 17% below 1995 levels by 2010 (5.2 million tonnes). Using damage cost estimates of \$38 and \$1,040 per tonne, the 2.9 million tonne reduction would result in a benefit to society of \$110 million to \$3 billion (C\$1997) in damage costs avoided due to reductions in year 2010 emissions. The 3.7 million tonne reduction would result in a benefit to society of \$141 million to \$3.85 billion (C\$1997).

If NSPI were to implement all of its planned/in-place and under investigation projects (without the Tufts Cove modifications) and convert a single 150MW unit to combined cycle, and assuming more optimistic participation rates in energy conservation and passenger transportation modal shift, Nova Scotia's GHG emissions could be reduced by 3.6 million to 4 million tonnes in 2010. The low estimate exceeds the minimum Kyoto target and the high estimate is 77% of the Suzuki target. A reduction of 3.6 million tonnes amounts to a net benefit to society of \$137 million to \$3.7 billion and a reduction of 4 million tonnes results in a benefit of \$152 million to \$4.2 billion.

These emission reductions and savings 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 between 4.1 million and 5.9 million tonnes by 2010. This would exceed both the Kyoto and Suzuki targets.

These damage avoidance values are benefit estimates of the primary impacts of GHG emissions (climate change). They do not include the estimates of the co-benefits of reducing GHG emissions, including reduced emissions of other air pollutants such as sulphur dioxides and nitrogen oxides. Using co-benefit estimates of \$11 to \$17 per tonne of elemental carbon, a 2.9 million tonne reduction would result in \$32 million to \$49 million in co-benefits. A 4 million tonne reduction would result in \$44 million to \$68 million in co-benefits.

The lowest reduction estimate of 2.9 million tonnes would result in total primary and secondary benefits to society of $142 million to $3.05 billion in 2010. If Tufts Cove 3 had been converted to combined cycle, or if any of the 150MW units in NSPI's system is converted to combined cycle, the highest reduction estimate of 4 million tonnes would result. The total primary and secondary benefits of this reduction would be $196 million to $4.27 billion.

Table 20. Summary of Some Possible Nova Scotia GHG Reductions in 2010

Sector	Measure	Emission Reduction (kilotonnes)	
		Low	**High**
Electricity Generation	NSPI projects planned/in-place[i]	631	631
	NSPI projects under investigation[ii]	682	682
	Tufts Cove 2000 modification[iii]	350	691
	Tufts Cove 3 convert to combined cycle[iv]	1,010	1,010
Residential	Household participation in energy conservation[v]	315	630
Transportation	Freight modal shift[vi]	15	15
	Passenger modal shift[vii]	146	228
	Automobile fuel efficiency standards[viii]	800	800
TOTAL (with Tufts Cove 2000 modification)		**2,939**	**3,677**
TOTAL (if Tufts Cove 3 had been converted to combined cycle)		**3,599**	**3,996**

Notes:

[i] NSPI projected emission reduction in 2010 from projects planned/in-place (1,322kt) minus the emission reduction for conversion to natural gas at Tufts Cove 1-3 (691kt) from Table 12, which is listed seperately in this Table.

[ii] See Table 12.

[iii] The low estimate was calculated in Section 6.1 (Table 17) and is based on the assumption that all Tufts Cove units are using natural gas 100% of the time. The high estimate is the NSPI projected emission reduction from Table 12.

[iv] Calculated based on the hypothetical scenario where Tufts Cove 3 is converted to combined cycle, allowing the decommissioning of Tufts Cove 1 and 2, Trenton 5 and Point Tupper 2 units. See Section 6.1 and Table 17. The Tufts Cove 3 combined cycle scenario is a proxy for what NSPI could choose to do with any of it's other 150MW units. Since the estimated retirement date for Trenton 5 is 2004 and conversion of this unit is listed by NSPI as a project under investigation, the emission reduction scenario described in Section 6.1 may actually be achieved before 2010.

[v] The low estimate is based on a household participation rate of 30% and the high estimate is based on a household participation rate of 60%. See Section 6.2.

[vi] See Appendix D. The freight transportation study compares reductions to projected BAU emissions, based on changes in emissions and costs over the period 1997-2010. There are no freight data or emissions prorated for 1990.

[vii] The low estimate is based on a 32% reduction (Hornung, 1998). The high estimate is based on a 50% reduction. See Section 6.3.

[viii] See Section 6.3.

Again, it must be noted that these emission reduction savings are based only on reductions in the three primary emissions sectors – energy production, transportation and residential energy use. If similar changes are made in other areas that account for 24% of current emissions, the co-benefits and total benefits described above would increase proportionately.

Even though these are crude cost-benefit estimates, they do point to reduction actions that can potentially can be excellent investments. More detailed sectoral analyses, along the lines of the freight study in Appendix D, are needed to identify the most cost-effective emission reduction strategies with greater certainty.

Pricing of electricity and fossil fuels is likely to be the main policy tool used to bring about the changes described above. To ensure that these measures are not regressive, they will have to be accompanied by tax structure reforms that compensate for fuel and electric price increases by reducing taxes on labour and income and ensuring that lower income groups do not suffer disproportionately. Although it is beyond the scope of this report, an analysis of potential tax shifting is key to bringing about the necessary changes. Some European countries, like Denmark, have begun to show the way and provide models of tax structure reform that the province can study.

In sum, it is not only practical and feasible for the province to reduce its greenhouse gas emissions substantially, but the necessary measures can be accomplished cost-effectively, practically, and without undue social dislocation.

7. Recommendations and Assessments of Genuine Progress

Based on these results, it is imperative for Nova Scotia:

1) To set reasonable and sector-specific targets for GHG emission reductions as soon as possible;
2) To determine the most cost-effective ways to meet those targets;
3) To set up incentives or regulations to implement the reduction mechanisms;
4) To set up systems for monitoring progress;
5) To explore macroeconomic changes, like tax-shifting, that would support the GHG reductions at a deeper economic level and enhance overall economic efficiency; and
6) To undertake without delay a concerted public education campaign to support the reduction initiatives at a deeper social level.

This study has already pointed towards concrete and practical means to achieve these goals and towards the further study and analysis required to provide accurate information to policy makers and the general public. To achieve these six goals, to make genuine progress in this area, and to provide a model for other jurisdictions, this report, and **GPI***Atlantic*, specifically recommend:

1) The minimum interim target must be attainment of the Kyoto Protocol target of a reduction in GHG emissions to 6% below 1990 levels by 2008-2012. For Nova Scotia this translates into an actual reduction of 2.9 million tonnes CO_2 equivalent per year by 2010.

To provide a model for other jurisdictions, the province should aim for the higher 5.2 million tonne reduction target (17% below 1995 levels) recommended by the David Suzuki Foundation. Reasonable sector-specific targets in electricity generation, residential energy use, and transportation have been noted in the previous Chapter.

2) To identify the most cost-effective ways to meet these targets, cost-benefit studies of various proposed emission reduction options should be undertaken without delay. The freight transport case study in Appendix D is intended to provide a practical model for such sector-specific analyses.

   By including a full range of economic, social and environmental co-benefits, the GMI proposed in that case study can provide a common measurement to compare the benefits and costs of alternative emission reduction strategies fairly, and to identify the "no regrets" and least cost measures that can be implemented most readily.

3) The costs and benefits identified in recommendation #2 above then become the basis for the financial incentives, tax penalties and regulations required to implement the specific reductions. In particular, tax shifting models and best practices from other jurisdictions should be studied for their applicability to Nova Scotia. Carbon taxes and wind energy initiatives in Denmark, mass transit innovations in Curitiba, Brazil, and the energy conservation and efficiency models described by Suzuki, Hawken, Lovins and others are just a few examples of the wide range of cost-effective actions that can be encouraged through appropriate incentives. Needless to say, the most effective incentive will be a determined public education program which is the essential basis for implementing any reduction measures in practice.

4) By including GHG emission reductions as one of its 22 core components, the GPI can monitor the province's overall progress towards the targets identified in recommendation #1 above. Specific monitoring at the provincial level is essential to provide accurate information and feedback to policy makers and to enable officials and the general public to assess the success or failure of specific strategies.

   Specific case studies modeled on the freight transport study in Appendix D will also allow routine assessments of progress in attaining predicted co-benefits and of the actual cost-effectiveness of particular emission reduction strategies. Such monitoring systems can also help identify needed program and cost adjustments. For example, the parameters of the freight study are clearly outlined so that progress towards the proposed 10% inter-modal shift from road to rail can be easily documented and its resultant benefits and costs assessed.

To achieve all these goals, there must clearly be ongoing work designed to refine and improve the methods of costing per tonne GHG emissions. In particular, the impact of alternative discounting practices must be well understood.

At the same time as these emission reduction strategies are under way, the province has no choice but to examine, assess and prepare for the impacts of the climate change that is likely already occurring. As in health, prevention is clearly desirable and cost-effective, but hospitals are necessary when sickness exists. Because of the long atmospheric life of GHGs, excessive emissions in the past will likely cause extreme weather events, drought, flooding due to sea level rise and other impacts for a considerable time into the future.

While we have no choice but to treat the illness caused by past ignorance, current knowledge and the precautionary principle do not permit continued blind adherence to behaviours and practices that seriously (and perhaps irreversibly) threaten the well-being of future generations. *Whether* to reduce GHG emissions is no longer an issue. The only issue is *how* to do so most effectively.

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9. Appendices

A. The Nova Scotia Genuine Progress Index: Purposes, Principles and Methods

A.1. Limitations of the GDP as a Measure of Progress

The most commonly used indicator of economic and social well-being is economic growth, as measured by the Gross Domestic Product (GDP). Yet, there is 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 growth rates to measure progress takes no account of the value of environmental assets, unpaid work, free time and other sources of natural and social capital. 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 well-being.

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 principal architects of the Gross National Product and national income accounting, never endorsed its modern use as an overall measure of progress. As early as 1934, Kuznets warned the US Congress:

> *"The welfare of a nation can scarcely be inferred from a measurement of national income."*[20]

As the GNP began increasingly to be used as a measure of general social well-being 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."*[21]

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[20] Cobb, C., Halstead, T., and Rowe, J., 1995, *The Genuine Progress Indicator: Summary of Data and Methodology,* Redefining Progress, San Francisco, California.
[21] Kuznets, Simon, *The New Republic,* Oct. 20, 1962 (cited in Cobb et al., 1995).

When the GDP is misused in this way, it frequently sends misleading and inaccurate signals to policy makers that can result in the depletion of vital resources and in investments 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 well-being, prosperity and wealth.

The flaws inherent in the misuse of the GDP as a measure of progress include the following:

1) 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.

   In this report, we examine how the current failure to account for our natural environment as a valuable natural capital asset can keep the costs of GHG emissions effectively off the policy agenda and prevent determined and concerted action to reduce emissions. Nearly a decade after Canada signed the UN Framework Convention on Climate Change and four years after Kyoto, there is little indication of any concerted policy effort to meet the modest targets already agreed, and Canada's GHG emissions continue to increase. As long as we continue to measure our well-being and progress according to economic growth rates, little will change.

   Indeed, according to current accounting practices, the more fossil fuels we burn and the more quickly we burn them, the faster the economy will grow, which in turn is interpreted as a sign of well-being and prosperity. The more cars and SUVs that are produced, sold and exported and the more quickly airline traffic increases, the "better off" we are. Neither the costs of fossil fuel depletion (the loss of a non-renewable resource), nor the costs of climate change, show up as costs anywhere in our current economic accounting system nor in the measures of well-being and progress based on it.

2) Secondly, the GDP 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.[22] This failure can send perverse messages to policy makers. The *Exxon Valdez*, for example, contributed far more to the GDP of Alaska by spilling its oil, than if it had delivered its oil safely to port, because all the clean-up costs, legal costs, media activity and damage repair made a huge contribution to the economic growth statistics.

[22] 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. This critique, therefore, applies only to the use of the GDP as a measure of progress, since industry and commodity shifts registered in the CSNA are rarely if ever invoked as signals of changes in societal well-being and prosperity.

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 well-being 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 well-being or a decline.

This incongruity extends to ordinary household purchases. For example, there is no recorded relationship 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. As long as people spend more money, "consumer confidence" is judged to be strong and the economy "healthy," regardless of what they buy or of the quality of goods purchased. None of this is the "fault" of the GDP: A simple quantitative measure is incapable, by definition, of assessing qualitative change.

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"* (Kennedy, 1993).

3) 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.

4) 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. Indeed, as the "value of leisure time" module in the GPI demonstrates, women have experienced an increase in their total work-load and an absolute loss of leisure time. Since we count longer work hours as contributions to economic growth, it is also not surprising that stress levels are rising across the country among all population groups, with 38% of working mothers now classified by Statistics Canada as "severely time-stressed." The failure to value leisure time is directly related to natural resource and environmental health and well-being. 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 well-being, can make a vital contribution to ecological health and stability.[23]

5) Finally, because it measures only total income but does not account for how that income is shared or distributed, GDP growth may mask growing inequality. GDP may rise substantially, as it has in recent years, even while most 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 particularly pronounced in the United States (Cobb et al., 1995a and Messinger, 1997), but it has increasingly become a feature of the Canadian and Nova Scotian economies as well.[24]

These shortcomings and others led to a recent joint declaration by 400 leading economists, 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.*"[25]

[23] 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.
[24] Messinger demonstrates that the absolute decline in the original US Genuine Progress Index 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. See also Dodds, Colin and Colman, Ronald, *Income Distribution in Nova Scotia,* July, 2001, Halifax.
[25] 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,

A.2. 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 new internationally accepted guidelines in *The System of National Accounts 1993* 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 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 produced 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 original US 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 (Messinger, 1997; Cobb et al.; 1995a; Osberg & Sharpe, 1998; and **GPI***Atlantic*, 1998).[26] These indices also distinguish direct contributions to economic welfare from defensive and intermediate expenditures and from economic activities that produce an actual decline in well-being.

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

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. For more information, see *Redefining Progress* at www.rprogress.org.

[26] Messinger compares the MEW and the original US Genuine Progress Indicator and replicates these models for Canada. On the original GPI (Genuine Progress Indicator), see Cobb et al.. 1995a. See also **GPI***Atlantic*, *Measuring Sustainable Development: Application of the Genuine Progress Index to Nova Scotia,* January, 1998 and *Project Profile,* March, 2000. These and other **GPI***Atlantic* materials are available on the **GPI***Atlantic* web site: www.gpiatlantic.org.

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.

At that time, in the early 1970s, the pioneers' understanding of the potential importance of time use surveys and environmental quality indicators 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 GPI possible.

For the first time, 10 and 20-year time series for many social and environmental indicators can actually be created. For example, it is only in the last two years, with new data from comparable volunteer and time use surveys between 1987 and 1998, that it has been possible for the first time to assess voluntary work trends in Canada. Until 1999, only single-year snap-shots were possible. 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 many 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 well-being of future generations.

According to Statistics Canada, the seminal Brundtland Commission definition 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. Statistics Canada notes that this therefore definition of sustainability includes the objective of "equity, both among members of the present generation and between the present and future generations" (Statistics Canada, 1997).

Some of 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, to provide a more comprehensive view of progress than is possible with the current-income approach of the GDP.

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"* (Daily, 1994).

A.3. Values, Approach, Methods and Data Sources in the Nova Scotia Genuine Progress Index

In essence, the fundamental approach of the Nova Scotia GPI 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, 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.[27]

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 stabilization of the earth's climate and the objective of preventing potential damage from climate change that can adversely affect the lives of future generations.

A reduction in GHG emissions, held by scientists to be the primary cause of climate instability and global warming, is therefore the primary indicator of success in moving towards that goal and in protecting a vital ecological and social asset – a climate conducive to human life on earth. Conversely, higher rates of GHG emissions signify a depreciation of that natural capital asset and an erosion of its value.

When the GDP is used to assess well-being and prosperity, "more" is always "better." In the GPI, "less" is frequently "better." *Less* crime, pollution, accidents, natural resource depletion and fossil fuel combustion (the primary source of GHG emissions) are indicators of genuine progress from the GPI perspective, in marked contrast to the GDP, which counts increases in all these areas as contributions to prosperity. This is common-sense economics. The GPI quite simply counts crime, pollution and GHG emissions as *costs* rather than gains to the economy, with reductions signifying "savings" to society and improvements in long-term well-being.

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 well-being, 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 and a stable climate are "better" for human well-being than more crime, more pollution and climate instability.

[27] 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 NS Government Inter-Departmental Consultation, March 3, 1998, World Trade and Convention Centre, Halifax. Available on the **GPI***Atlantic* web site at www.gpiatlantic.org.

GPI*Atlantic* feels confident, as a result of 18 months of extensive consultations, 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 well-being, 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 this particular component of the GPI. Unlike other GPI components like crime, employment and water quality, the impacts and costs of climate change are (a) global rather than local, (b) long-term rather than short-term. This lack of immediacy frequently blunts policy initiatives designed to reduce GHG emissions. The inclusion of GHG emissions as a core GPI component therefore depends on our ability to transcend a narrow short-term perspective and to comprehend our "well-being" in terms of impacts on our children, on future generations and on human beings and other species throughout the planet.

Needless to say, logic and experience dictate that if climate change-induced flooding due to sea level rise in Bangladesh kills or displaces millions of Bangladeshis, Canadians will not be immune from the costs of foreign aid disaster relief and the impacts on trade, refugees and global economic and social dislocation. Nevertheless, the clarification of these connections requires real educational effort. Similarly, our own prosperity may temporarily increase by an acceleration of fossil fuel combustion, just as it did in the 1980s through an expansion of government spending and debt. Again, it takes some raising 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 or through climate change damage costs.

Excessive GHG emissions and natural resource depletion now produce an ecological debt in the future that is no less costly than a financial debt accumulated through excessive material consumption. Indeed, both kinds of debt frequently have the identical cause.

Because the connection between GHG reductions and well-being therefore clearly requires a longer-term and more global 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, we have adopted a different approach in presenting this module. Unlike other GPI components, this report therefore includes an extensive "educational" Section (Appendix B) designed to explain climate change in lay terms and to raise awareness among all Nova Scotians.

If this province is to take a lead in acting responsibly to reduce GHG emissions and to protect our 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.

The economic costing procedures, which are an essential ingredient of GPI accounting methods and of every GPI report, are included in this study as well. But Appendix B on the basic science of climate change may be the most important Section of this report, because it addresses the more fundamental assumption in the GPI that makes climate stability a core component in measures of well-being. In other words, it addresses the normative basis of the GPI altogether and the reasons for inclusion of this component in our core measures of progress. Appendix B can function as a stand-alone module suitable for classroom use.

Data Sources and Methodology

The Nova Scotia GPI in general 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 and other government sources where ever possible, to ensure accessibility and ease of replication by other jurisdictions.

Unlike the GPI water quality report, which was inhibited by a lack of integrated local sources and the absence of good comparative data, the primary data difficulties facing climate change researchers are the widely different *interpretations* given by scientists and economists to the same data sources, and the difficulty of assessing local and regional impacts based on global data. These difficulties are discussed in detail in Appendix B. As well, rather than present a single cost estimate for climate change damages, **GPI***Atlantic* has used a wide range of estimates to demonstrate potential costs (Chapter 5). When future impacts are largely unknown but *potentially* catastrophic, the precautionary principle, explained in Chapter 1, dictates reliance on higher-end estimates until more conclusive evidence to the contrary is available. Again, these data difficulties are particularly acute for this component of the GPI.

For more information on the background, purposes, indicators, policy applications and methodologies of the Nova Scotia GPI, please see the background documents on the **GPI***Atlantic* web site at www.gpiatlantic.org

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.

Core funding for this particular component of the GPI was not available, but research was aided by contributions from Environment Canada's Science Horizons internship program, the National Round Table on the Environment and the Economy, the NS Voluntary Planning Agency, Halifax Regional Municipality and an anonymous donor. Most of the work in this report was done on a volunteer basis and through the support of member contributions. The one exception is the concluding case study in this report, on the application of the GPI full-cost accounting methodology to an analysis of GHG emissions in the freight transport sector, which was funded by Environment Canada ($7,000) and the NS Departments of Environment ($4,000), Natural Resources ($2,000) and Transportation and Public Works ($2,000). **GPI***Atlantic* gratefully acknowledges this support.

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.

Eventually the data should be usable to evaluate the impacts of alternative policy scenarios and investment strategies on overall progress towards sustainable development in the province. It is precisely to demonstrate the applicability of the GPI approach at the micro-level, in evaluating particular investments from a full-cost accounting perspective, that this study applies the GPI methods to GHG emission reductions in the freight transport sector. Similar studies should be conducted for public transportation, energy use and other sectors, in order to determine the most cost-effective strategies for GHG reduction in Nova Scotia.

A.4. 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 will be discussed in detail as the separate modules are presented. But it may be helpful to list some of the major issues at the start.

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 should be included in the GDP, or that the costs of crime, water 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 uses a capital, or investment, approach to accounting. It therefore acts as a balance sheet of social, economic and environmental assets and liabilities, and it 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.

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, 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.

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 always precede and form the basis for the subsequent monetary accounts. In the present report, likewise, physical and qualitative indicators of both climate change and of GHG emissions are presented before economic costs and valuations.

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 in their own right, alongside market indicators. This will also allow for greater accuracy and precision than relying on derivative economic values.

While the assignment of monetary values to non-market assets may appear absurd and even objectionable, we do currently 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 and provides a more accurate measure of progress than excluding them from our central wealth accounts.

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 GPI itself should give way to multi-dimensional policy analysis across a number of data bases. 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 well-being and progress (Waring, 1998).

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.

If this caveat is not thoroughly understood, there is a real danger that efforts at monetization can be dangerously misused to imply the substitutability of natural capital by other forms of capital. For example, the use of a common monetary measurement might be taken to imply that vital ecosystem services could be replaced at a certain price by technological man-made substitutes. This is clearly not the case in considering climate stability. There are vital ecosystem services providing essential life-support functions to human and other species that cannot be replaced at *any* price.

In short, the use of damage costs in this and other climate change studies can only serve as proxy measures for actual threats to human society, not as literal descriptions of reality. Nor can they be taken to imply that the danger of climate instability can be "bought off" at a certain price by engineering substitutes for natural processes.

Monetization of potential climate change damage is essential as a strategic tool both to counter the even more dangerous tendency of our current economic accounting system to focus only on control costs and to ignore potential future damage. And climate change damage, from sea level rise, hurricanes and other extreme weather events, *does* after all carry real economic costs. But that strategic use of monetary values to draw attention to critical hidden costs must always be tempered by the reality that ecosystem services are generally not replaceable at any price.

A.5. Methodological Challenges

The GPI 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 as positive investments in environmental restoration. In other words, are *more* defensive expenditures are 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 GHG mitigation are, after all, *both* a cost of prior excess and neglect *and* a positive sign that concerted efforts are being made to take necessary action. 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. This is a major methodological distinction between the Nova Scotia GPI and the original US GPI, which did base its "bottom line" assessment of progress on monetary values.

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 GHGs or the acceleration of global warming trends. Beyond relative progress towards "greater" sustainability, a more absolute standard of sustainability is also needed, based on the actual capacity of the atmosphere, earth and oceans to absorb GHGs without warming the planet.

Rather than offering any pretence of definitive answers 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, but seeks to improve its accounting methodologies over time in accord with the constructive feedback its work receives.

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.

This problem of precision is accentuated further in the natural resource accounts, with attempts to value ecological services and the non-market functions of natural assets. For example, there is no doubt that water bodies, wetlands and forested 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 vital 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. A new depleted resource state is then accepted as the norm by future generations without reference to its original value or capacity.

How then, are such ecosystem 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 recently released GPI Water Quality Accounts,

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? And does the waste treatment upgrade really provide a substitute for the full range of functions once performed by that degraded water body or only for one element of those functions? May not the use of "replacement values" altogether imply the unrealistic assumption of the substitutability of natural processes discussed above? These methodological difficulties are vastly accentuated in estimating climate change costs because of the great difficulty in estimating the local impacts of global trends and the global impacts of local emissions, and because natural climate regulation processes are essentially not substitutable.

In the preceding pages, there are many such difficult valuation choices and **GPI***Atlantic* has chosen to present a wide range of valuations based on different 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 be pretend to be precise.

A.6. 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 rather 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 impacts of climate change 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 methods 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 results of this study suggest that the inclusion of climate change 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. 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 GPI 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. 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 in 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 well-being 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.

A.7. Nova Scotia GPI: Release of Natural Resource Accounts

This particular report is the fourth full release of data for the Nova Scotia GPI natural resource and environmental accounts, on which research has been ongoing for the past three and a half years and follows the release of the GPI Water Quality accounts in July, 2000, the Nova Scotia Ecological Footprint in March, 2001, and the first component of the GPI Soils and Agriculture Accounts in April, 2001. In the coming weeks and months, **GPI***Atlantic* will also release resource accounts for forests and fisheries/marine environment as well as other components of the soils and agriculture accounts; the GPI air quality component; and the first stage of a sustainable transportation analysis that applies full-cost accounting principles to a comparison of different modes of transportation. All these reports are nearing completion and will be released before the end of the year 2001, if funding permits. In the spring of 2002, **GPI***Atlantic* will release its solid waste resource component.

These releases of data on the health of Nova Scotia's natural resources and on the province's environmental quality, follow the release of several social accounts. These included full reports on the economic value of civic and voluntary work and on the economic value of unpaid housework and child care, released in July and November, 1998, with voluntary work updates released in February, 1999 and February, 2000. Those two studies measured important economic assets that are hidden and unvalued in our current accounting system and demonstrated that unpaid voluntary work and household production provide critically important economic services to society that are an essential precondition for a healthy market economy. The studies also showed that any deterioration in these sectors directly affects a society's standard of living and quality of life and has serious repercussions for the market economy.

The third GPI data release, in April, 1999, laid the groundwork for these natural resource accounts, by challenging the conventional economic growth paradigm, in which "more" is always assumed to be "better." **GPI***Atlantic*'s *Cost of Crime* report showed clearly that growth in and of itself does not necessarily signify an improvement in well-being and that this simplistic, prevailing assumption can mislead policy makers and skew the policy agenda. The contrast between the *Cost of Crime* report and the first two reports on the value of unpaid work, is therefore a useful illustration of Simon Kuznets' dictum that "goals for 'more' growth should specify of what and for what".

While higher crime rates produce more spending on prisons, police, burglar alarms and theft insurance, all of which make the GDP grow, crime clearly diminishes the quality of life and diverts precious economic resources from health, education and other activities that enhance human and social welfare. In the GPI, as discussed earlier, "less" is frequently "better." Unlike the signals emanating form the GDP, in which growth of any kind signifies "progress" and a "stronger" and more "robust" economy, it was pointed out above that the GPI counts *less* pollution, crime, sickness, fossil fuel combustion and natural resource depletion as signs of genuine progress. *The Cost of Crime* was the first GPI report to demonstrate that principle and this report follows the same logic.

In July, 2001, **GPI***Atlantic* released its report on *Income Distribution in Nova Scotia*, which demonstrated that although the GDP provides information on total income, it tells us nothing about how that income is shared. The results showed that GDP can grow even while most people are becoming poorer and while the gap between rich and poor grows. Economic growth does not necessarily translate into improved well-being for most people, even in simple economic terms that consider only income, and even without consideration of more subtle and hidden social and environmental realities.

In 2000 and 2001, **GPI***Atlantic* has also released several indicator sets of its population health component, including an assessment of *Women's Health in Atlantic Canada,* a report on *The Costs of Obesity in Nova Scotia,* which demonstrated that obesity costs the Nova Scotia health care system \$120 million a year in direct costs and a further \$140 million annually in lost productivity, a study on *The Costs of Tobacco in Nova Scotia,* a study on *The Cost of HIV/AIDS in Canada,* and an assessment of *The Economic Impact of Smoke-Free Workplaces.* These reports demonstrate the utility of the GPI full-cost accounting approach to the analysis of specific health policy issues. Though sickness produces more spending on doctors, hospitals and drugs, all of which make the GDP grow, the GPI recognizes *less* sickness and improved population health as a core indicator of genuine progress.

While the next few months will see **GPI***Atlantic* focussing primarily on the release of its natural resource and environmental accounts, there will be ongoing work by GPI researchers in the coming months on other social and economic components of the GPI, including employment and work hours, and the value of leisure time. If funding permits and if research proceeds on schedule, there will be further data releases in these areas in the coming months.

A.8. A Capital Approach to Accounting

The previous GPI data releases to date help establish a context for this present report on GHG emissions and for the other natural resource accounts that follow. Just as crime signifies the deterioration of a social capital asset (a peaceful and secure society), so a decline in climate stability signifies the deterioration or depreciation of an environmental asset. The GPI treats natural, social and human capital in a way that is similar to the way the conventional accounts assess the value of produced capital. From that perspective, the environmental asset considered in this module is the relatively stable climate regime that has historically produced a wide range of services and benefits to human society.

If the climate is destabilized and this capital asset deteriorates in value, thereby threatening the continued provision of vital ecological services, then renewed investment in natural resource conservation is required in the same way that a factory owner must consider the repair or replacement of old or malfunctioning machinery. The only major caveat to this analogy is that, unlike manufactured capital which always depreciates over time, there is no *inherent* reason for natural capital to depreciate in value, because it has the capacity for self-renewal. If used sustainably, the quality and value of natural capital can actually be maintained *without* additional investment.

That is a big "if," but the distinction must be borne in mind to overcome the dangerous prevalent assumption that accepts the decline in environmental quality as "inevitable," or assumes the infinite substitutability of manufactured for natural capital. Natural capital assets can, in effect, provide a range of ecological services indefinitely and even repair and replenish themselves, provided that depletion rates are within a sustainable range. The notion of a "stable" climate, does not, therefore, imply that it never changes, but rather that there is a natural range of historical fluctuation and change that may now have been dramatically distorted as a result of human activity.

The need for re-investment in natural capital therefore literally signifies the *cost* of previous unsustainable use and of human activities that have previously failed to respect and understand the natural limits, cycles and balance that exist in the natural world. Unlike manufactured capital depreciation, which represents a drawing down on *past* and *present* resources, natural capital depreciation *also* represents a drawing down on *future* resources, of favouring present consumption over the welfare of future generations.

For example, the marine environment and freshwater rivers and lakes are *inherently* capable of providing as stable a level of fish stocks for future generations as at any time in the past. The 80% decline in Atlantic salmon returns, described in the GPI Water Quality report, is therefore not only a present cost of unsustainable resource use and human excess, but also a cost that will be borne by our children and for many generations to come. The "re-investment" that future generations will have to make in forest and water restoration and in other forms of natural resource conservation, to ensure their own survival, is therefore a cost that they will bear as the price of actions by past and present generations. That displacement of cost burdens to future generations is likely truer of GHG emissions than of any other component in the GPI.

While the depreciation metaphor is useful to illustrate the concept of natural capital, this crucial distinction between manufactured and natural capital must always be kept in mind. Since produced capital depreciation is inevitable, further investment in manufactured capital can potentially *add* real value that enhances well-being and improves the standard of living and quality of life of future generations. By contrast, natural capital depreciation that requires further investment almost *always* signifies a prior *cost* incurred through previous excess or unsustainable use. Unsustainable human activity in effect defers investment costs to future generations, because sustainable use would allow the resource to regenerate naturally without further investment.

A.9. Further Development of the GPI

This brief overview establishes the context of this present report in the framework of past and ongoing work on the GPI. Altogether the Nova Scotia GPI will consist of 22 components.[28] These are listed at the end of this Appendix. By the end of the year 2001, enough components of the GPI will be complete for any jurisdiction to adopt the index as an actual policy tool and strategy for sustainable development.

GPI*Atlantic* will also continue to cooperate and work closely with other parallel efforts in Canada and throughout the world, including the new sustainable development indicators initiative by NRTEE and Environment Canada, the ongoing development of resource satellite accounts, total work accounts and the Index of Social Health at Statistics Canada, the Index of Economic Well-being developed by the Centre for the Study of Living Standards, the exploration of new health indicators by Health Canada, the ongoing pioneering work of Redefining Progress in the US, the outstanding community indicators work in Newfoundland, the Quality of Life Indicators Project of the Canadian Policy Research Networks, and many other similar initiatives that share the goals and aspirations of **GPI***Atlantic*. In fact, **GPI***Atlantic* is represented on the Sustainable Development Indicators steering committee of NRTEE, a process that has the potential of bringing together and promoting cooperation among the many synchronous indicator efforts currently under way.

As work develops, **GPI***Atlantic* would welcome a formal national consultation to discuss the GPI results and their implications as well as the results of similar indicator projects, to review the methodologies and measurement tools in detail, to identify core indicators that can serve as annual benchmarks of progress, to make specific recommendations to fill data gaps necessary to maintain the index over time, and to explore the potential for aggregating particular indicator sets

In consultation with Statistics Canada and in the interests of policy relevance, it has been decided to adopt a sectoral "bottom-up" approach to the Nova Scotia GPI, presenting as comprehensive a portrait as possible of each of the 22 components that comprise the Index. Wherever possible, as mentioned earlier, monetary values will be imputed in order to demonstrate linkages between the market and non-market sectors of the economy.

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[28] The components of the Nova Scotia GPI are described in detail in the **GPI***Atlantic* profile "*Measuring Sustainable Development*" (updated March, 2000), available on the **GPI***Atlantic* web site at www.gpiatlantic.org.

When this sectoral development is complete, aggregation will present a major challenge and it is now anticipated that the final GPI will more likely consist of several sets of sub-indices, corresponding to the five-fold division of components listed below, rather than as a single aggregated "bottom line" index. Challenges will include the elimination of double-counting, the consideration of appropriate weighting mechanisms and the identification of core indicators that will allow a more integrated GPI to assess progress towards overall sustainable development. The construction of this more composite index will require intensive consultations with Statistics Canada and NRTEE staff, other government officials and independent experts and is not a task **GPI***Atlantic* plans to undertake alone.

While the initial construction of the index is complex and time-consuming, as these first reports demonstrate, the goal is that the final index will be easy to maintain and update in future years, that the design will enable ready comparability with other jurisdictions, and that results will be presented with a view to practical policy relevance and application. Each report describes in detail the methodologies used to derive results, so that other provinces can more easily replicate the measurements. Each report also describes the data requirements necessary to maintain the index and points to existing data gaps, and each report also emphasizes major policy implications indicated by the findings. Upon completion, the Nova Scotia GPI should not be regarded as a final and rigid formula, but as a work in progress that will be constantly modified and refined to reflect improved methodologies and new approaches and data sources.

Finally, it should be mentioned that, alongside these national, provincial and regional efforts to establish macro-indicators of well-being and sustainable development, **GPI***Atlantic* is also working with two Nova Scotia communities, in rural Kings County and Glace Bay in industrial Cape Breton, to develop genuine progress indicators at the local level. These community indicators can serve as highly useful tools for sustainable community development strategies, by identifying local strengths and weaknesses and by suggesting practical policy initiatives to local planners, community groups and public officials that can improve the well-being and quality of life within communities. These two projects are also pilots that will provide practical tools for measuring genuine progress to communities throughout Canada.

That is the basic framework for this fourth data release of the Nova Scotia GPI natural resource accounts – the GHG accounts for the province. The more detailed background documents for the project, the completed modules of the index to date, including summaries and press releases, current GPI newsletters, membership information, and a summary of this report are available to the public on the GPI web site at www.gpiatlantic.org. Information on upcoming reports and data releases will be posted on that web site as it becomes available.

A.10. 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
* Costs of Underemployment
* Value of Leisure Time

Natural Capital:
* Soils and Agriculture
* Forests
* Marine Environment/Fisheries
* Non-renewable Subsoil Assets

Environment:
* Greenhouse Gas Emissions
* Sustainable Transportation
* Ecological Footprint Analysis
* Air Quality
* Water Quality
* Solid Waste

Socio-Economic:
* Income Distribution
* Debt, External Borrowing and Capital Movements
* Valuations of Durability
* Composite Livelihood Security Index

Social Capital:
* Health Care
* Educational Attainment
* Costs of Crime
* Human Freedom Index

B. The Science of Climate Change: A GPI Primer for Nova Scotians[29]

B.1. Climate and Climate Change

Scientific Background for Human-Induced Climate Change

"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. Climate records include both statistical averages and the range and extremes of heat, moisture and air movements. When we discuss climate change, then, we are referring to long-term patterns, such as those observed over hundreds, thousands or millions of years. This is why, although intuitively we may have a feeling that the climate of our particular area is changing, we have to look at long term records and natural variability to determine whether the change is significant or is just a part of the natural variation in climate.

What do we really mean by the term climate? Fundamentally, climate is the net result of the earth's interaction with incoming radiation from the sun. This includes the way earth's atmosphere redistributes the sun's energy. The amount of sunlight striking the earth depends on latitude and season. The tropics are heated much more intensely than the poles. The large temperature difference between the tropics and the poles is actually the primary driving force for our wind and ocean currents. Because of these variations in heating, it is common to have regions of cooler air near regions of warmer air, causing differences in the temperature and pressure in the atmosphere. These differences in atmospheric temperature and pressure, then, create weather and climate variations. Winds and moving weather systems are nature's way of balancing these differences.

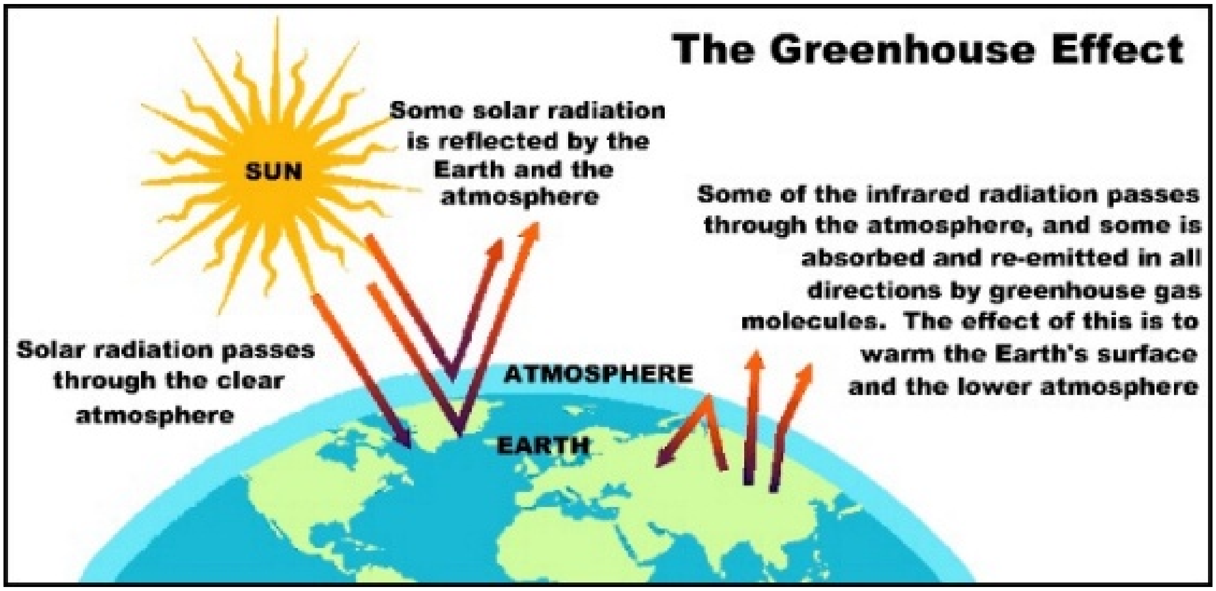
As radiation from the sun passes through the earth's atmosphere, some radiation is reflected back to space by the earth's surface and the atmosphere, but most of the radiation is absorbed by the earth's surface and warms it. The relative amounts of solar radiation that are reflected back into space or 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 ultraviolet radiation, 46% in the visible spectrum; and 47% infrared or long-wave radiation (Griffiths, 1976).

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 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, represented in Figure 17, is known as "the

[29] Please note that references in Appendix B refer to the reference section of the main report.

greenhouse effect," whereby 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 be warmer.

Figure 17. 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.

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. The greenhouse gas (GHG) effect that we read about in the news should actually be called the "enhanced GHG effect." Just as glazing the greenhouse glass causes it to become more opaque to outgoing radiation and to trap more heat inside, so higher concentrations of gases that absorb the longer wave lengths can cause the atmosphere to become more opaque and to trap more of the radiation. Any factors that affect the amount of solar radiation reaching the earth's surface or leaving the atmosphere can potentially have an effect on climate.

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, methane and nitrous oxides. Increased emissions of these gases are of concern partly because they have a long lifetime in the atmosphere. Each GHG is rated, by internationally accepted standards, according to its ability to trap solar heat on a scale called the "global warming potential" (GWP). In this scale, the warming potential of each gas is compared to the global warming potential of 1 kg of carbon dioxide (CO_2), in this case over a period of 100 years.

Table 21 presents the GWP of the primary GHGs, along with their estimated lifetimes in the atmosphere. The overall contribution of each GHG depends upon:

- the global warming potential
- the amount of the gas released into the atmosphere annually
- the atmospheric lifetime of the gas
- the indirect effect that emissions of each gas will have on atmospheric chemistry.

Thus it is clear that the same amount of methane or nitrous oxide has much greater potential to enhance the greenhouse effect than does carbon dioxide. It is estimated that rising CO_2 levels account for well over half of global warming. Also contributing to global warming are increases in concentrations of methane, nitrous oxides, and halocarbons and other halogenated compounds from aerosols, most of which were phased out through the 1987 Montreal Protocol. Because of the long lifetime of GHGs in the atmosphere, today's emissions can affect atmospheric concentrations for more than 100 years (Suplee, 1998). For example, several centuries after CO_2 emissions occur, about a quarter of the increase in CO_2 concentrations caused by these emissions is still present in the atmosphere (IPCC 2001, p. 17).

Table 21. Characteristics of Major Greenhouse Gases

Gas	Atmospheric Lifetime (years)	Global Warming Potential for 100 years	Major Anthropogenic Sources of Emissions
Carbon Dioxide (CO_2)	100 to 200 years, depending on removal mechanisms	1	Fossil fuel combustion, cement production, land use changes and deforestation
Methane (CH_4)	12±3	21	Fossil fuel combustion, biospheric (animals)
Nitrous Oxide (N_2O)	120	310	Automobiles
Hydrochlorofluorocarbons (HCFCs)	1 to 200+	140 to 11,700	
Sulphur hexafluoride (SF_6)	3,200	23,900	
Perfluorocarbons (PFCs)	3,000 to 5,000	6,500 to 9,200	

Source: IPCC, 1996a.

Atmospheric concentrations of CO_2 are determined by the rate of naturally occurring emissions, the rate at which human activities are emitting CO_2 to the atmosphere, and the rate at which the earth removes or absorbs CO_2 from the atmosphere. The latter activity is referred to as "sequestration," in that the CO_2 is sequestered from the atmosphere into the soil, water or life forms. These storage reservoirs are called "carbon sinks." The main long-term reservoirs of carbon are the ocean, soil, trees and grasslands, as well as fossil fuel reservoirs and limestone muds at the bottom of oceans. It is estimated that about 50% of the earth's CO_2 emissions are absorbed by and stored in these reservoirs and the rest are building up in the atmosphere.

Because of deforestation and other land use practices, terrestrial ecosystems are storing about 38% less carbon in their vegetation and 12% less in soils, compared with pre-industrial times (Freedman, 1998). Globally, some 25-30% of total human-caused emissions of carbon are the result of deforestation and land use change (Van Kooten et al., 2000).

In other words, the problem of human-induced climate change is not only related to increases in fossil fuel combustion and GHG emissions, but also to the loss of natural carbon sinks due to human activity. While reducing fossil fuel use and GHG emissions must have first priority if CO_2 levels in the atmosphere are ever to be stabilized, it is clear that attention must also be paid to the forestry and other land use practices that have depleted the earth's capacity for sequestration of carbon.

Recent studies have found that preservation of natural old-growth forests can protect the earth's carbon sequestration capacity, because older trees transfer far more carbon into a permanent pool of soil carbon, in the form of passive organic matter or black carbon, than young trees. As well, studies indicate that "terrestrial forest ecosystems do not reach an equilibrium of assimilation and respiration and act as net carbon sinks until high ages." Replacing unmanaged old-growth forest with young trees will therefore "lead to massive carbon losses to the atmosphere" (Schulze et al., 2000). Old-growth forest preservation must therefore accompany GHG reduction strategies if the effects of human activity on climate change are to be ameliorated.

B.2. Evidence of Climate Change from Observed Records

In order to put recent global warming into perspective, we must look at global warming and climate change over millions of years to understand the background against which today's trends are occurring. Scientists have reconstructed climate patterns throughout the history of the earth by using bore holes in the ice in the Arctic and Antarctic, bore holes in the earth in other parts of the world and paleoclimatic data (radiocarbon dated pollen, lake-level reconstructions, and ocean sediments).

When the different layers of the earth can be dated by means of radioactive isotope dating and other measures, evidence of temperature can be matched to the date of the layer and thus it is possible to reconstruct the probable temperature of the earth throughout the ages. These are called proxy records. One of the most famous examples of this type of work comes from the Vostok Core, an ice core taken near the Russian Vostok station in Antarctica (Petit et al., 1999). The core shows changes in carbon dioxide, methane concentrations and the temperature of the air trapped in bubbles in the ice.

When discussing climate change, it is important to keep in mind the scale of time being used. Viewed over millions of years, there appears to be a regular global alternation of warm and cool climates. Viewed over centuries or decades, however, many climatic events occur and may appear to be random and not part of any regular cycle. Another consideration is that climatic changes may occur at different times in different parts of the globe.

Popular usage of the term "ice age" actually refers to a period of "glaciation," in which glaciers advance to cover large parts of the earth's surface. Such major glacier advances can be caused by a decrease in average global temperature of less than 4 degrees Celsius. However, these dramatic glacial shifts can occur even during periods, like the present, when the polar regions are cold, when there are large differences in temperature from the equator to the pole and when large continental-size glaciers already cover large regions of the earth (Maasch, 2000). During the last three million years, when these conditions have existed, glaciers have advanced and retreated over 20 times, often covering North America with ice. Thus glaciation (advancing of glaciers) and deglaciation (retreat of glaciers) can both occur as a result of very small changes in temperature. Periods between glaciations are called *interglacial* periods.

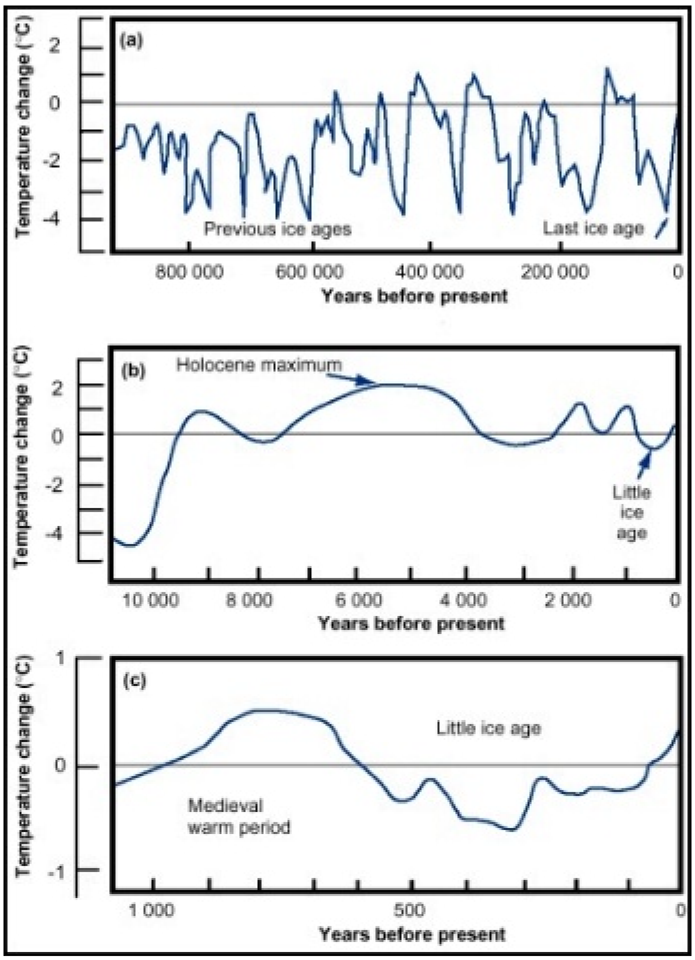
Based on proxy records for the past million years, scientists have concluded that temperatures have followed a cycle of long-term variation, with major global glaciations occurring roughly every 100,000 years (Environment Canada, 1995). A 4-6^{o}C warming (over centuries) that led to an interglacial period has followed each glacial period. Scientists have identified three distinct periods of glaciation in the history of the earth: 1) around 600 million years ago; 2) a glaciation about 275 million years ago that affected areas of Africa, India and Australia; and 3) the most recent period, which began about 1.5 million years ago and has subsided within the last 15,000 years. The average global temperature of the most recent glaciated period was only about 5^{o}C cooler than today's average global temperature.

The earth is currently in an interglacial period, called the Holocene, which began 10,000-12,000 years ago with a rapid global warming and sea level rise. During the past 10,000 years, temperatures peaked about 5,000-6,000 years ago (last Holocene maximum). This peak temperature was about 1.8 degrees Celsius higher than the current average global temperature. Several periods of greater cooling have occurred at approximately 2500-year intervals, the latest between 1400 AD and 1900 AD (known as "The Little Ice Age"). This period of greater cooling is thought to be the result of increased volcanic activity or of low magnetic activity (sunspots) at the surface of the sun, although it is not understood how the latter might affect earth's climate (Graedel and Crutzen, 1995). According to the glaciation cycle that has occurred roughly every 100,000 years, the earth should now be in a cooling period, heading towards the next period of glaciation in about 90,000 years.

Figure 18 presents an overview of variability in average global temperatures over the past million years, over the past 10,000 years and over the past 1,000 years. Rather than absolute temperatures, these graphs plot the *degree of change* in temperature from current day averages. These graphs illustrate the beginning of the interglacial period at the end of the "last ice age" around 135,000 years ago, the beginning of the Holocene around 10,000 years ago and the "Little Ice Age". They show that previous "ice ages," or glaciations, were accompanied by a change in average temperature of only 4^{o}C or less.

In the 20th Century average global surface air temperature (Figure 19) has increased between 0.4 and 0.8^{o}C (0.6±0.2^{o}C), an increase that is more rapid than at any other time in history (IPCC, 2001 and Suplee, 1998). Night-time temperatures over land have increased more than day-time temperatures and regional changes have also occurred. Recent years have been among the warmest since 1860, even with the cooling effect of the Mt. Pinatubo volcanic eruption (1991). The warming has been greatest over mid-latitude continents, with the exception of a few areas of cooling trends, such as parts of the North Atlantic Ocean. Precipitation has increased over land in high latitudes of the Northern Hemisphere and global sea level has risen by 10-25cm over the past 100 years.

Figure 18. Global Temperature Variation of the Past One Million Years



Note: The graphs show departures of average global temperatures from current values (represented here as 0°C) (a) over the past 1,000,000 years, (b) the past 10,000 years and (c) the past 1,000 years.

Source: Environment Canada, 1995.

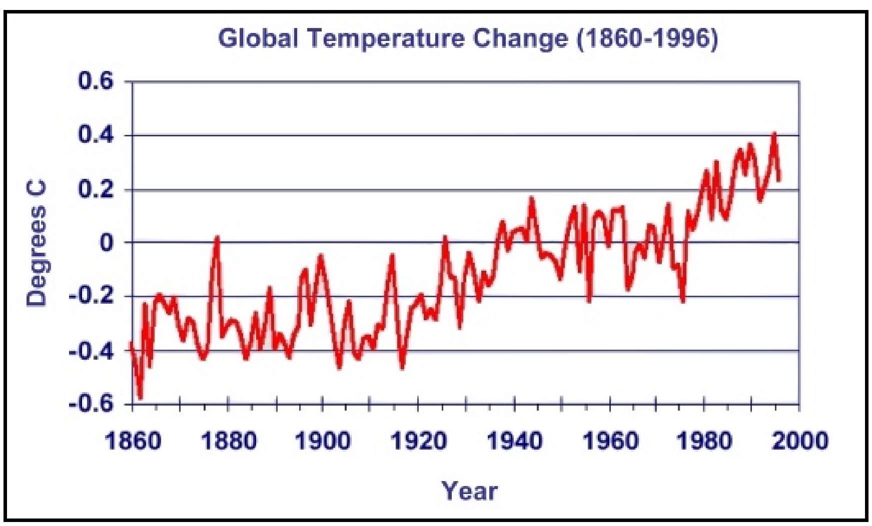
Figure 20 shows the variation in annual global surface temperature over the past 140 years by depicting the difference between annual average temperature and the mean for the period 1951 to1980. Globally, the 1990s were the warmest decade since the beginning of instrumental measurements in the 1860s and included 7 of the 10 warmest years. There have now been 20 consecutive years with above normal temperatures worldwide and the 1900s were the hottest century during the past 1200 years (World Meteorological Organization, 2000 and Statistics Canada, 2000). Although global changes in weather extremes and climate variability are evident, these trends are not always observed on a regional basis (IPCC, 1995). Figure 21 presents similar records for Canada.

Recently discovered evidence of global warming comes from temperature trends over the past five centuries reconstructed from bore hole temperatures (Huang et al., 2000). Using over 600 bore holes, driven deep into the earth in North America, Europe, Asia, Australia, Africa and South America, scientists have concluded that the last 100 years have been the hottest in the last millennium.

During the last global deglaciation (about 15,000 years ago), which included a change in the Canadian landscape from a massive layer of thick ice to the varied ecosystems of today, the estimated increase in global average temperatures was between 4 and 7^{o}C (Canadian Climate Program Board, 1998). The difference in this type of warming and what we are experiencing (and expecting) today is that the 4-7 degree temperature change referred to above took place over 5000 years.

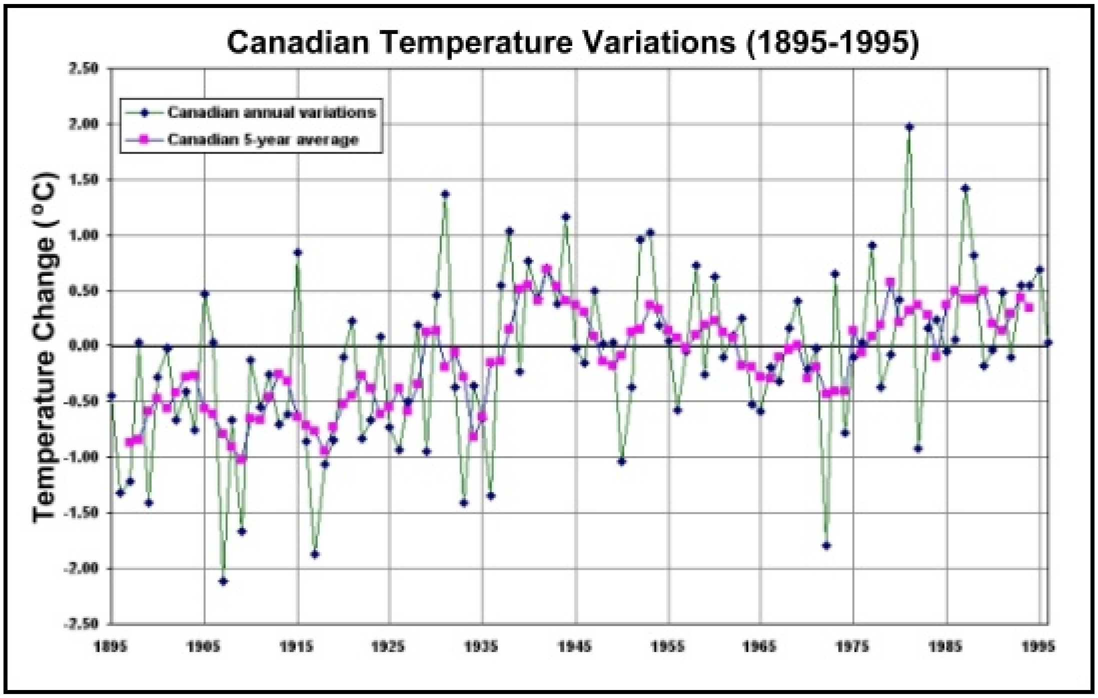
Ice cores have also revealed that global climate can shift with frightening speed. One such shift occurred about 12,000 years ago. Within a general period of warming, average temperatures in polar regions and eastern North America plummeted by about 12-15^{o}C over a period of 200 years, returning the world to near glacial conditions. This period (called the Younger Dryas) lasted about 1,300 years before temperatures warmed again by 5-10^{o}C within a few decades (Alley et al., 1993 and Environment Canada, 2000a). Such rapid climate change would have catastrophic consequences for humans and living ecosystems.

Figure 19. Change in Average Global Surface Air Temperature (1860-2000) Relative to Average Temperature, 1951-1980



Source: Canadian Climate Program Board, 1998.

Figure 20. Canadian Temperature Variations



Note: This indicator represents averaged temperature variations from a mean for the period 1951-1980.

The mean is represented here as 0^oC.

Source: Environment Canada, 1998.

The IPCC (2001) has said the following about the current degree of climate change:

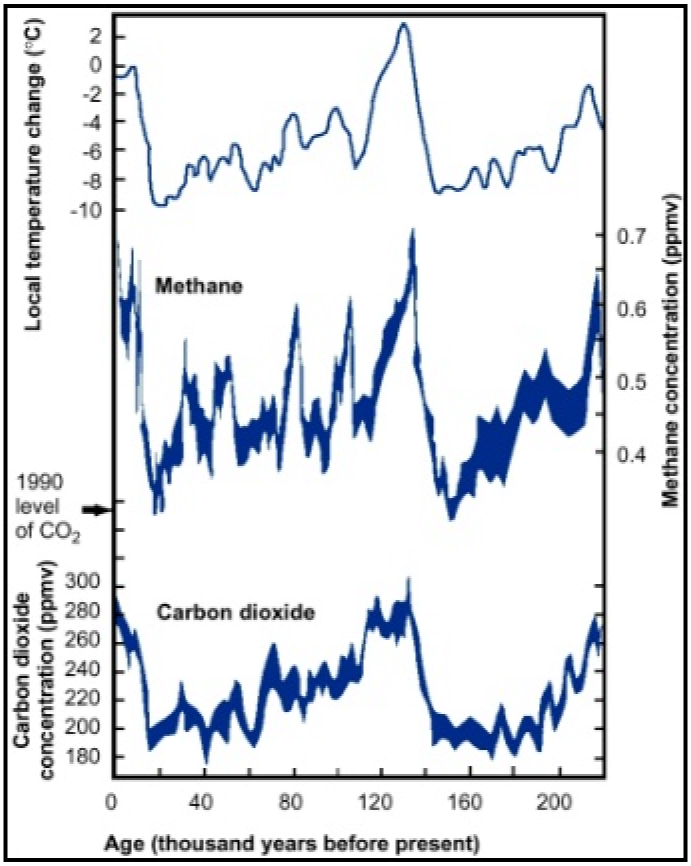
> *"The global average surface temperature has increased since 1861. Over the 20th century the increase has been 0.6±0.2°C… New analyses of proxy data for the Northern Hemisphere indicate that the increase in temperature in the 20th century is likely (66-90% chance) to have been the largest of any century during the past 1,000 years."*

B.3. Evidence of Human Influences on Climate

Although it may not be possible to establish a direct cause-and-effect relationship between global warming and increasing GHG emissions, we can show a very high correlation between increasing GHG concentrations in the atmosphere and atmospheric temperature. Figure 21 shows the parallel trends in temperature and GHG concentrations in Antarctica for the past 200,000 years, deduced from the Vostok ice cores. With these data, there is some question as to whether the temperature change caused the increase in the gases in the atmosphere or vice versa. Nevertheless the correlation is very high over 200,000 years.

A recent study by Crowley (2000) examined the rise in global temperature over the past 1000 years to determine how much of the rise is due to volcanic and solar activity and how much is due to anthropogenic (human-induced) GHG and aerosol emissions. The author used an Energy Balance Model (EBM), calibrated to produce a similar response to external climate forcing as the more elaborate coupled ocean-atmosphere models.

Figure 21. Parallel Trends in Temperature and GHG Concentrations in Antarctica for the Past 200,000 Years



Source: Environment Canada, 1995.

The temperature fluctuations produced by Crowley's model agree well with fluctuations recorded in tree rings, ice cores and coral. The model was not good at predicting the late 19th century cooling or regional variations in temperature over time. The late 19th century cooling is generally thought to be influenced by dramatic changes in land use (Mann, 2000). Crowley concluded from his study that a) much of the climate history of the past millennium can be explained in terms of a few well-established radiative forcings and b) the dramatic warming of the 20th century can almost certainly not be explained by natural forcings but instead is due to the anthropogenic GHG forcings of the 20th century.

Recently, researchers compiled the first direct evidence that increases in concentrations of GHGs are actually leading to an enhanced greenhouse effect. Through satellite observations, Harries et al. (2001) studied the makeup of the earth's long wave radiation, which carries the imprint of the GHGs. They found that changes in the long-wave radiation between 1970 and 1997 point to long term changes in atmospheric carbon dioxide, methane, and ozone, as well as chlorofluorocarbons.

The IPCC (2001) has issued the strongest statements yet about the influence of human activities on climate change:

> *The warming over the past 100 years is very unlikely (1-10% chance) to be due to internal variability alone, as estimated by current models. Reconstructions of climate data for the past 1,000 years also indicate that this warming was unusual and is unlikely (10-33% chance) to be entirely natural in origin… Detection and attribution studies consistently find evidence for an anthropogenic signal in the climate record of the last 35 to 50 years. In light of new evidence and taking into account remaining uncertainties, most of the observed warming over the last 50 years is likely (66-90% chance) to have been due to the increase in greenhouse gas concentrations.*

B.4. Projections of Future Greenhouse Gas Emissions and Atmospheric Concentrations

Emissions Scenarios

Since predictions of future climate change are based on projections of GHG emissions and atmospheric concentrations, the projection of GHG emissions is a critical component of any model. Projections of GHG emissions can vary widely when differing assumptions are used. In general, emission scenarios can project emissions for BAU, meaning no new policies are put into place to control emissions, or they may explicitly include specific GHG reduction policies. Here, we will first look only at the "baseline" or BAU scenarios. Because projections of emissions, even within the BAU category, are determined by assumptions about future population growth, economic growth and energy efficiency, any scenario must spell out these determinants.

In 1992, the IPCC (1995) devised a set of six BAU scenarios. The IPCC has now updated these scenarios (IPCC, 2001). The assumptions behind the new scenarios (labeled A1, A2, B1 and B2) can be summarized as follows:

A1 Assumes rapid economic growth; rapid introduction of new and more efficient technology; global population growth that peaks in the middle of the century and declines thereafter; and a substantial reduction in regional differences in per capita income.

A2 Assumes a very heterogeneous world; more emphasis on self reliance and preservation of local identities; high population growth; less concern for rapid economic and technological development.

B1 Assumes population growth as in A1; rapid changes in economic structures towards a services and information economy; a move toward a less materialistic society; introduction of clean technologies; rapid technology development; emphasis on global solutions.

B2 Assumes moderate population growth; less rapid but more diverse technological change; emphasis on local solutions and environmental sustainability.

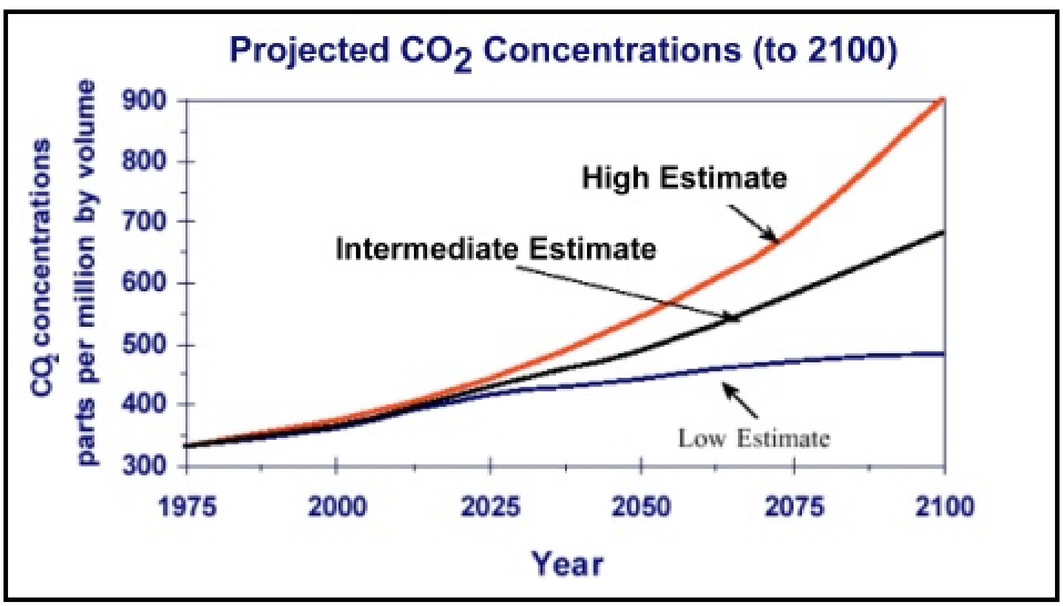
As shown in Table 22, for all scenarios except B1, CO_2 emissions in 2100 are more than double those in 1990. Scenario B1 represents a highly optimistic view of the world during this time period. All of the scenarios represent at least a doubling of CO_2 concentrations since pre-industrial times, when the atmospheric CO_2 concentration was around 280 ppm.

Table 22. Anthropogenic Emissions for 2100 for Four Emission Scenarios

	1990	2100			
		A1	A2	B1	B2
Fossil CO_2 (Gt/year)	6.2	13.2	28.8	6.5	13.7
Net deforestation (Gt/year)	1.1	-0.6	0.2	1.4	-0.2
SO_2 (Tg/year)	72	28	61	29	47

The Canadian Climate Board (1998) has also produced scenarios for low, medium, and high projected CO_2 concentrations to the year 2100 (Figure 22).

Figure 22. Projected Global Atmospheric CO_2 Concentrations to the Year 2100



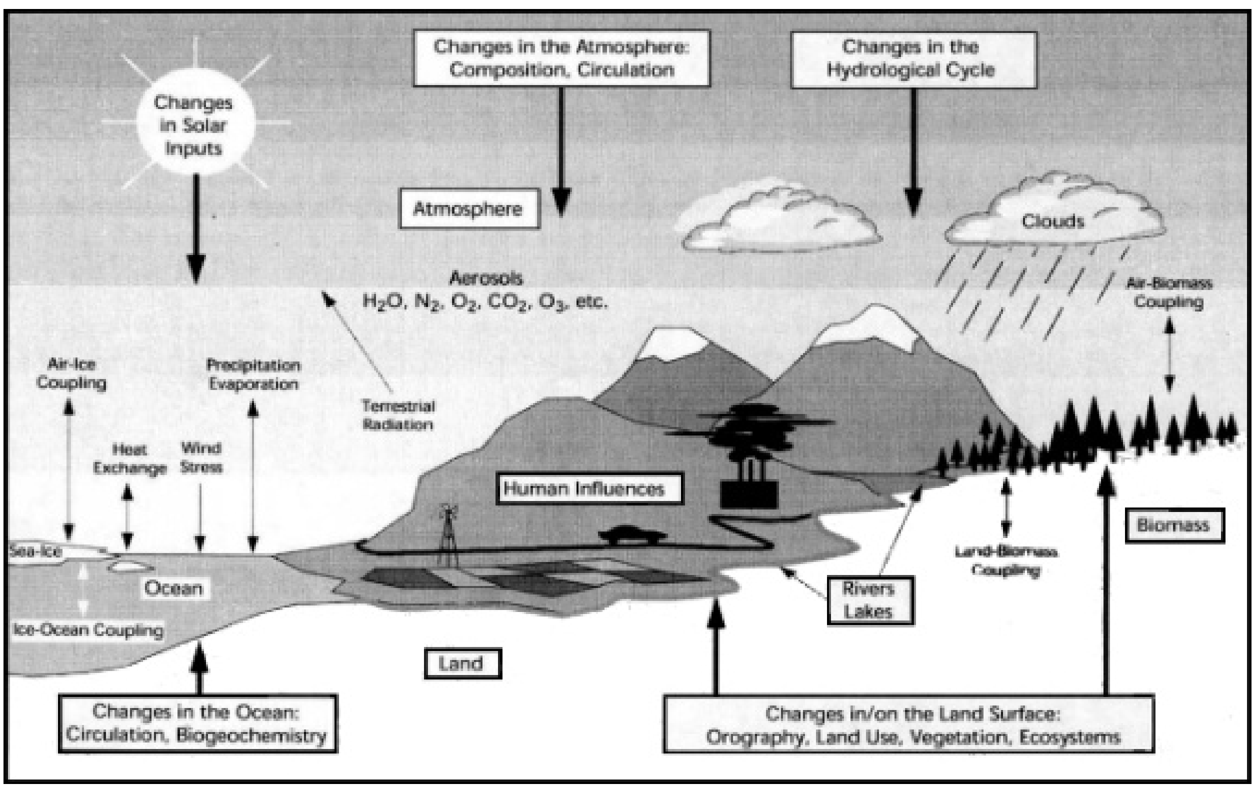
Source: Canadian Climate Program Board 1998.

Predictions of Future Climate Change

In order to understand the relative impact on climate of the many factors involved, scientists have constructed mathematical models of climate. In these models, climatic processes are described as mathematical equations, based on the fundamental laws of physics that govern the processes. Further equations are then written to describe the interactions of different processes. Models of past and present climate can be tested to see how accurately they "predict" past or present climate. Once a suitable level of reliability is reached, then the models can be used to tell us how the future climate might react to a given set of conditions. The models can also be used to describe historical climate records, using physical evidence from the past as inputs.

The state of the art model commonly used is the General Circulation Model (GCM). This includes a number of variations, all of which are three-dimensional models that attempt to replicate the structure of the global climate system, its major processes and the feedbacks that affect it. Figure 23 presents an overview of the many factors and interactions that must be modeled in this complex climate system. Modern GCM models are those that include coupled atmosphere-ocean models (AOGCMs). Currently these models are being used to try to answer questions such as, "How would earth's climate system respond to a doubling in GHGs in the atmosphere within a certain time period"?

Figure 23. Major Elements of the Global Climate System



Source: IPCC, 1996a.

When GCM models of present climate are compared to actual climate measurements, certain trends in reliability are found:

- The models reproduce the large-scale features of the present climate (such as north-south distribution of pressure, temperature, wind and precipitation) very reliably.
- The models are less reliable on a regional or sub-continental scale, particularly for precipitation, soil moisture and snow accumulation.
- Acknowledged uncertainties about global warming trends include deficiencies in models and data deficiencies.
- Models must be improved in their ability to include:
    - feedbacks from the global cloud regime;
    - the role of the oceans;
    - the effect of stratospheric ozone depletion; and
    - the generation and impacts of atmospheric aerosols.

These improvements are hampered not only by funding and expertise but also by our incomplete understanding of many aspects of climate processes. Interrelationships between clouds, oceans, polar ice, ozone depletion and the climate system are not fully understood (Environment Canada, 2000). Research continues in an effort to make the models more reliable and in particular, to improve the models so that they can more accurately predict the effects of clouds and so that they can include a more dynamic model of the oceans.

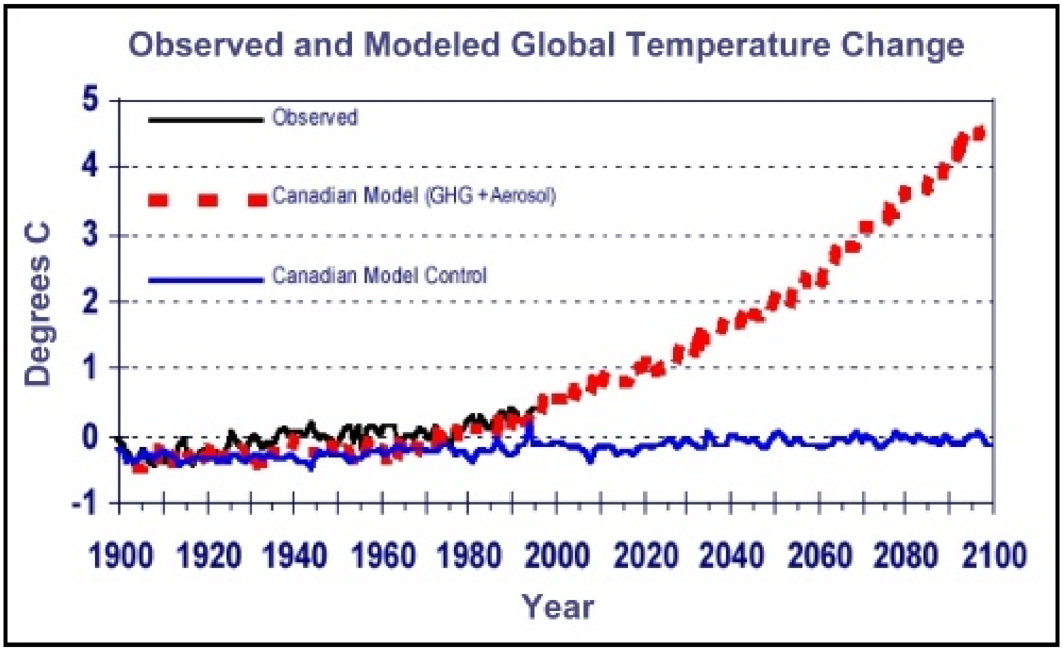
Data deficiencies which contribute to uncertainties are:

- a relatively short period of global temperature measurements;
- differences in observation techniques;
- uneven distribution of observing sites;
- urban effects on the sites; and
- natural climate variability.

Figure 24 shows the observed and modeled global temperature change over the past century. In this graph, the observed changes in temperatures are very close to the modeled changes that are predicted to result from increases in GHGs. As the model extends its predictions to 2100, with a doubling of 1990 GHG emissions, the temperature rises by 1^{o}C in 2010. Based on population growth and predicted economic growth, a doubling of atmospheric concentrations of CO_2 by the year 2100 is now a fairly conservative estimate.

The latest predictions from the IPCC (2001) are that the globally averaged surface temperature will increase by 1.4 to 5.8^{o}C over the period 1990-2100. The IPCC states that the projected rate of warming is much larger than the observed changes during the 20th century and is very likely (90-99% chance) to be larger than any change during the last 10,000 years.

Figure 24. Observed and Modeled Global Temperature Change Relative to 1951-80 Average Temperatures



Note: Observed temperature changes through 1995 are compared with temperature changes modeled by the Canadian Coupled Climate General Circulation Model (CCCGCM). Projected changes modeled by CCCGCM compare a control (no increase in GHGs) with changes predicted from doubling of 1900 atmospheric concentrations of greenhouses gases.

Source: Canadian Climate Program Board, 1998.

B.5. Issues in the Climate Change Debate

The three main issues in the debate about climate change are:

1) Has there been a significant global warming in the past century as compared with natural climate variability?
2) Is there sufficient evidence to believe that this warming is being caused by human activities?
3) How reliable are the models that predict future global warming?

The first question has two parts: (1) Has there been a warming? and (2) Is it significant in relation to natural climate variability? The question of whether there has been a warming has been complicated by the difference in temperature measurements between ground level instruments and satellites. Since 1979, when satellite measurements of atmospheric temperature became available, the layer from about 1 to 5km above the earth's surface showed virtually no warming, while measurements taken at the earth's surface showed a globally averaged warming of 0.3 to 0.4^{o}C over the same period (Parker, 2000).

An expert panel was commissioned by the US National Research Council (2000) to study this question. The commission concluded that, while improvements and standardization are needed in the measurement of the earth's surface air temperatures, the warming trend in global mean surface temperature observations during the past 20 years is

> *"... undoubtedly real and is substantially greater than the average rate of warming during the twentieth century. The disparity between the surface and upper air trends in no way invalidates the conclusion that surface temperature has been rising."*

The panel concluded that the upper atmosphere might have warmed less rapidly than the earth's surface, but also cautioned that the upper atmosphere and surface atmosphere are two different entities that should not be expected to react in the same way to changes in atmospheric composition. The panel further cautioned that trends based on data for such short periods are not necessarily indicative of the long-term behavior of the climate system.

The question of the significance in relation to natural variability is difficult to answer because we are comparing a record of increasing temperatures over 100 years with evidence that spans millions of years. Temperatures have been far less variable during the last 10,000 years (the Holocene) than in the previous 100,000 years. Based on the incomplete evidence, it appears unlikely that global mean temperatures have increased by 1^{o}C or more in a century at any time during the last 10,000 years, or during the present interglacial period (IPCC, 1996).

The question of whether the observed warming is the result of increasing emissions of GHGs may not be definitively answered because cause and effect can rarely be proven, even with the best science. The more appropriate question to ask is, "What is the likelihood that the warming is related to increased GHG emissions?" The IPCC (2001) states:

> "*In light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely (66-90% chance) to have been due to the increase in greenhouse gas concentrations.*"

The third question concerns predictions of future global climate change based on increasing GHG emissions. While the models are far from perfect, the improvements needed will require time and money and will not produce more reliable estimates for some time. However flawed the existing models are, both the hard evidence that does exist and our knowledge of atmospheric science point to the potential for serious and possibly irreversible damage from climate change in the coming century.

While strenuous efforts are being made to improve the predictive models, it nevertheless seems unwise to delay action until we have more certainty about climate change. Such a delay would fundamentally contravene the precautionary principle. If we act decisively now to reduce GHG emissions and if it is established at a later time that fossil fuel combustion has little or no impact on climate change, then fossil fuels will still be available to be burned without future generations being put at such risk. If, on the other hand, we continue to burn fossil fuels with abandon until it is more conclusively shown that fossil fuel combustion causes climate change, then it will be too late to reverse the trend.

It is prudent to take into consideration the sources of uncertainty in the science of climate change. Many critics use these uncertainties as a reason for not taking action (Idso and Idso, 2000). For example, Bob Peterson, president of Imperial Oil is quoted as saying the Kyoto agreement on global warming is "bad science and flawed public policy" (Chronicle Herald, 2000) and the Bush administration has now abrogated its Kyoto Protocol commitments. These criticisms must be acknowledged and answered as far as possible. Until they are answered, leaders from business and government will be able to use these arguments as an excuse for taking no action on climate change. For that reason, it is essential for ordinary citizens to familiarize themselves with the basic science of climate change.

In the meantime, on an issue as significant as climate change, it is also imperative to invoke and explain the precautionary principle (above). Uncertainty is a sword that cuts both ways (Hawken et al., 1999). Just as we can never be one hundred percent certain that human GHG emissions are causing global temperature change, we must also acknowledge that our estimates of predicted climate change and resultant damages may also be considerably *lower* than the actual changes that could occur. Sudden shifts in average global temperature, unexpected feedbacks such as massive methane releases from melting permafrost, and surprises from extreme events are definite possibilities. The models do not account for such surprises and potentially catastrophic weather events (Peter Bein, pers. comm., 2000). Far from being a justification for inaction, scientific uncertainty is actually an important reason to act quickly and to identify "no regrets" actions to reduce GHG emissions without delay.

C. Greenhouse Gas Emissions and the Nova Scotia Energy Strategy[30]

C.1. Introduction

Global climate change from anthropogenic GHG emissions may manifest itself in a number of different ways, from increased desertification to loss of habitat. Many coastal regions, including almost all of Nova Scotia, will be particularly vulnerable to some of the predicted effects of climate change, notably sea level rise and extreme weather events. A sea level rise of less than half a metre, coupled with a high-tide and a storm surge could severely disrupt the lives of many people living in low-lying communities along much of the Atlantic coast and the Bay of Fundy.[1]

At some 19.8 tonnes of carbon dioxide (and carbon dioxide equivalent) per person per year, Nova Scotians are among the world's top emitters of GHGs, although slightly below the Canadian average of 20.8 tonnes per person per year.(see above)[2] In December 1997, Canada signed the Kyoto Protocol, agreeing to cut its GHG emissions to 94 percent of 1990 levels by 2008-2012[3]; if these targets are to be met, Nova Scotians will be expected to make significant changes in their energy consumption habits.

The document, "*Powering Nova Scotia's Economy*," makes several references to climate change and the greenhouse effect. This report reviews the material on climate change in the document and then discusses ways in which Nova Scotians could decarbonize their economy.

C.2. Background

"*Powering Nova Scotia's Economy*" refers to climate change and GHG emissions in several sections, two of which are reviewed here.

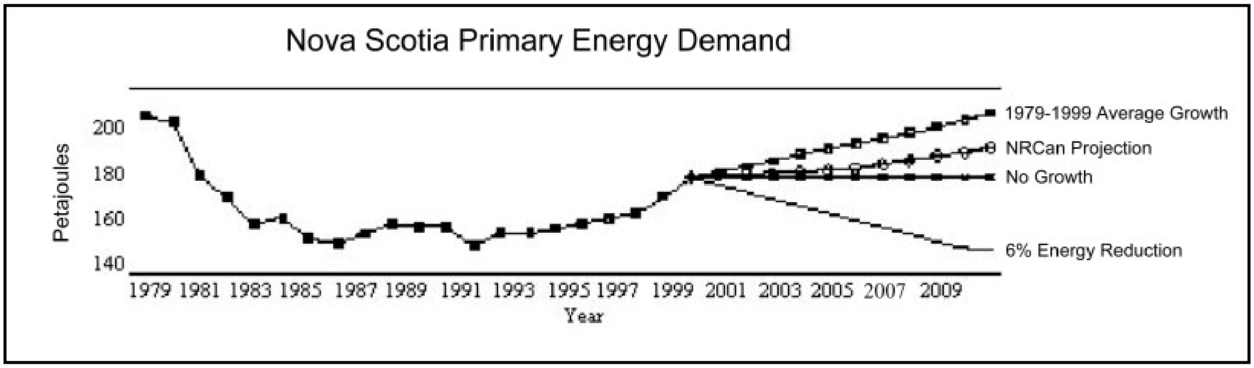
Nova Scotia's Energy Use Today

On page vii of this section, the authors present a chart, titled "Nova Scotia's Primary Energy Demand," which is reproduced here (Figure 25).

Figure 25 is for the years 1979 to 2010 (1979 to 1999 are historical data). The projections (2000 to 2010) show four possible growth curves: average growth, NRCan's projected growth, no growth, and a "6% Energy Reduction." The footnote associated with the 6% Energy Reduction projection states: "Targets a 6% reduction from 1990 levels by 2010."

[30] This Appendix was prepared by Larry Hughes, Ph.D, Department of Electrical and Computer Engineering, Dalhousie University. This report was originally prepared and submitted in June 2001 to the Nova Scotia Energy Strategy. Some values for GHG emissions may therefore not correspond to values in the main text since different sources were used. References in this Appendix refer to the list of citations at the end of this Appendix.

Figure 25. Nova Scotia Primary Energy Demand: Historical and Alternative Projections



Notes:

Projected at Natural Resources Canada (NRCan) forecast growth rates. Targets a 6% reduction from 1990 levels by 2010. Projected at same rate of growth experienced from 1989-1999. 1979-1999

Source: **Historical Data**: Statistics Canada.

Despite the chart title, the data in the above chart do not refer to primary energy demand. According to the document (page v), Nova Scotia's primary energy demand in 1999 was 269.4 petajoules (PJ); the chart shows a value below 180PJ. It is possible that the chart refers to Nova Scotia's end-use energy demand (page v of the document states that end-use demand in 1999 was 179.0PJ). End-use energy demand refers to energy that is used by a sector where the energy could have undergone a transformation (for example, coal or oil to electricity). Anyone interested in the total GHG emissions from Nova Scotia should examine primary rather than end-use energy data.

The authors have completely misunderstood the meaning of the six percent reduction pledged by Canada at Kyoto. Canada pledged a six percent reduction in emissions not a six per cent reduction in energy demand (primary or end-use).[3]

This is more than semantics. Consider:

- Nova Scotia could maintain its current primary energy demand and reduce its emissions by six percent of 1990 levels through fuel substitution; for example, replacing coal by renewable forms of energy.
- A six percent drop in emissions does not necessarily translate into a six percent drop in a given fuel. For example, because of Nova Scotia's energy mix and the ratio of carbon dioxide emitted by different fuels, a six percent drop in energy-related emissions would require an 18 percent reduction in coal consumption or an eight percent reduction in oil consumption (based upon 1990 primary energy consumption for Nova Scotia[4]).

Global Climate Change

Document pages xxxiii and xxxiv are devoted to the problem of global climate change. The authors of the document present a brief summary of the problem and include a discussion of

Nova Scotia's role, in light of Canada's commitment to cut its GHG emissions to 94 percent of 1990 levels by 2008-2012 (in other words, a six percent reduction).

On page xxxiv, the document states "Nova Scotia's GHG emissions had risen from 19,400kt (kt) equivalent of CO_2 equivalent to 20,100kt of CO_2 equivalent by 1998... Emissions are estimated to be 21,100kt of CO_2 by 2010. Achieving a "'Kyoto-like' target in the reduction of emissions would require a 16 percent reduction from a BAU forecast."

The "16 percent emissions reduction" is incorrect:

- Nova Scotia's 1990 emissions were, as stated in the document, 19,400kt of CO_2 equivalent.[5]
- To meet the Kyoto target, a six percent reduction is required; six percent of 19,400kt is 19,400 × 0.94, or 18,236kt.
- Assuming that Nova Scotia's projected emissions of 21,100kt by the year 2010 are correct, then the percentage decrease in emissions to meet the Kyoto target must be (21,100 - 18,236) / 21,100 or 13.5 percent.

The 16 percent emissions reduction is incorrect because it is based upon incorrect information, presumably obtained from Voluntary Planning's "Climate Change Workbook" (issued as part of the Government of Nova Scotia's consultations held with stakeholders in 1999).[6] Page 7 of the Climate Change Workbook states that in 1990, Nova Scotia's emissions were 19.4 million tonnes of CO_2 and that a six percent reduction would give a reduction target of 17.7 million tonnes. As has been shown above, six percent of 19.4 million is 18.2 million, not 17.7 million.

Page xxxiv of this section lists the following options for reducing emissions (there is no suggestion that this list is exhaustive):

1. Using renewable energy sources.
   Achieving a decarbonized economy will eventually require Nova Scotia to abandon fossil fuels in favour of renewable energy sources such as biomass, solar, wind, and small scale hydro. The document admits to this on page xxviii, where it states: "Alternative energy sources can, in many cases, reduce the environmental impacts associated with energy produced by fossil fuels. The reduction of carbon emissions in particular may have significant impact on future mandatory reductions resulting from the ratification of an international climate change treaty." Despite this admission, the document's main thrust is for the development of oil and natural gas.

2. Switching to lower-carbon fossil fuels (for example, oil to gas).
   As will be shown in the next section, limited substitution of lower-carbon fuels does not guarantee a significant decline in GHG emissions if there is no concomitant decline in energy consumption. Furthermore, basing emissions reduction on finite fossil fuels simply postpones the inevitable need to move to renewable energy.

3. Improving energy efficiency.
   Improving energy efficiency is intended to reduce energy demand. This will, in turn, reduce emissions. (By how much depends, once again, on the fuel: a reduction in coal will have a

greater impact than an equivalent reduction in oil consumption). Improvements in energy efficiency can be achieved through technological change (such as hybrid automobiles) or through social change (such as people shifting from automobile use to more sustainable modes of transportation).

4. Sequestration of carbon in agricultural soils or forests.
   Sequestration of carbon is a permitted method of emissions reduction under various UNFCCC agreements.[7] There are many concerns about sequestration that must be addressed. For example, carbon dioxide sequestration is greatest while trees are young. Once mature, the rate decreases, and as a result, these forests will have to be logged and replanted at regular intervals. The felled trees and their residue cannot be combusted as this will add to the atmosphere's carbon dioxide levels. The GPI Forest Accounts (2001) point to significant carbon releases due to current logging practices. Also, forests can be destroyed by disease, fire, or storm, all uncontrolled means whereby the sequestered carbon is re-released to the atmosphere.

   Further, as demonstrated in the GPI Forest Accounts (2001), old growth forests actually store significantly more carbon than young forests, even though the *rate* of sequestration is greater when trees are younger. When old forests are cut, soil carbon is released, adding to atmospheric CO_2 concentrations. In short, there are serious unresolved issues that make it doubtful whether forests can be relied on for carbon sequestration in light of current forest practices.

5. Capturing methane from landfills and underground mining.
   If all landfill methane could be captured in Nova Scotia, it would represent the equivalent of about three percent of the province's total GHG emissions. Once captured, the methane is usually combusted, creating more carbon dioxide. A long-term strategy of minimizing the amount of organic matter put into landfills may prove to be a better solution. As noted in the GPI Ecological Footprint report, Nova Scotia has made significant progress in diverting organic wastes from landfills.

   Fugitive methane from underground coal mining has been decreasing significantly over the past decade as provincial coal mines have been closed (from 1.2Mt equivalent in 1990 to 0.83Mt CO_2 equivalent in 1996[5]). This number will probably continue to decrease. Interestingly, a significant source of fugitive methane comes from natural gas production and transportation [5], meaning that provincial pipelines may replace coal mining as Nova Scotia's principle source of fugitive methane.

6. Storing generated CO_2 below ground.
   The problem with capturing CO_2 and storing it below ground is that it takes energy to undertake both of these activities. However, because of declining oil stocks, a technique known as Enhanced Oil Recovery captures CO_2 and pumps it into "depleted oil fields," thereby extracting additional oil. (The energy balance may be negative, but North America's need for oil is such that this is an economically attractive option). At present, Pan Canadian imports CO_2 from North Dakota for its Enhanced Oil Recovery program at the Weyburn Oilfield[8].

CO_2 capture is intended for stationary power plants. Capturing CO_2 from automobiles is much more problematic because of the complexities associated with fitting the necessary equipment on every automobile.

7. Emissions trading.
   The purpose of emissions trading is to reduce CO_2 emissions by opening it to market forces. Each organization (i.e., country, company, or individual) that is committed to reducing emissions is given a target. Organizations will either produce fewer emissions than their target or more. Organizations that produce fewer emissions are awarded "credits" which can be sold on the open market to other organizations that produce more emissions.

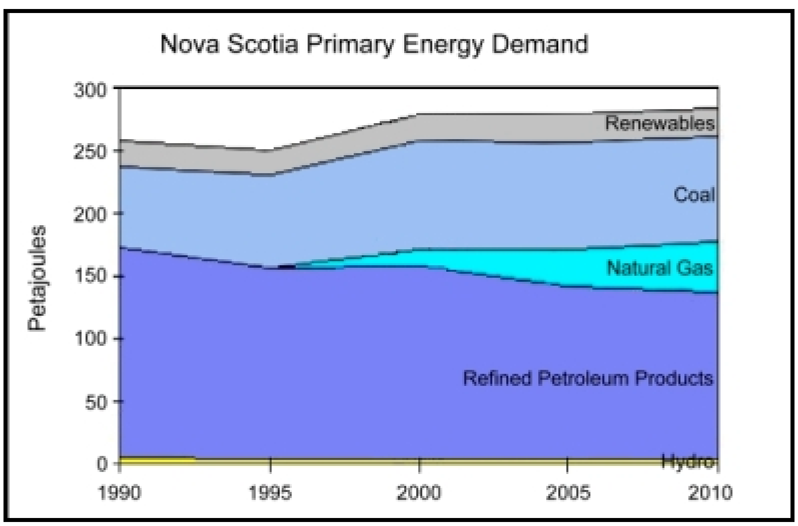
   The concept works in principle, but requires monitoring agencies to verify that targets have truly been met. Furthermore, the cost of not meeting the required targets must be such that missing a target will become a financial burden on the organization. (This is another reason why many developed countries that are heavily dependent upon fossil fuels are reluctant to join emissions trading schemes).

C.3. Emissions from Energy Sources

Before considering emission reduction strategies, it is worthwhile examining NRCan's primary energy demand projections for Nova Scotia and the resulting GHG emissions.

Figure 26 is NRCan's historical (1990 and 1995) and projected (2000, 2005, and 2010) primary energy demand for Nova Scotia.[4]

Figure 26. Nova Scotia Primary Energy Demand by Type: Historical and Projected

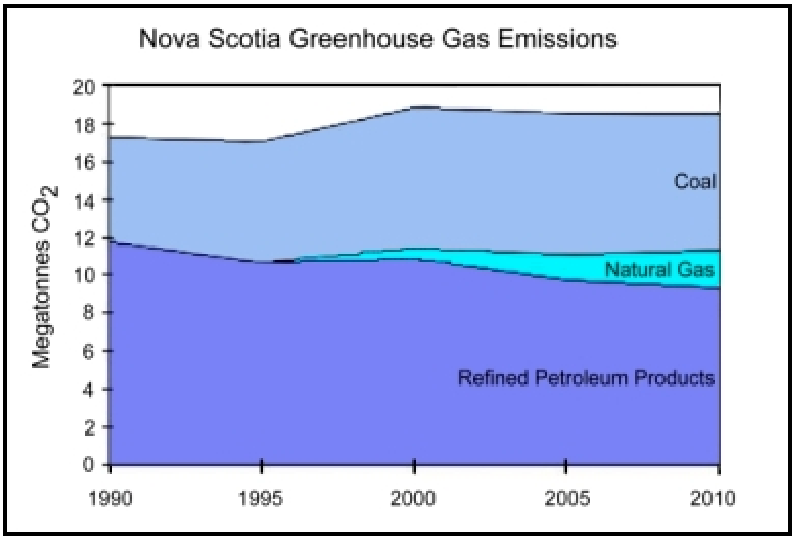


Source: Natural Resources Canada, 2000.

Over the next decade in Nova Scotia, NRCan projects that natural gas will come on-stream, displacing oil in the commercial, industrial, and residential sectors as well as for electrical generation. However, natural gas is projected to make little impact on coal consumption (for electrical generation). Primary energy demand is expected to grow from 253.0PJ in 1990 to 281.2PJ in 2000 and 285.6PJ in 2010.

The effect of the introduction of natural gas to the energy mix would be expected to make a significant impact on the province's GHG emissions. However, as Figure 27 shows, this is not the case because energy consumption is projected to increase, diminishing the benefits of "cleaner" natural gas.

Figure 27. Nova Scotia Greenhouse Gas Emissions by Fuel Type



Source: Natural Resources Canada, 2000.

If NRCan's projections are correct, the decline in CO_2 emissions from energy sources will be gradual and modest, peaking at 18.9Mt in 2000 and holding steady at 18.5Mt for 2005 and 2010.

The following assumptions were made in the creation of Figure 26 and 27:

- Carbon dioxide emissions are from energy sources only. GHG emissions from other sources are not included.
- Emissions from renewable sources of energy, notably biomass, are carbon-neutral. (i.e., CO_2 released from the burning of biomass will be removed from the atmosphere by new biomass growth).
- Emissions from refined petroleum products are assumed to be 70 tonnes per terajoule.[9]
- Emissions from coal are assumed to be 85 tonnes per terajoule.[9]
- Emissions from natural gas are taken as 49.68 tonnes per terajoule.[9]

C.4. Emission Reduction Strategies

In the document (and elsewhere), GHG reduction is portrayed as a monolithic action, applied to the entire economy. This approach is naive, since it fails to recognize that the economy is made of various sectors, each with its own energy requirements. By examining each sector individually (Table 23), emission reduction strategies can be tailored to the energy requirements of the sector, potentially making it more acceptable to the public at large.

Table 23. 1996 Energy-Related CO_2 and CO_2-Equivalent Emissions for Nova Scotia[5]

Sector	Emissions (kt)	Percentage
Electrical generation	7,280	40.4%
Transportation	5,200	29.2%
Residential	2,000	11.2%
Industrial	1,479	8.3%
Commercial	786	4.4%
Fugitive	830	4.6%
Other	228	1.3%
Total	**17,800**	**100%**

Emission reduction strategies for the four sectors of the Nova Scotia economy as well as electrical generation are now considered.

Residential

Many emission reduction strategies for the residential sector focus on replacing existing lighting systems with more energy efficient systems. Although this will make an impact, more significant reductions can be achieved by considering total residential energy demand. For example, in 1995, Canada's residential energy demand is presented in Figure 28.[9]

Figure 28. Canada's Residential Energy Demand (1995)

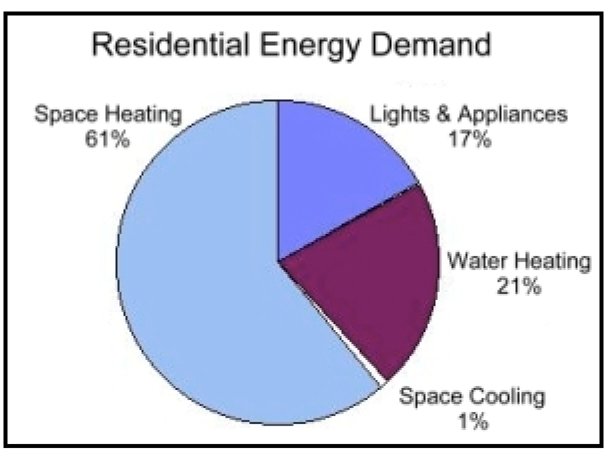


Figure 28 shows that with the exception of electricity for lighting and appliances, most of the energy used for residential purposes in Canada is for space and water heating.

In 1997, residential energy use in Nova Scotia was 48PJ, primarily from oil (25.4PJ), electricity (13.2PJ), and wood (8.1PJ).[4] Based upon the Canadian residential energy demand, one can assume that oil, wood, and some electricity were used for space heating. Using oil and electricity for space heating is an extremely inefficient use of expensive "high-grade" energy sources.

Sustainable alternatives to oil and electricity exist and should be considered for space and water heating as part of a provincial energy policy:

- District heating.
  In Nova Scotia, most thermal power stations are no more than 40 percent efficient, meaning that about 60 percent of the fuel burned in the power station is discarded as "waste" heat. District heating is the utilization of the so-called "waste" heat from thermal power stations for space heating and domestic hot water in buildings, including residences. The "waste" heat is piped as hot water from the power station to residential neighbourhoods, where the pipes are connected to residential heating systems.

  District heating offers numerous advantages: more efficient use of energy, improved air quality (by reducing the number of furnaces in a neighbourhood), local employment, and choice of fuels (since the hot water is not dependent upon the fuel source).

  District heating is an extremely efficient use of energy: it replaces two fuel sources (one for electrical generation and the other for space/water heating) with one fuel source (part for electrical generation and the "waste" part for space/water heating). In fact, district heating is an example of how "saving the environment" actually "saves money", since less fuel is consumed to perform two tasks.

  At present, only cities and towns that are near existing thermal power stations can realistically take advantage of district heating systems. These cities and towns would be in the vicinity of the Tufts Cove, Trenton, Point Aconi, Lingan and Point Tupper thermal generating plants (see Figure 15). However, in those cities and towns that are not located near a thermal power station, smaller "combined heat and power" (or CHP) plants can be built to generate electricity and heating water. The source of energy for CHP plants can be existing fossil fuels or other fuel sources, such as biomass[10].

- Passive or active solar technology.
  Most buildings in Nova Scotia are not designed for solar gain, either passive or active. By constructing new residential buildings to maximize their solar gain, space heating requirements for these buildings would be reduced.

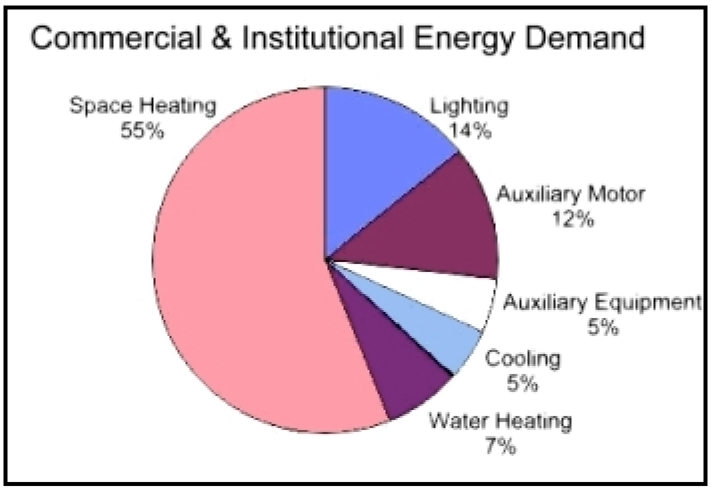
- Building Insulation.
  Residential space heating requirements can be reduced even further by improving the building insulation.

Commercial

Commercial and institutional energy demand in Nova Scotia in 1997 was 23.5PJ from electricity (10.4PJ), oil (11.4PJ), and liquid propane gas (1.8PJ).[4] The application of commercial and institutional energy demand in Canada in 1995 is represented in Figure 29.[9]

As with residential energy use, significant energy reduction could be achieved by meeting space and water heating requirements (currently satisfied by electricity and oil) with district heating, passive and active solar, and improved insulation.

Figure 29. Canada's Commercial and Institutional Energy Demand (1995)



Industrial

Nova Scotia's industrial energy demands have averaged about 50PJ per year (NRCan predicts this trend to continue to at least 2010). In 1997, Nova Scotia's industrial energy demand was 50.8PJ, primarily from electricity (10PJ), oil (26.9PJ), and pulp spenting and wood waste (10.1PJ).[4]

Over the past decade, significant improvements in energy usage have taken place in much of Canada's industrial sector, in order to keep costs down and remain competitive with foreign companies.[9] The industrial sector can play a major role in "helping the environment" *and* "saving money" at the same time. By keeping Nova Scotia's industrial sector competitive through improvements in energy efficiency (i.e., by "saving money"), it is possible to help the environment by significantly reducing GHG emissions.

Transportation

At 29.2 percent in 1996, transportation was the second largest emitter of GHGs in the province (5,200kt CO_2-equivalent). The top three GHG emitters in the transport sector are presented in Table 24.

Table 24. Energy-Related CO_2 and CO_2-Equivalent Emissions, 1996

Vehicle Type	Emissions (kt)	Percentage
Gasoline Automobiles	1,580	8.8%
Light-Duty Gasoline Trucks	1,140	6.4%
Heavy-Duty Diesel Trucks	895	5.0%

Note: "Percentage" refers to percent of the provincial total energy-related CO_2 and CO_2-equivalent emissions

It is impossible to examine the transportation sector without taking into account a multitude of factors which carry both direct and indirect costs to human society, including:

- Land use:
  - loss of crop land to roads;
  - loss of land to parking lots;
  - loss of compact urban form and growth to low-density housing.

- Demographics:
  - loss of mobility for the aged;
  - loss of mobility for the working poor;
  - loss of communities to low-density housing which results in loss of social interaction.

- Human health:
  - effects of PM_{10} including chronic bronchitis in adults, coughs, chest discomfort, eye irritations, asthma attacks, respiratory hospital admissions, and acute bronchitis in children;
  - nitrogen oxide compounds are known to affect human mortality and morbidity;
  - ground-level ozone, formed from the reaction of nitrogen oxides, oxygen, volatile organic compounds, and sunlight, are known to cause a wide range of health effects, include eye, nose, and throat irritation, chest discomfort, coughs, and headaches. Some studies suggest that there is a link between ozone and childhood asthma and some cancers.
  - costs of accidents.

- Energy costs:
  - rising energy costs mean a larger percentage of income devoted to the automobile;
  - rising energy costs increase the price of imported foods and other imports.

- Greenhouse gas emissions:
  - increased distances traveled lead to increased emissions.

- Road costs:
  - rising cost of road construction and maintenance.

- Congestion:
  - increasing traffic volumes outstrip highway capacity;
  - loss of "quality" time with families.

Although transportation is central to our "lifestyle," it is widely acknowledged that continued growth in auto-centric transportation is unsustainable.[11] With this in mind, it is time to re-think how people and goods are transported in Nova Scotia. By reducing our dependence on the automobile, energy demand can be reduced with an associated decline in GHG emissions.

Technological change, such as the introduction of novel fuels, may well reduce GHG emissions, but the problems associated with the automobile (some of which are listed above) will remain.

Electrical Generation

Nova Scotia required 99.6PJ of fuel for electrical generation in 1997: This came from coal (86PJ), oil (10.1PJ), and hydro-electric (3.5PJ).[4] The end-use demand for electricity amounted to 33.6PJ from the following sectors: residential (13.2PJ), commercial (10.4), and industrial (10PJ). The difference between the fuel required for generation (99.6PJ) and the electricity consumed (33.6PJ) is 66PJ; one or twoPJs were used within the generating stations. The remainder, about 64PJ, was discarded as "waste" heat (actually thermal pollution) from thermal power stations to the environment.

(As discussed previously, much of this "waste" heat could be used in district heating systems for low-grade heating requirements in the residential and commercial sectors. District heating would make a sizeable impact on GHG emissions in towns and cities that are located near existing fossil fuel thermal power stations, such as Tufts Cove in Halifax/Dartmouth.[12])

In addition to district heating, another way in which GHG emissions can be reduced is to replace existing thermal power stations (i.e., coal and oil-fired) with renewable energy sources, including some of those suggested in the document "*Powering Nova Scotia's Economy*" (page xxvi): biomass, solar, wind, and small-scale hydro. All of these technologies are "mature" in that they have proven track records around the world. Furthermore, Nova Scotia has excellent potential for many of these technologies; for example, the off-shore wind regime has the potential to supply up to ten times Nova Scotia's current electrical energy needs.[13]

The development of renewable energy in Nova Scotia is being hampered, in part, by Nova Scotia Power's pricing arrangements, which discriminate against independent power producers. Other jurisdictions encourage independent power producers by requiring utilities to "wheel" power across their grid.

Another approach which is gaining widespread acceptance in the United States is the introduction of "Renewable Portfolio Standards" (RPS), in which utilities are required by law to include renewable energy in their energy mix. RPS is different from existing "green power" schemes in that the utility cannot charge a differential fee for renewable energy. Most RPS schemes require their utilities to supply a small percentage of their power as renewables. This percentage increases each year until it reaches a maximum, which must be maintained by the utility (for example, see de Azua, 2001[14]).

C.5. Summary and Recommendations

From reading "*Powering Nova Scotia's Economy*," it is clear that the Nova Scotia government is more interested in promoting oil and natural gas use than in reducing GHG emissions and tackling the problem of climate change. Despite this lack of interest, there is an underlying problem that will not go away – the price of fossil fuel-based energy will continue to rise in step with increasing world demand. [15]

- The cost of home heating fuel is rising and affecting many Nova Scotians on fixed incomes.
- The cost of gasoline will continue to rise and affect Nova Scotian motorists and the cost of shipping goods to and from Nova Scotia.

The most obvious way of solving this problem is to decarbonize Nova Scotia's economy. If Nova Scotians were to reduce their consumption of fossil fuels using the measures outlined in this report, not only would they be "saving money" (by using energy more efficiently), but they would also be "saving the environment."

Despite about the enormous hopes placed in off-shore oil and natural gas, reserves will not last forever. To build a long-term "energy strategy" based on the depletion of non-renewable fossil fuels is folly. What is needed is a sustainable energy policy that will ensure the long-term energy future for all Nova Scotians. Such a policy would:

- foster the growth of a renewable energy industry in Nova Scotia by adopting an RPS.
- require all existing thermal stations (coal and oil) to convert to combined heat and power.
- offer low-cost loans to communities that wish to take advantage of combined heat and power.
- institute a provincial transportation strategy, consisting of community buses (operating in rural communities), regional buses (connecting rural communities to regional centres), and inter-city buses and trains (connecting regional centres).
- shift freight goods wherever possible from tractor-trailers on provincial highways to rail. Local distribution can be handled by local trucking firms.
- Reintroduce and implement the energy efficiency projects and programs formerly operated by the provincial government.
- introduce zoning laws that would require all new buildings to maximize their reliance on solar energy.
- require the Auditor-General to present an annual report on the province's progress towards a sustainable energy future.

By developing a policy such as the one described above, Nova Scotians will become leaders in the field of sustainable energy, gaining knowledge and expertise that could be shared with the world. In the process, the province will substantially reduce its GHG emissions.

C.6. Acknowledgements

The author would like to thank Phil Thompson, Andy George, Vanessa Kind, and Dr. Tim Little for their assistance with this report.

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D. Application of the Genuine Progress Index Approach to Analyzing Reduction of Greenhouse Gas Emissions in the Nova Scotia Freight Transport Sector *[separate report]*

APPLICATION OF THE GENUINE PROGRESS INDEX APPROACH TO ANALYZING REDUCTION OF GREENHOUSE GAS EMISSIONS IN THE NOVA SCOTIA FREIGHT TRANSPORT SECTOR

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May 1999.

EXECUTIVE SUMMARY

The impetus for this study arose from the desire of leaders in several Nova Scotia Government Departments to 1) take a proactive stance on reduction of greenhouse gases and 2) to find a method for analyzing the impact of various GHG reduction strategies on the environmental, social and economic health of the province. The overall objective is to determine the usefulness of the Genuine Progress Index approach for analyzing and comparing costs and benefits of various greenhouse gas reduction scenarios. Specifically, the study sought to produce a Greenhouse Gas Mitigation Index, which would be a measure of the cost to reduce CO_2 emissions by one tonne in the truck and rail freight transportation sector in Nova Scotia.

The study analyzed for-hire truck traffic and mainline rail traffic along the corridor from Halifax, N.S. to Amherst, N.S. in an effort to determine the potential for GHG emissions reduction through a modal shift of freight from truck to rail. Because the study relied on available statistics, namely Statistics Canada catalogues "Rail in Canada" (which aggregates data for Atlantic Canada) and "Trucking in Canada" (which only includes for-hire trucking companies with annual income greater than $1 million), data limitations were substantial.

Costs and benefits included in the study were property tax; fuel tax; registration fees; license fees; toll fees; infrastructure costs (capital and maintenance); policing costs; administrative costs; costs of air pollution and climate change; accident costs; and costs of fossil fuel depletion. The Income and Expense Statements for Truck and Rail (below), under the Business-as-Usual Scenario and under a Modal Shift from truck to rail, summarize the net societal costs of trucking and rail for the HA-800 freight. Under the business-As-Usual Scenario, net societal costs for trucking are six times those for rail.

The current (1997) modal mix for long-haul freight between Halifax and Amherst is 67% rail and 32% truck. Because the potential for shifting freight from truck to rail is limited by the type of freight shipped, the maximum modal mix possible is 77% rail and 23% truck, which is the recommended modal mix. The change to this modal mix would save roughly $141 million over the 14 years represented here. The cumulative reduction in CO_2 emissions was estimated at 191,750 tonnes. A 10% shift of freight away from truck toward rail would result in an average annual decrease in CO_2 of 13,696 tonnes at a net average annual social benefit of $10 million.

The GHG Mitigation index is estimated at -$715 per tonne of CO_2. It is noted that the recommended modal shift would cause a decrease in total employment remuneration of 12.3%, and trucking remuneration is reduced by 30%.

The modal shift of 10% truck freight to rail is considered a "No Regrets" measure, since it results in net benefits to society. However, it is not a significant measure in the overall challenge of greenhouse gas reduction in Nova Scotia.

The GPI approach to GHG reduction strategies was found to be highly useful and applicable for many different scenarios. The GHG mitigation index allows a means of comparing the effectiveness of many different strategies.

Table ES.1. Income and Expense Statement (1997), Business-As-Usual Scenario, HA-800 Truck And Rail Freight

	Truck	Rail
1.1.1.1.1.1 Revenues to Society		
Government Revenues		
- Property Tax		$1,000,000
- Diesel Fuel Tax	$607,867	$321,110
- License Fees	$50,444	
- Registration Fees	$529,000	
- Toll Fees	$2,820,000	
1.1.1.1.1.2 Total Societal Income	**$4,007,311**	**$1,321,110**
1.1.1.1.1.3 Expenses to Society		
Government Costs:		
- Highway Capital Costs	$1,788,569	
- Highway Maintenance Costs	$570,469	
- Policing Costs	$3,295,900	
Administrative Costs	$14,568,200	
- External Costs		
- Accidents	$3,782,720	$1,151,864
- Air Pollution	$7,224,174	$2,357,617
- Climate Change	$1,656,996	$513,624
- Fossil Fuel Depletion	$4,921,648	$2,652,319
1.1.1.1.1.4 Total Societal Expenses	**$37,808,672**	**$6,675,752**
NET PROFIT (EXPENSE)	**($33,801,361)**	**($5,354,642)**
SUM Net Expense Rail and Truck	**($39,156,003)**	

Note: Numbers may not agree exactly with text numbers due to rounding. Total societal income and expenses refer only to those categories included in the study.

Table ES.2. Income and Expense Statement (1997), Recommended Modal Mix Scenario, HA-800 Truck And Rail Freight

	Truck	**Rail**
1.1.1.1.1.5 Revenues to Society		
Government Revenues		
- Property Tax		$1,239,084
- Diesel Fuel Tax	$424,159	$397,934
- License Fees	$35,203	
- Registration Fees	$369,131	
- Toll Fees	$1,967,761	
1.1.1.1.1.6 Total Societal Income	**$2,796,255**	**$1,637,019**
1.1.1.1.1.7 Expenses to Society		
Government Costs:		
- Highway Capital Costs	$1,248,033	
- Highway Maintenance Costs	$398,051	
- Policing Costs	$2,299,824	
Administrative Costs	$10,165,447	
- External Costs		
- Accidents	$2,639,519	$1,427,305
- Air Pollution	$5,040,907	$2,921,385
- Climate Change	$1,156,224	$636,444
- Fossil Fuel Depletion	$3,434,244	$3,286,558
1.1.1.1.1.8 Total Societal Expenses	**$26,382,250**	**$8,271,692**
NET PROFIT (EXPENSE)	**($23,585,996)**	**($6,634,673)**
SUM Net Expense Rail and Truck	**($30,220,669)**	

Note: Numbers may not agree exactly with text numbers due to rounding. Total societal income and expenses refer only to those categories included in the study.

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LIST OF ABBREVIATIONS

APTC	Atlantic Provinces Transportation Commission
BAU	Business as Usual
CB&CNS	Cape Breton and Central Nova Scotia Railway Ltd.
CCFM	Canadian Council of Forest Ministers
CN	Canadian National
CO	Carbon Monoxide
CO_2	Carbon Dioxide
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GMI	GHG Mitigation Index
1.1.1.1.2 GPI	Genuine Progress Index
HA	Halifax to Amherst Route
HA-800	Halifax to Amherst Route (minimum distance of 800km)
HC(s)	Hydrocarbon(s)
IPCC	Intergovernmental Panel on Climate Change
Kt	Kilotonnes
NOx	Nitrogen Oxides
PM	Particulate Matter
PM_{10}	Particulate Matter $\leq$10 Millimicrons in Diameter
RMM	Recommended Modal Mix
SO_2	Sulphur Dioxide
UNFCCC	United Nations Framework Convention on Climate Change
UV	Ultraviolet
VOC(s)	Volatile Organic Compound(s)

10. Introduction

10.1. Impetus for the Study

The impetus for this study arose from the desire of leaders in several Nova Scotia Government Departments to 1) take a proactive stance on reduction of greenhouse gases and 2) to find a method for analyzing the impact of various greenhouse gas (GHG) reduction strategies on the environmental, social and economic health of the province. In meetings among staff of **GPI***Atlantic* and officials from Nova Scotia Department of Environment, NS Department of Natural Resources, and NS Department of Transportation and Public Works, as well as Environment Canada, Atlantic Region, it was concluded that the Genuine Progress Index (GPI) might provide a broad and fairly comprehensive tool for estimating effectiveness and impacts of different strategies. To test the applicability of the GPI for this purpose, a pilot project was undertaken to determine the potential for reducing greenhouse gases through modal shifts of freight from truck to rail and to determine the impact of such shifts on the environment and the economy of Nova Scotia.

10.2. Climate Change and Greenhouse Gases

Climate change and global warming have become the number one item on the environmental agenda, both nationally and internationally. In the 20th Century average global surface air temperature has increased between 0.3 and 0.6˚C, an increase that is larger and more rapid than at any other time in history (Suplee 1998). Night-time temperatures over land have increased more than day-time temperatures, and regional changes have also occurred. While recent years have been among the warmest since 1860, even with the cooling effect of the Mt. Pinatubo volcanic eruption (1991), the warming has been greatest over mid-latitude continents, with a few areas of cooling trends, including the North Atlantic Ocean. Precipitation has increased over land in high latitudes of the Northern hemisphere, and global sea level has risen by 10-25cm over the past 100 years. Although regional changes in weather extremes and climate variability are evident, inadequate data exist to detect such trends globally (IPCC 1995).

In this same time period, concentrations of GHGs in the atmosphere have risen dramatically. Since pre-industrial times (about 1750), atmospheric concentrations of CO_2 have increased by 30%, methane by 145%, and nitrous oxide by 15% (IPCC 1995). The Intergovernmental Panel on Climate Change (IPCC) (1995) predicts that maintenance of emissions at 1994 levels would cause an increase in atmospheric concentrations for the next two centuries. By 2050 alone, emissions will have reached twice the pre-industrial concentration (an increase generally referred to as "doubling of CO_2").

It is estimated that rising CO_2 levels account for 60% of global warming, while increases in methane concentrations are thought to account for 15% of global warming. Because of the long lifetime of greenhouse gases in the atmosphere, today's emissions can affect atmospheric concentrations for more than 100 years. (Suplee 1998).

Although uncertainties remain with models used to predict climate change, such as General Circulation Models, projections of temperature change for a doubling of CO_2 range from an increase of 1˚C to an increase of 3.5˚C by 2100. The mid-range estimate is a 2˚C increase over 1990 temperature (IPCC 1995). Putting this into a shorter time perspective, the mid-range prediction is for an increase of 1˚C to 3.5˚C over the next 100 years, as compared to the increase of 0.3-0.6 ˚C over the past 100 years (Suplee 1998). These temperature changes are not expected to be distributed uniformly: more substantial warming is predicted over Canada, particularly in winter (Environment Canada 1997b).

Resulting warming of the oceans would lead to an increase in sea level of about 50cm from present (1995) levels by 2100. The range of sea level increase predicted by models is 15-95cm. Confidence in global model predictions is high but confidence in regional predictions is low. In both temperature and sea level, regions may differ significantly from global averages. The IPCC (1995) sums up model predictions as follows:

> *"All model simulations, whether they were forced with increased concentrations of greenhouse gases and aerosols or with increased concentrations of greenhouse gases alone, show the following features: greater surface warming of the land than of the sea in winter; a maximum surface warming in high northern latitudes in winter; little surface warming over the Arctic in summer; an enhanced global mean hydrological cycle, and increased precipitation and soil moisture in high latitudes in winter. All these changes are associated with identifiable physical mechanisms."*

Contradictions between measured surface temperatures and climate models with satellite data have been reconciled by allowing for changes in the angle of the satellite over time due to atmospheric drag (Hansen et al. 1998). These reconciliations, however, are based on a satellite record of less than two decades. Gaffen (1998) argues that the reconciliations make little difference in results based on systems that were never designed for climate monitoring. Thus the debate on global warming continues, and conclusions from the present report could be altered as increasingly accurate data and predictions become available.

Recent evidence of a cooling of the earth's upper atmosphere (stratosphere) have been cited as the latest, biggest, and most unequivocal evidence that the earth's climate really is changing (Pearce 1999). The stratosphere (50-90km above the earth's surface) has been cooling by as much as a degree every year for the past 30 years. The connection to global warming of the troposphere (the layer of the atmosphere immediately below the stratosphere) is that when the greenhouse effect causes radiant energy (heat) to be trapped in the troposphere, this heat is no longer available to warm the stratosphere, and the upper atmosphere begins to cool. This cooling is thought to be related to the decrease in the ozone layer in the stratosphere, since the degradation of ozone occurs at lower temperatures. Shindell (cited in Pearce 1999) predicts that the lower stratosphere of the arctic will be 8˚C to 10˚C colder by 2020 than it would have been without the greenhouse effect and ozone loss will be double what it would have been without the greenhouse effect.

Potential effects of the predicted global warming include (Suplee 1998):

- increased water vapour in air, leading to increased rainfall, more extreme weather events, and uneven distribution of rainfall;
- more serious heat waves;
- collapse of the Atlantic "conveyor belt" system that brings warm water north from the equator, resulting in arctic-like temperatures for much of Northern Europe; and
- sea level rise.

These effects translate into damages to human health, ecosystems, agriculture, fisheries, forestry, and coastal zones. Although these are effects of global climate change, no region is insulated from these impacts.

In the past 30 years, central and northwestern Canada have shown an increase in air surface temperatures up to 0.5˚C, while cooling of up to 0.4˚C has occurred east of the Labrador Coast (Canadian Climate Program Board and Canadian Global Change Program 1996). Canadian areas of particular sensitivity to climate change are human health, water systems, natural ecological systems, forests (especially boreal forests), coastal ecosystems and coastal zones, and agriculture.

Canada is one of the world's highest emitters of GHGs on both a per capita and a per dollar of GDP basis (Canadian Climate Program Board and the Canadian Global Change Program 1996). Canada's GHG emissions (in CO_2 equivalents) have increased from 567,000 kilotonnes in 1991 to 619,000 kt in 1995 (Jaques et al. 1997). Ninety-one percent of emissions come from stationary fuel combustion (50.6%); mobile fuel combustion (26.7%) and industrial processes (15.1%). These are the areas that offer the greatest opportunity for large reductions in GHG emissions.

Although Canada has 10% of the world's forested area, there is evidence that since the 1980s most of these forests have become a source of CO_2 emissions, rather than a sink [Canadian Council of Forest Ministers (CCFM) 1997].

In the face of potentially damaging and irreversible impacts, the United Nations Framework Convention on Climate Change (UNFCC) adopted the precautionary principle in Article 2 (IPCC 1995), which states that Parties should:

> *"...take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost effective so as to ensure global benefits at the lowest possible cost."*

In terms of mitigating GHG emissions, "No Regrets" measures are those whose benefits equal or exceed their cost to society, not counting the benefits of climate change mitigation. They are measures which are worth doing even without the pressure of mitigating climate change (Canadian Climate Program Board and the Canadian Global Change Program 1996). The IPCC (1995) has stated that "the risk of aggregate net damage from climate change provides an economic rationale for mitigation that goes beyond "no regrets."

10.3. Climate Change and Atlantic Canada

The Nova Scotia Action Plan on Climate Change (Government of Nova Scotia 1996) states:

> *"In Atlantic Canada, an enhanced greenhouse effect could lead to shifts in ocean currents resulting in a cooler, wetter climate for Nova Scotia. Implications for forestry and agriculture could be profound. Shifting ocean currents could also cause change in fish migratory patterns."*

Whereas there has been a global warming trend of 0.3-0.6˚C, Atlantic Canada has shown a warming trend of only 0.2˚C for the period 1895-1995 and for the period 1948-1995, a cooling trend of 0.7 ˚C (Environment Canada 1997c). Indeed, computer models of ocean circulation show that a cooling effect on regions bounding the North Atlantic is a possible result of global warming (Mellor 1993). Four trends have been shown in the period 1944-1990 (Environment Canada 1997c, p.19):

1) *a decreasing trend in the number of days per year with a maximum temperature above 25˚C;*
2) *an increasing trend in the number of days per year with a minimum temperature below -1.5˚C;*
3) *an increasing trend in the number of daily precipitation events above 20mm.;*
4) *a very slightly increasing trend in the number of daily snowfall events above 15 cm.*

The Canada Country Study (Environment Canada 1997c) outlined six major areas of climate change sensitivity in the Atlantic Region: fisheries; coastal zone; ecosystems and water resources; agriculture; forestry; and socio-economic dimensions. The conclusions presented are summarized below.

Fisheries

Changes in temperature can have effects on fish growth, spawning and reproduction, distribution, abundance and migration, and catchability and availability. Changes in migration patterns and the timing of various aspects of fish life cycles may have a great impact on productivity of the fishery. Changes in the vertical temperature gradient of the water may lead to changes in the ratio of pelagic fish to ground fish.

Coastal Zone

The potential effects of climate on the Atlantic coastal zone include effects of accelerated sea level rise and effects of variable storminess. Relative sea level is now rising along most parts of the Atlantic Canada coast. Increased flood risk in some areas, coastal erosion in others, and sediment redistribution and coastal sedimentation are likely effects of the rise. Variations in storminess may increase erosion, cause storm-surge flooding, and increase wave energy. Both types of effects would have serious socio-economic impacts, since the rate of coastal property development in Atlantic Canada is on the rise.

Ecosystems and Water Resources

Changes in temperature, greater variations in temperature, and seasonal time shifts may change the normal characteristics of the water cycle, creating problems for human and ecosystem users. Impacts may include habitat loss and decreases in the quantity and quality of water available for human use. Modifications of the ice regime with temperature increases may provide increased convenience to humans but could disrupt some aquatic species that depend on the ice cover for winter survival. Changes in the evapotranspiration balance may lead to lower water tables and to the loss of wetlands. Migratory birds will be particularly susceptible to climate change, through loss of habitat with sea level rise, disruption of the timing in the bird's life cycle, and changes in migratory boundaries.

Agriculture

Atmospheric warming may have both positive and negative impacts on agriculture in the Atlantic Region. Increased temperatures may expand production of corn, soybeans, tree fruits, and specialty crops. Increased precipitation will help to offset effects of drought but may increase susceptibility to foliar-type fungal diseases, which thrive under moist conditions. At the same time, it may increase leaching of nutrients from fields, increase soil erosion, and decrease the number of days available for fieldwork. Milder winters could improve the potential of alfalfa, clover, winter wheat, strawberries, tree fruits and grapes, in some areas. For 1997 and 1998, Nova Scotia experienced unusually dry conditions which led to economic losses for farmers and resulting compensation from government.

Forestry

While increased temperatures may lead to greater forest productivity, it may also lead to greater susceptibility to disease, as well as changes in disturbances such as fire frequency, insect outbreaks, and wind-storm damage. It may also lead to changes in distribution of tree species. One scenario predicts warmer winters and springs but cooler summers for the Maritimes. This could increase the growth rates of conifers, but late frosts or early extended thaws may be more damaging to hardwood species.

Socio-Economic Dimensions

Economic predictions of climate change impacts, particularly at a regional level, are fraught with uncertainties. With that in mind, predictions have been made for economic impacts on agriculture and forestry. Damage from climate change is expected to produce a decrease of 2% to 10% of the current agricultural GDP in Atlantic Canada. Forestry yields are expected to increase between 7.5% and 15%.

While predictions have not been made for the fishery, the well-known sensitivity of the Atlantic Canada fishery to environmental factors make it likely that there will be decreases in productivity and other disruptions to the fishery. Other socio-economic dimensions include impacts on marine transportation, on offshore oil and gas development, and on energy sources and demand.

Human health impacts of climate change include those caused by temperature extremes, extreme weather events, increase in vector-borne diseases, decreased water quality and quantity, and risks from increased UV radiation from the sun. Fossil fuel use also causes an increase in air pollution and increase in acid rain. Environment Canada recently announced (CBC Radio, April 15, 1999) that in the spring and summer of 1999 there will be up to a 5% greater than usual amount of UV radiation from the sun and warned citizens to take extra precautions to prevent unnecessary exposure to the sun.

10.4. Canadian Kyoto Commitments

In spite of the uncertainties related to causes, effects, and costs of global warming, the Kyoto Protocol to the UNFCC, acting on the precautionary principle, established the target of reducing overall global emissions of GHG by at least 5% below 1990 levels in the period 2008-2012, with ratifying parties agreeing to demonstrable progress in achieving their commitments by 2005. Clearly, in assessing levels of atmospheric CO_2, the issue of sinks is as important as that of emissions, as recognized in the Kyoto Protocol. The protocol states in Article 3.3:

> *"The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments under this Article of each Party included in Annex I. The greenhouse gas emissions by sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8."*

In this regard, it is important to note that the most recent data released from CCFM (1998) indicated that Canadian forests may be net GHG emitters rather than sinks. Although thirty six countries signed the agreement on April 29, 1998, in order for the agreement to be ratified and come into force, 55 countries, representing 50% of global GHG emissions, must make commitments to emission reductions.

Canada signed the Kyoto Agreement on April 29, 1998, agreeing to a reduction of GHG emissions to 6% below 1990 levels but will not ratify the agreement until there is an implementation plan (Bangay 1998). This translates into an annual emissions goal of 532,980 kt in Canada, a decrease of 13.9% decrease from 1995 levels. If emissions continue unabated, considering predicted economic growth, it is predicted that Canada will need to reduce its emissions by 25% in 2010 in order to meet this target. In other words, the longer the problem goes unabated, the greater the reduction that will be required.

While Environment Canada has committed to spending $150 million over three years and is starting to develop a strategy for implementation, the Commissioner for the Environment and Sustainable Development in the Office of the Auditor General has filed a report saying that the government has shown no indication it can deal with the causes of climate change and pointing out that there has been little concrete action at the federal level so far (Bueckert 1998). The report predicts Ottawa will not meet its 1992 commitment to stabilize emissions at 1990 levels by 2000 because of poor planning and ineffective management. Since the Auditor General's report, the federal government has instituted the Climate Change Process, under which are established a number of tables to determine the best options for reducing greenhouse gases in a number of sectors.

On April 24, 1998, the Canadian federal, provincial and territorial ministers of energy and environment met to discuss how to implement the Kyoto agreement. In addition to approving mechanisms for stakeholder input and strategy development, the ministers agreed to establish by 1999 a "system for crediting verifiable early action to reduce greenhouse gas emissions against any future emission obligations" (Joint Meeting of Federal, Provincial and Territorial Ministers of Energy and Environment 1998). Recognizing the strength of the Voluntary Challenge and Registry Program, they agreed to publicly recognize "good performers" in reducing GHG emissions and to instigate further incentives for voluntary action.

10.5. Nova Scotia's Greenhouse Gases Emissions

The present study examines GHG emissions, not atmospheric concentrations. Although atmospheric concentrations of GHGs are not currently measured in Nova Scotia, they are not necessarily related to emissions in Nova Scotia since Nova Scotia receives emissions from the U.S. and central Canada as a result of prevailing winds. Thus, in addressing GHG reduction, Nova Scotians are being asked to take local action to respond to a global problem. Nova Scotians will not reap immediate benefits from GHG reduction, although we might reap benefits from money that is saved as a result of GHG reduction. From an economic point of view, the advantage for Nova Scotia taking action to reduce greenhouse gases is to become a model that other jurisdictions could follow.

In 1995, Nova Scotia GHG emissions were 18,600 Kt CO_2 equivalents, compared with 18,800 in 1991 (Jaques et al. 1997). This amounts to 3% of national emissions or 19 tonnes per capita, as compared to 20 tonnes per capita nationally. Thirty percent of these emissions come from mobile sources. Rail accounts for 43 Kt and heavy-duty diesel trucks account for 818 Kt. Together these two sources comprise 16 % of mobile emissions and 4.8% of total GHG emissions in Nova Scotia. Of the total GHG emissions in Canada from the transportation sector, Nova Scotia emissions account for 3.4% (National Climate Change Process 1998).

The Nova Scotia Action Plan on Climate Change outlined initiatives for GHG abatement in provincial government, energy management, transportation, coal research and development, alternative energy, forest productivity, agriculture, pollution prevention and solid waste management.

Other studies offering options for GHG emission reduction are "Policy Tools for Combating Greenhouse Gas emissions in Nova Scotia" (CEF Consultants 1994), "Energy Strategy 1991" (Government of Nova Scotia 1991) and "Private Woodlot Management in the Maritimes" [National Round Table on the Environment and the Economy (NRTEE) 1997a].

While regional and provincial responsibilities for emission reductions have not been specifically addressed in Canada, one of the principles of the Joint Ministers Meeting was that no region should have to bear an unreasonable burden for the reductions. Therefore, even though Nova Scotia is responsible for only 3% of the GHG emissions, it is likely that the province will be asked to help offset the emission reduction requirements for provinces such as Alberta and Ontario, where emissions are much higher. This could have a significant impact on economic development in Nova Scotia, which is heavily dependent on fossil fuels. On a per capita basis, federal policies could have significant negative impact, since Nova Scotians are relatively high per capita emitters of GHG.

10.6. Principles of Full Cost Accounting

A fundamental principle of full cost accounting is that economic efficiency and accurate assessments of costs and benefits is enhanced to the degree that:

- fixed costs become variable, based on usage;
- external costs are internalized; and
- non-market costs are incorporated into market prices.

Of all methods of bringing this about, the actual accounting framework used by government (as opposed to the private sector) is most amenable to moving in the direction of fuller-cost accounting.

Three sequential steps in terms of institutional change toward full-cost accounting are:

1) changing how government keeps its accounts;
2) legislative steps by government to move the market towards fuller cost accounting through incentives and penalties related to environmental and social costs; and
3) change in market prices to reflect full social and environmental costs.

10.7. The Genuine Progress Index

The Genuine Progress Index (GPI) contributes primarily to the first step above by placing economic values on social and environmental costs and benefits of societal activities. The GPI approach holds that environmental and social costs should be built into all economic development decisions so as to favour those developments that have the least environmental and social costs.

The GPI approach is being tested in this study as a method for evaluating effectiveness and impacts of GHG reduction strategies. The GPI is a comprehensive measure of progress that integrates social, environmental, and economic factors, estimates monetary values for service flows from human and natural resources according to full cost accounting methods, and assigns a monetary value to human and natural resources, in order to link their values to conventional economic accounts. The GPI treats these resources as capital stocks and develops measures for estimating the extent of their increase or decrease on an annual basis. It accounts for depreciation or reinvestment in human and natural capital just as investment-based accounting presently assesses the value of produced capital assets.

The GPI, when fully developed, will thus provide a more complete picture of society's progress on an annual basis than short-term market statistics alone are able to do. Although the full annual GPI is in the development stage and will not be completed before the year 2000, the principles of the approach used by the GPI can be applied to any projects for which a broader analysis of the social, environmental, and economic costs and benefits is required.

The Gross Domestic Product (GDP), introduced during the Second World War for the purpose of measuring total wartime production has come to be used as a standard yardstick for measuring progress. Because the GDP excludes nonmonetary production, value of leisure time, income distribution, quality of life, and natural resource conservation and degradation, and because it fails to distinguish economic activities that contribute to well-being and prosperity form those that cause harm, it is inadequate as a measure of true, genuine progress. As Robert Kennedy has remarked, the GDP counts the cost of crime, sickness, road accidents, pollution, resource depletion, and other liabilities as contributions to economic growth and progress and therefore "measures everything, in short, except that which makes life worthwhile."

Since the early 1970's, efforts have been underway internationally to expand the scope of measuring progress. In "The System of National Accounts 1993," the United Nations, World Bank, International Monetary Fund, OECD, and the Commission of the European Committee prescribe international guidelines stating that natural resources should be incorporated into government balance sheet accounts. In 1997, Statistics Canada released the Canadian System of Environmental and Resource Accounts, which will be incorporated into Canada's national balance sheets and input-output accounts (Statistics Canada 1997a). A major goal of Statistics Canada's new Environmental Protection Expenditure Accounts is to "provide those who might be interested in calculating an environmentally-adjusted GDP along these lines with the information necessary to do so" (Statistics Canada 1997).

The Nova Scotia Strategy for Sustainable Development prepared by the Provincial Round Table on Environment and Economy clearly recognized that, until environmental "externalities" are fully incorporated into the province's financial structure, pricing mechanisms, and economic accounting framework, these systems would continue to send misleading signals to policy makers and promote unsustainable behavior" (Nova Scotia Round Table on the Environment and the Economy 1992).

The Nova Scotia GPI integrates 22 social, economic and environmental components into a comprehensive measure of sustainable development for the province. To this end, the Nova Scotia GPI includes valuation of natural, human, and social capital for the following areas:

Time Use:

* Economic Value of Civic and Voluntary Work
* Economic Value of Unpaid Housework and Childcare
* Costs of Underemployment
* Value of Leisure Time

Natural Capital:

* Soils and Agriculture
* Forests
* Marine Environment/Fisheries
* Nonrenewable Subsoil Assets

Environment:

* Greenhouse Gas Emissions
* Sustainable Transportation
* Ecological Footprint Analysis
* Air Quality
* Water Quality
* Solid Waste

Socioeconomic:

* Income Distribution
* Debt, External Borrowing and Capital Movements
* Valuations of Durability
* Composite Livelihood Security Index

Social Capital:

* Health Care
* Educational Attainment
* Costs of Crime
* Human Freedom Index

Statistics Canada has designated the Nova Scotia GPI project as a pilot project for other Canadian provinces. Nova Scotia can lead the way not only by further developing a framework for valuing natural and human resource capital, but also by using these accounts as indicators of sustainability and by identifying data gaps or other barriers to monetizing the accounts. It should be noted that estimation of monetary values is not an end in itself but a necessary means to integrate environmental or social variables into the conventional economic accounts and eventually into pricing, taxation, and other financial structures. Monetary accounts in the GPI project are always based on physical accounts.

11. Scope of The Study and Project Objectives

11.1. Scope of the Project

Because GHG emissions result in long-term global consequences, rather than immediate local or regional impacts, emissions estimates are usually carried out on large national or international levels (Jaques 1997). Likewise, estimates of the cost of reducing emissions, or mitigating their effects, have mostly been carried out at this level. Since the most effective actions are likely to be those at a regional or provincial level, and since provincial governments will be required to respond to federal initiatives, cost effectiveness studies must also be conducted at the provincial level. The present study, using the GPI approach, applies some of the methods used in national studies to study cost effectiveness at the provincial level.

The pilot project chosen is a study of the costs and benefits of reducing greenhouse gas emissions in Nova Scotia through a shift in freight traffic from truck to rail. This study was chosen because it is well known that greenhouse gas emissions per tonne of rail freight are much lower than those for truck freight.

Since the present project is limited in scope and funding, it was approached as a case study. Since rail is competitive with truck only at distances greater than 800-1000 km (see Section 3), the shift in freight chosen for the study is long-haul freight. The freight qualifying for these terms in Nova Scotia is the freight between the Port of Halifax and Quebec (and points west). The segment of Nova Scotia rail and highway considered in this study is therefore the corridor between Halifax and Amherst, and the freight considered is freight being shipped a distance of at least 800 km. The route and the freight used are referred to as "HA-800." This route is the only mainline rail in the province. The highway segment comprises 24 % (428 of 1,750 2-lane equivalent km) of the total km of 100-series highways in the province and 3% of two-lane equivalent km of paved road in Nova Scotia. The highway route between Halifax and Truro is said to be the most heavily traveled highway segment east of Montreal.

Additional reasons for choosing this transportation corridor are: 1) it allows use of statistics on shipping from and to Halifax (without surveying the shippers) and 2) it is small enough to be completed within the scope of the study. The importance of short-line rail to Nova Scotia is recognized but is not analyzed in this study.

This study estimates the shift in freight from truck to rail that will produce the greatest GHG reduction at the lowest social and economic cost and develops an index which can be used to compare the relative cost of different greenhouse gas mitigation measures. This ***GHG MitigationIndex*** is the net additional cost required to effect the desired market shift of freight from truck to rail, expressed as cost per tonne of CO_2[31] emission reduction. This index expresses the net cost of CO_2 reduction, taking into account both reductions in overall costs as a result of the shift and any increases in cost (based on freight demand factors) necessary to bring about this market shift.

The time frame of the study is 1997-2010. This time frame was chosen because 1997 is the most recent year for which reliable data and statistics are available and projections of market forces and increases in freight are available to the year 2010. All costs are expressed in 1997 dollars.

11.2. Project Objectives

The overall objective is to determine the usefulness of the GPI approach for analyzing and comparing costs and benefits of various greenhouse gas reduction scenarios. Specific objectives are:

1) To develop a ***GHG Mitigation Index*** for transportation modal freight shifts that can subsequently be used to compare efficacy of mitigation measures in other sectors of the economy;[32]
2) To estimate the optimal modal mix of rail and truck freight for reducing greenhouse gas emissions in Nova Scotia at the lowest total cost;
3) To estimate additional user fees that would be required to obtain the required shift of freight from truck to rail, stated in terms of costs per tonne of CO_2 reduction; and
4) To comment on the potential impact of the modal shift on employment in Nova Scotia and to suggest policies that have been effective in achieving such a modal shift in other jurisdictions.

11.3. Data Limitations

Because Nova Scotia is a relatively small province, much of the shipping data (especially in the rail sector) is confidential and is only reported at the level of the Atlantic provinces. Therefore many assumptions and extrapolations were necessary to determine estimates of tonne-km hauled along this corridor and estimates of costs per tonne-km. One of the biggest limitations of the freight tonnage data is that they do not distinguish intermodal shipments, which are thought to be steadily increasing. Data on many of the costs that were estimated were available only on a provincial level, and therefore extrapolations were used to determine the portion of the provincial estimates that should be applied to the HA-800. In each section of the report, the data limitations are made clear and the methods of extrapolating are clearly outlined. It is hoped that this transparency will allow improved updates of these results as better data become available.

[31] "CO_2" is used throughout the document to refer to "CO_2 equivalents," defined as all greenhouse gas emissions converted to the equivalent global warming of one tonne of CO_2

[32] Since the costs and benefits of GHG mitigation in other Nova Scotian sectors have not been analyzed, the comparison cannot be made in this study. Such a comparison would require additional research.

To gain a more realistic and complete picture of the potential for GHG reduction through modal shifts, it would be necessary to conduct a detailed shippers' survey. Increasing options provided by new technologies in truck, rail, and intermodal shipments make the situation much more complicated than the truck versus rail scenario presented here. Changes in shippers' behaviour as a result of these new options can only be discerned by surveys.

Nonetheless, the present study serves as a useful scoping exercise for GHG reduction in one corridor of Nova Scotia and demonstrates the usefulness of the GPI as an approach to the challenge of analyzing strategies for reduction of GHG emissions.

11.4. Structure of the Report

Section 3 of the report includes a literature review assessing the cost of climate change generally; full cost transportation studies in Canada; and the truck and rail freight transportation industries in Canada and Nova Scotia.

Section 4 presents the methodology, data sources, and input data for the study. For each parameter estimated, data sources, extrapolations used, and data limitations are explained

Section 5 presents the results of the study. It begins with a description of 1997 freight tonnage along the HA-corridor and a discussion of the potential for transferring freight from truck to rail. Next is presented a comparison of current (1997) societal and government costs (including costs of GHG emissions) for truck and rail freight along the HA-800 corridor. From these costs and emissions, the optimal modal mix of truck and rail freight is presented. Based on this modal shift, projections of costs and greenhouse gas emissions to the year 2010 [under a "business as usual" (BAU) scenario and under the modal shift scenario] are then presented.

Section 6 summarizes several conclusions that may be drawn from the results:

- the magnitude of the potential GHG reduction for the HA-800 corridor;
- the impact of such a reduction on Nova Scotia Society;
- additional user costs necessary to effect the modal shift recommended;
- the GHG Mitigation Index for the HA-800 corridor; and
- conclusions on the usefulness of the GPI approach and its potential application to other GHG reduction scenarios.

The section ends with a discussion of successful policies used in other jurisdictions to effect modal shifts, as well as recommendations for further study.

12. Literature Review

12.1. Assessing the Costs of Climate Change

Range of Cost Estimates

Assessing the costs of climate change is a subject of great controversy, even when there is agreement on the degree of predicted change. Damage costs of emissions, called "shadow prices", are based on estimates of the cost of the wide range of potential effects of global warming (Bein, 1996) and can be as high as $1,000 per tonne of CO_2 (US 1990 $). Cline (1995) found a reasonable range for the price of environmental damage from global warming to be $20-$50 per tonne of CO_2 (US 1990$). Obviously, estimates of the damage cost depend on the baseline emissions used and the time frame examined.

The challenge of trying to assess the value of projected damage is onerous, and most investigators opt for assessing the cost of controlling emissions of greenhouse gases. Even within this approach, estimates of the cost of removing a tonne of CO_2 equivalents vary from negative costs to $200 per tonne, largely depending on the assumptions held and on compatibility between new and existing technologies. This is not surprising since proposals for reducing greenhouse gases must rely on beliefs about market behaviour and political realities, both of which are functions of that unpredictable quality, human behavior.

Repetto and Austin (1997) analyzed 16 leading simulation models that estimate the cost of controlling greenhouse gases as a percentage of the GDP (U.S.). Included were top-down models and bottom-up models. The top-down models are aggregate pictures of the whole economy, based on the sale of goods and services by producers and the flow of labour and investment funds from households to industries. They include "computable general equilibrium" models that are based on market supply and demand and on the assumption that consumers and producers allocate their resources to maximize their welfare or profits. Top-down models also include optimizing models that are based on statistical behaviour in the past. The top-down models are useful for predicting long-term effects of policy options.

"Bottom-Up" models analyze the technological options for energy savings and fuel switching by industrial sector and then aggregate them to calculate the overall cost to the economy of reducing greenhouse gas emissions. The bottom-up models tend to be more optimistic, partly because they may overlook barriers to implementation, such as management and retraining time, risk-aversion, and household preferences.

Arguments for a zero cost of reducing emissions are based on offsetting benefits of the measures. Indeed there are many examples of energy savings producing financial benefits, as cited by Lovins and Lovins (1997):

- Dupont expects to save the equivalent of 18 million tonnes of CO_2 by the year 2000 through simple measures that will also save $31 million each year.
- Energy saving projects at Dow Chemical in Louisiana produced returns on investment of 204%.
- A process innovation at Blandin Paper Company saved 37,000 tonnes of CO_2 per year and more than $1.8 million.

While these examples tend to promote optimism about the cost of reducing CO_2 emissions, other studies have shown cause for caution. A top-down study that helped establish Canada's negotiating position at the Kyoto conference (Standard and Poor's DRI study, discussed in: Holling and Somerville 1998), showed that measures to stabilize emissions at 1990 levels by 2010 would depress the GDP by about 2% for the first decade, after which it would recover to "business-as-usual" levels. Several scenarios used indicated that there would be a transition cost on the economy but that the long-term productive capacity of the economy would not be significantly affected.

Holling (1997) expresses the need for caution:

> *"Optimistic forecasts imagine a clearly logical decision maker making the most logical cost/benefit choices, with the least incentive, in the most rapid way. More pessimistic forecasts imagine confused, uncertain decision makers, caught by past investments and momentum, who will only change when sharp increases in prices provide little alternative. This is not a question of science or economics but of behaviour of individuals and organizations. How can we better understand the sources of novelty and of the processes by which individuals and organizations either smother or release novelty?"*

A useful benchmark in the discussion is the marginal cost of "backstop technology," or non-carbon substitutes, which it is estimated will be available by the second half of the 21st century at a cost of $65 (US 1990$) per tonne of CO_2 replaced (cited in Cline 1996). The IPCC (1995) has not recommended a particular value for the cost of either the damage caused by CO_2 or the mitigation costs.

Table 1 presents a range of estimates of the damage costs and reduction costs of one tonne CO_2, from a variety of representative sources. Both damage and mitigation costs will increase as the delay in implementing GHG reduction measures increases. It is beyond the scope of the present study to delve into a discussion of the many types of assumptions used about the extent of global warming and the market assumptions used to derive these values. In a situation of widely varying estimates, it is perhaps best to use a range of values for the cost or reducing GHG emissions, but also to use the precautionary principle. The impacts of climate change are only beginning to be understood, and the element of surprise that could cause effects to increase or decrease by orders of magnitude must be taken into consideration.

In the long run, reducing GHG emissions requires the development of renewable energy sources, necessitated by the depletion of non-renewable sources. In the meantime, the present study takes a moderate view by choosing values that are neither overly optimistic nor pessimistic: $10; $35; and $96.

Table 25. Estimate of Damage Costs and Costs of Mitigating One Tonne of CO_2

Type of Estimate	Amount per tonne CO_2	Amount (1997$C)
Damage Costs (Cline 1996)	$20-$50 (1990$US)	$38-$96
Damage Costs (Bein 1997)	$1,000 (1995$C)	$1,040
Control Costs (IBI 1996)	$34 (1995$C)	$35
Control Costs; Klein (1998)	$10 (1997$C)	$10
Backstop Technology (Cline 1995)	$65 (1990$C)	$124

Discounting

The second controversial area in assessing the cost of climate change is the ratio of present value to future value. Discounting is the process by which total social costs and benefits in different years are converted to a common metric 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 show the costs of changing climate over time in present day dollars. 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 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.

It can be argued that the discount rate for environmental studies should be zero, if we wish to leave behind environmental resources for future generations (Environment Canada 1997b). This is especially true when project impacts may lead to irreversible outcomes. The discount rate chosen can have an enormous impact on the outcome of 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.

12.2. Full-Cost Transportation Studies in Canada

For the purposes of this study it is understood that any recommended modal mix of rail and truck freight must be sustainable, which according to NRTEE (1997) means that it:

- allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health and with equity within and between generations;
- is affordable, operates efficiently, offers a choice of transport mode, and supports a vibrant economy; and

- limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, reuses and recycles its components, and minimizes the use of land and the production of noise.

Full cost accounting is based on the idea that the economy would benefit if each enterprise recovered all its costs from consumers (Lee 1995). The question of whether highway users pay their way, when environmental and social costs are taken into account has spawned many studies on full-cost accounting for highways, more on passenger traffic than on freight traffic.

Full cost accounting for transportation includes not only traditional costs but also costs that have been termed "external", which are a result of transportation activities and affect the welfare of the general public without any compensation or payment being made (Button 1993). Although these costs are often difficult to quantify and monetize, by ignoring them, a monetary value of zero is placed on them. This practice gives an inaccurate picture of the real costs of transportation. Some external costs related to transportation include the costs of accidents, pollution, noise, traffic congestion, land use, and the costs of transportation's contribution to global warming. Lee (1995) summarizes four categories of transportation costs: expenditures, opportunity costs of capital assets, externalities, and social overhead.

Litman (1997) studied the following internal (borne by user) and external (borne by others) costs for passenger transportation:

Internal

- Vehicle ownership
- Vehicle operating
- Travel time
- Internal accident
- Internal parking

External

- Operating subsidies
- External accident
- External parking
- Congestion
- Road facilities
- Roadway land value
- Municipal services
- Opportunity loss of equity
- Air pollution
- Noise
- Resource consumption
- Barrier effect (increased travel time and inconvenience)
- Land use impacts
- Water pollution
- Waste disposal
- Climate change

This classification of transportation costs includes both market and non-market costs.

Six studies were reviewed in detail that are related to full-costing of freight transportation in Canada:

- Royal Commisssion on Passenger Transportation 1991. "*Directions: The Final Report of the Royal Commission on National Passenger Transportation*."
- Khan, 1991. "*Energy and Environmental Factors in Freight Transportation*."
- IBI Group 1995. "*Full Cost Transportation and Cost-Based Pricing Strategies*."
- Transmode Consultants Inc. 1995. "*Ontario Freight Movement Study*."
- Transport Concepts 1993. "*External Costs of Truck and Train*."
- Bein 1997 (B.C. Ministry of Environment). "*Monetization of Environmental Impacts of Roads*."

Royal Commissison Report

The Royal Commission Report is an exhaustive, four- volume study that focused primarily on passenger transportation but did include some analysis of freight transportation. Two recommendations related to freight costs were that provincial and territorial governments institute axle weight and distance taxes for trucks and that conventional tolling systems be considered in new or expanded highways. In terms of emissions, the Commission recommended that regulations be set so as to impose similar obligations in terms of costs per unit of emission abatement on each mode.

The study examined road costing practices, taking into consideration that the principle pavement used in Canada is a flexible pavement, whereas rigid pavements are more common in the U.S., where many of the road costing studies have been done. In Atlantic Canada the poor quality sub-grades require thicker pavements than in some other provinces. Generally flexible pavement in Canada will be resurfaced twice in 40-50 years before a decision is made to reconstruct the pavement.

In order to apportion road costs among different transportation modes, it is necessary to estimate the relative costs of damage caused by the mode.

The principle mechanisms contributing to deterioration of pavements are the stresses posed by heavy axle loads and by freeze-thaw cycles. Using the concept of load equivalency, the report states that one 10,000kg truck axle (the maximum load limit in three Canadian jurisdictions) does 160,000 times as much damage to a flexible pavement as a car axle load of 500kg. The relative contribution of heavy axle loads and environmental conditions to the deterioration of pavements depends on several factors, including the harshness of the environment, the average axle loads, the volume of traffic, and the type of pavement constructed. Generally, where traffic volume is light, environmental factors are thought to be the major contributor to deterioration, and where traffic volume is heavy, axle-weight is a more important contributor. The study concludes that even on high-volume roads, environmental conditions may account for up to 50% of road deterioration.

Generally the costs of road deterioration are distributed among different modes of transportation based on their relative volumes. Small et al. (1989) state categorically that it is the weight per axle that matters in the amount of damage inflicted on roads. They report on studies that conclude a) that time and weathering merely exacerbate the damage done by traffic loadings and b) that climate has an effect independent of traffic load, especially in moist freezing climates. According to discussions with engineers in the Nova Scotia Department of Transportation, almost all the damage done to asphalt pavements is from heavy trucks.

Ontario Freight Movement Study

Transmode Consultants (1995) examined three options for improving energy efficiency and emissions of truck and rail freight in Ontario. The options included technology improvements; changes in operating prices; and modal shifts. The study used a life-cycle costing method for GHG emissions, which adjusted emission totals to account for emissions created during the extraction, refinement and distribution of the fuels. Previously reported fuel efficiency estimates in the literature varied by a factor of 12. The Transmode Study calculated energy efficiency of inter-city diesel trucks at 61.4 tonne-km per litre. A shift of one-third of truck shipments to intermodal caused a decrease in emissions of 19% between 2000 and 2010. The study found that combinations of all options analyzed could not offset the impact of increased growth in freight transportation. With more moderate growth in freight, a combination of all options examined would allow Ontario to meet its emission reduction targets.

Full Cost Transportation and Cost-Based Pricing Strategies

The study by IBI (1995) examined the extent to which users of each transportation mode in Canada and Ontario bear the full cost of each mode and assessed the implications of pricing and related initiatives to encourage use of more sustainable modes in Ontario. User charges were defined as the sum of fares and tariffs paid by users to transportation carriers and the full capital and operating costs borne by the users (such as car and fuel costs). While the study focused on passenger transportation, some aspects of freight transportation were included. IBI considered three categories of costs for inter-city freight in Canada: user fees, government subsidies, and external costs (which include accidents and airborne emissions (including carbon dioxide). Government subsidies are defined as government transportation expenditures (such as infrastructure costs) minus government revenues. For government expenditures plus external costs, IBI calculated a cost of 2.88 cents per tonne-km. for intercity truck freight and a cost of 0.424 cents per tonne-km. for intercity rail freight.

Strategies for GHG reduction examined involved increased user charges, reducing basic subsidies, and reducing external costs. Long term (1994-2015) strategies relevant to freight transportation included fuel/tailpipe emissions premiums, a weight-distance tax, and promotion of intermodal freight transportation. With the long-term strategies, taking ionto consideration projected growth in freight transportation, a decrease of 26% CO_2 , compared with projected base case scenario, could be accomplished by 2015. In comparison to 1994 levels, however, this represents a 26% *increase* in CO_2 emissions. As in the Transmode study, it was concluded that while various strategies can reduce overall emissions, no strategy or combination of strategies was able to offset the effect of growth in vehicle-km in the longer term (1994-2015).

Energy and Environmental Factors in Freight Transportation

Khan (1991) developed energy efficiency estimates for different modes of freight transportation and examined impacts of modal shifts and changes in weights and dimensions regulations. Over the Montreal-Toronto route, a comparison of intermodal options with all-highway options showed that the intermodal is more than twice as efficient as truck transport alone. The study examined energy and emissions implications for 1) BAU (1988); 2) inclusion of weight and dimension regulations (that were not in place at the time); 3) a 10% reduction in the cost of rail freight; and 4) a combination of #2 and #3. Three markets were examined: Ontario-Quebec; Ontario-B.C.; and Ontario-Manitoba. The study also examined the effect of emissions controls expected to be in effect in 1995. The weight and dimension regulations were expected to lower trucking costs and thereby cause some shift of freight from rail to truck. The magnitude of the modal shift would depend on the commodity and the length of haul. In terms of modal share, it was found that the combination of #2 and #3 would restore the original balance of rail and truck freight, after the predicted decrease in truck rates. This scenario would decrease total freight costs by 27-30% and would decrease CO_2 emissions by 28%, as compared with the 1988 base case (BAU).

External Costs of Truck and Train

The Transport Concepts (1993) study examined the following external costs of truck and rail freight: accidents; pollution; congestion; infrastructure; cash subsidy; fuel taxes and license fees; and property taxes on rail corridors. Internal costs included vehicle costs, own accident risk, and accident costs covered by insurance. Overall average external costs of inter-city trucking were estimated at $.0215 per tonne-km. and for rail freight, $0.0051 per tonne-km. Road infrastructure costs due to big trucks was estimated at $0.0069 per tonne-km.for tractor-trailers and $0.0052 per tonne-km.for double trailers. The study concluded that a shift of 10% of truck freight to rail in Canada would save $230 million annually; a 20% shift would save $459 million; and a 30% shift would save $689 million. A U.S. study cited apportioned 41% of highway infrastructure costs to heavy trucks. The authors recommend increasing user fees and subsidizing rail infrastructure to help effect such a shift.

Monetization of Environmental Impacts of Roads

The B.C. Monetization Study (Bein 1997) sought to establish appropriate and defensible per unit costs for different environmental impacts of transportation and to identify the values that cannot be monetized. The study examined costing of greenhouse gases; air pollutants; noise and vibrations; land use impacts; resources and energy (does not include opportunity cost of non-renewable fossil fuel); waste disposal; water pollution; barrier effects (increased travel time, etc.); and impacts on biodiversity. These costs are expressed as dollars per kilometre driven, per person affected, per hectare of land, or per tonne of greenhouse gases and pollutants.

The author points out that, since average alternative use of resources in other industrial or public projects is rarely known, transportation project costs are usually assessed in terms of comparison to a “do nothing” or “business as usual” scenario. Criticism of a market-based approach to transportation costing is that it fails to take into account the uncertainty of ecosystem functioning; the irreversibility of some natural resource degradation or loss; and the critical nature of some natural components for which man-made capital cannot be substituted. The author argues for a damage cost approach to environmental impacts of transportation, stating that control cost estimates are usually inappropriate for determining total environmental impact costs.

Newer methods of discounting to account for intergenerational equity are discussed. Emissions calculations are based on those presented by Khan (1991) and Transport Concepts (1991). Shadow pricing for one tonne of CO_2 shows that the shadow price is heavily dependent on discounting rate and on value judgments, such as the monetary value of a human life. Using a precautionary approach and a worst-case scenario, the cost of damage incurred from one tonne of CO_2 is set at $1,000 (C$ 1989). Overall, this study points out the inadequacies of previous methods to account for total environmental impact of transportation.

12.3. Rail and Truck Freight Industries in Canada and Nova Scotia

Over the past 20 years, the Canadian transportation system has undergone massive changes, including [Atlantic Provinces Transportation Commission (APTC) 1996a]:

- Privatization of CN Rail;
- Sale of branch lines to independent operators;
- Abandonment of rail lines;
- Increase in intermodal systems;
- Double-stacking on rail cars; and
- Trucking industry becoming a strong competitor for long-haul movements.
- Trucking industry now handling majority of freight in Atlantic Canada.

Free trade, deregulation, loss of freight subsidies, and technological innovations have all contributed to these changes.

Canadian Trucking Industry

The Canadian trucking industry consists of three types of carriers:

- *For-Hire Carriers*: firms that maintain their own fleets; account for about 50% of all commercial truck freight movements in Canada ;
- *Private Carriers*: firms that maintain their own fleets; and
- *Owner Operators*: can work for private or for-hire carriers.

Most private trucking is local. Companies with private fleets are usually retail distributors of consumer goods, chemical products producers, pulp and paper companies, beverage distributors, and wholesale distributors of agricultural products (Industry Canada 1998). Beyond distances of 500 km, for-hire trucking captures 90% of the market share of shipping. Some private fleets, however, are extending their range of operations and have substantial intercity operations.

The trucking industry in Ontario, Quebec, and the Atlantic Provinces is more dependent on inter-regional trade and transborder trade with the U.S. than on domestic trade with western Canada (APTC 1996a).

Atlantic Canada Rail Industry

Only the Halifax-Montreal corridor remains as a long-haul line in Atlantic Canada. When system costs are included in financial accounting, the Atlantic Region is viewed as CN's weakest region, with the lowest priority in terms of investment and improvements (APTC 1996b). CN's official position is that it intends to continue at least the core line between Montreal and Halifax. On May 7, it was announced that the Port of Halifax would not be the site of the new post – Panamax terminal. Although one newspaper account stated that CN may close the Halifax-Montreal line if the Port of Halifax does not win the bid for the terminal (Chronicle Herald, March 3, 1999), after the post-Panamax terminal announcement, CN reaffirmed its commitment to the Port of Halifax and its ability to attract new container traffic destined for the U.S. midwest (Hayes 1999). CN stated that it has made investments in its Halifax intermodal terminal, the St-Clair tunnel linking Sarnia, Ontario and Port Huron, Michigan, and Gateway Intermodal Terminal at Chicago to help position the Port of Halifax as a point of entry to the midwest.

In contrast to the CN line, short-lines have been very successful. The Cape Breton and Central Nova Scotia Railway Ltd. (CB&CNS) increased traffic by 20% in its first year of operation and the Windsor-Hantsport Railway showed a 60-70% increase in traffic over the amount handled by the former CN line in this area (APTC 1996b). Local operators are able to keep costs down and to be more flexible in responding to shippers' needs.

The APTC (1996b) has recommended formation of a regional railway for Atlantic Canada, which would consist of the Halifax-Montreal line combined with the short-line feeders. Such a system should be able to have lower base costs and more efficient operations than the current system.

12.4. Competition Between Truck and Rail

Rail is the dominant mode for transporting crude materials over all distances. Under 1500 km, truck dominates in the carriage of food, feed, beverages, and tobacco (Khan 1991). Truck has advantages over rail in delivering perishable items and for time-sensitive deliveries. The two commodity groups which offer the most opportunity for rail to gain an increased share of the freight are fabricated materials and end products.

The top three factors emphasized by shippers in carrier choice are (Industry Canada 1998):

1) price;
2) service frequency; and
3) carrier response to customer needs.

A 1996 survey of North American shippers by KPMG (Bowland 1997) revealed the following factors as important in choice of modal and carrier choice:

- reliable delivery (99% of shippers);
- freight rates (98%);
- total transit time (90%); and
- door-to-door service (84%).

Competition has forced for-hire trucking to add services such as (Industry Canada 1998):

- contract logistics;
- air and marine freight forwarding;
- customs brokerage;
- intermodal rail services;
- warehousing and distribution;
- documentation;
- insurance;
- expedited and zero inventory distribution systems; and
- just-in-time inventory deliveries.

Freight Demand Factors

Changes in rail freight tonnage brought about by changes in the cost of truck freight are estimated by using cross elasticities and freight demand factors. These factors estimate the degree to which freight tonnage of one mode is dependent on prices of a second mode. They predict the percent impact on rail freight tonnage of a given percent increase or decrease in trucking price. Recent trends in this field of study have produced models that measure impact in both the short-term and the long-term (Yevdokimov and Prentice 1999). While the study of freight demand models is beyond the scope of the present study, a rough estimate shows that rail freight is likely to increase by 0.5 for every 1% increase in trucking costs (Cambridge Systematics Inc. 1995). This is the factor that is used in the present study to estimate increases in trucking rates necessary to produce a modal shift of freight from truck to rail.

12.5. Freight Transportation Studies in Nova Scotia

Three studies that included freight transportation in Nova Scotia were reviewed. Two of these (ADI 1989 and Peat Marwick et al. 1989) included surveys of shippers in order to fill in data gaps. Although these studies provide a useful background, they were conducted before the privatization of CN Rail and before the opening of the CN Intermodal Terminal in Halifax. The ADI study is based on data from 1984 and 1986, while the Peat Marwick study includes 1987 data. Because of the small size of the transportation industry in Nova Scotia, much of the data collected by Statistics Canada is confidential, and therefore surveys are the only way of obtaining an accurate picture of the sector. A recent study (Gardner Pinfold 1997) has provided provincial analysis of some Statistics Canada data.

In general, the trucking industry showed rapid increases in freight between 1984 and 1986 (79% increase), primarily due to the growth in the service sector, whereas the freight volume for rail showed only a 19% increase (ADI 1989). In 1989, trucking accounted for virtually all the freight moved within the province, except for crude products. Trucking predominates in the movement of food products and end products, whereas rail dominates shipment of crude materials. Since rail tends to move the lower revenue bulk commodities, such as gypsum, rail accounts for a higher percentage of the tonnage but a lower percentage of the revenues for freight transportation within, to and from Nova Scotia (ADI 1989). Industries with the greatest dependence on rail are shipping lines, automotive product companies, and building supply firms. In 1989, private trucking accounted for approximately 45% of freight moved within Nova Scotia and 20% of that moved to and from the province.

Gardner Pinfold (1997) provides the following information:

- The Port of Halifax was said to operating at 68% of its capacity.
- Approximately two thirds of the 1995 container traffic was associated with mainline rail transfer.
- The CN mainline is operating at about 30% capacity, offering opportunities for growth for the Port of Halifax.
- In 1996, rail in Nova Scotia handled 15 million tonnes of cargo, while truck handled 8.5 million tonnes.
- Overall cargo demand (marine, air, rail and truck) is expected to increase 37% from 56 million tonnes in 1998 to 77 million tonnes in 2007.
- Of the projected increase in cargo, rail cargo is expected to increase from 16.8 million tonnes in 1998 to 23 million tonnes by 2007; truck cargo is predicted to increase from 9.5 million tonnes in 1998 to 13.2 million tonnes in 2007.

The study also provides a breakdown of freight at the Port of Halifax. In 1996, total cargo handled was 13 million tonnes, of which 3.2 million (25%) was containerized; 0.4 million tonnes (3%) was general; and 9.3 million tonnes (72%) was bulk. Of the bulk cargoes, 3.6 Mt was crude oil; 3.3 Mt gypsum; 2.0 Mt refined oil; and 0.4 Mt grain and other commodities.

Although it has now been announced that the Port of Halifax will not be the site of a new post-Panamax Terminal, port authorities have stated that container traffic at the port is up 70% in the first quarter of 1999 (Hayes 1999). Personal Communication (Jill Vandersand, Halifax Ports Corporation) indicated the increase was 17%, not 70%.

13. Methodology and Data Sources

13.1. General Approach

This section describes methods of deriving estimates in cents per tonne-km. for 1997 rail and truck freight on HA-800 for the following parameters:

Government Revenue and Expenditures
- Government Revenue
  - Property Tax
  - Fuel Tax
  - Registration Fees
  - License Fees
  - Toll Fees
- Government Expenditures
  - Infrastructure Costs (capital and maintenance)
  - Policing Costs
  - Administrative Costs

Additional Environmental and Social Costs
- Air Pollution and Climate Change
- Accident Costs
- Cost of Fossil Fuel Depletion

In addition, estimates were made of the contribution rail and truck freight make to employment in Nova Scotia. With the exception of employment, all estimates were entered into a simple model to determine the overall cost and the overall emissions of greenhouse gases for different modal mixes. Employment income was also a consideration in choosing the desired modal mix of rail and truck freight. Clearly there are other external costs which could be taken into account but are not included here because of the limited scope of the project.

After the most satisfactory modal mix was determined, a freight demand factor was applied to determine the additional cost necessary to produce the desired shift in freight. This cost was then translated into dollars per tonne of reduction of CO_2, which is called the "GHG Mitigation Index."

For a province the size of Nova Scotia, many types of data required for this type of study are not routinely collected, and much of the data collected is confidential. The only way to increase accuracy of such a study is to collect new data through a survey of shippers. Within this limitation, the study used available data and pro-rated them where necessary. The data sources and use of data have been made completely transparent, so that readers can judge for themselves the reliability of the data.

Every effort was made to obtain specific data for Nova Scotia or for the Halifax-Amherst Route. When this was not possible, efforts were made to determine reasonable percentages or ratios to allow derivation of the parameters for the HA-800 Route. Table 2 summarizes the basis on which various costs and types of income were allocated to HA-800 freight.

Table 26. Basis of Apportioning For-Hire Trucking Costs and Income to HA-800

Cost	Statistical Base	Percent Used	Derivation of Percent
Maintenance Costs	Hfx-Amh. Route	47%	HA-800 tonnes/Hfx-Amh. tonnes
Capital Costs	Hfx-Amh. Route	47%	HA-800 tonnes/Hfx-Amh. tonnes
Toll Fees	Hfx-Amh. Route	47%	HA-800 tonnes/Hfx-Amh. tonnes
Heavy Truck Registration	NS	23%	HA-800 tonnes/total tonnes in NS
Class I license fees	NS	23%	HA-800 tonnes/total tonnes in NS
Policing Costs	NS	23%	HA-800 tonnes/total tonnes in NS
Accident Costs	Heavy trucks NS	23%	HA-800 tonnes/total tonnes in NS
Administrative costs	NS	23%	HA-800 tonnes/total tonnes in NS

Note: Hfx-Amh. Route = Halifax to Amherst Route

Only for capital and maintenance costs, and for toll fees, were statistics available for the Halifax-Amherst 102-104 route. For these statistics, costs were allocated by the ratio HA-800 freight tonnage: Halifax-Amherst tonnage, which is 47% (detailed below). Other statistics were available only on a provincial level and were allocated to HA-800 by the ratio HA-800 tonnage: total Nova Scotia tonnage, or 23%. All ratios are based on for-hire trucking only, since these are the only data available. Truck registration income is based on weight and distance, so the tonnage ratio is quite appropriate. While it is not as applicable to income from Class I license fees, it is probably more appropriate than a ratio based on kilometres. Because tonnage reflects the intensity of traffic, it is considered an appropriate means of apportioning policing, accident, and administrative costs. Again, these statistics are available only on a provincial basis, so they are allocated to HA-800 at 23%.

In the remainder of this section of the report, methods and input data are described in detail.

13.2. Data Sources, Assumptions, and Estimations

Estimation of Total HA-800 Freight by Truck and Rail

Freight chosen for analysis in this study is all freight that is carried along the corridor between Halifax and Amherst and that is potentially competitive between truck and rail. It is assumed that any long-haul freight with southern or western destinations or origins will travel along this corridor. Although distance is not the only factor determining whether rail and truck are competitive, it is the factor that allows us to choose *potentially* competitive freight. In terms of the minimum length of haul that is considered competitive, Khan (1991) states that freight travelling more than 1500 km is potentially competitive, while Industry Canada (1998) states that for distances greater than 500 km, 90% of the freight is hauled by rail. For the purposes of this study, it seemed safe to assume that freight hauled for distances of at least 800 km is potentially competitive between truck and rail. The freight analyzed, then, is all Nova Scotia interprovincial freight travelling distances of 800 km or more in a southerly or westerly direction. This segment of freight, and the corridor is referred to as HA-800. Tonnage was translated into tonne-km by multiplying tonnes X total km on the route.

1.1.1.2 Rail Freight

Rail freight data for 1997 for the Atlantic Region were obtained from Statistics Canada, and the percent of freight entering and leaving Nova Scotia was estimated by applying a ratio of Nova Scotia: New Brunswick freight published by Statistics Canada from 1989-1991. HA-800 rail freight may be overestimated since data on distance hauled were not available and it was assumed that all tonnage was hauled 800 km or more.

Table 3 shows estimated rail freight for HA-800 in 1997, and Table 4 presents relative tonnage of major commodities. A total of 3,153,581 tonnes is hauled along this corridor, representing 37% of rail freight in Atlantic Canada in 1997. Tonne-km are calculated on the basis of a total track length of 267 km, which includes spurs, but does not include switching and yard track. The greatest percentage of freight (mixed carload; freight forwarded; other) is essentially unclassified. The largest imports, after the unclassified, are petroleum products and paper and forestry products. Unclassified freight comprises a smaller portion of exports, and paper and forestry products are the major export.

Table 27. Estimated 1997 Tonnes and Tonne-km of Rail Freight for HA-800

To/From Atlantic Region	To/From Atlantic Region	Percentage To/From Nova Scotia	Tonnes To/From Nova Scotia	HA-800 Tonne-km To/From Nova Scotia @ 267km Total Route
Import	4,211,164	42.3%	1,781,323	475,613,241
Export	4,328,891	31.7%	1,372,258	366,392,886
Total	8,540,055		3,153,581	842,006,127

Source: Statistics Canada 1999.

Table 28. Relative Tonnage of Commodities Shipped by Rail on HA-800

Commodity Group	Imports		Exports	
	Tonnes	% of Total	Tonnes	% of Total
Mixed carload; freight forward; other	980,846	53.9%	636,004	46.4%
Petroleum products	142,641	8%	17,850	1.3%
Paper and forestry products	162,396	9%	516,267	37.6%
Clay, cement, sand	108,880	6%	29,570	2.2%
Feeds, grains, and non-perishable food preparations	116,334	6.5%	7,605	0.55%
Automobiles, engines, parts	81,103	4.6%	17,733	1.3%
Chemicals	117,762	6.6 %	28,168	2%
Ore, plastics and metal building materials	69,604	3.9%	90,940	6.6%
Total percent of tonnage		98.5%		98%

Source: Statistics Canada 1999.

1.1.1.3 Truck Freight

Truck freight data were obtained from Statistics Canada, Transportation Division (Statistics Canada 1999) from the 1997 For-Hire Trucking Survey (Table 5). This is a quarterly survey of non-local shipments by for-hire trucking companies having annual inter-city revenues of $1 million or more. It is unknown what percentage of total truck freight is represented by the For-Hire Trucking Survey, but approximately 90% of long-haul truck freight is thought to be included. The limitations of the data were presented in Section 2. Table 5 presents HA-800 tonnage and tonne-km.

Table 29. Estimated Freight Tonnage by For-Hire Trucking in Nova Scotia, 1997

Import/ Export	Total for NS (tonnes)	Total Halifax-Amherst (tonnes)	Total for HA-800 (tonnes)	HA-800 % of Total for NS	HA-800 Tonne-km @ 214 km for route
Import	2,264,705		1,173,579	51.8%	251,145,906
Export	2,209,334		747,754	33.8%	1 60,019,356
Total	4,474,039	4,075,970	1,921,333	42.9%	411,165,262

Source: Statistics Canada 1999

The total tonnes of import/export freight travelling in a western or southern route (and presumed to travel along Hwy 102-104) was 4,075,970. This represents 91% of the for-hire import and export freight traffic. Of this total, freight hauled 800 km or more was 1,921,333 tonnes. This HA-800 freight represents roughly 42.9% of the total for-hire trucking imports and exports in Nova Scotia and 47% of estimated total of all for-hire Halifax-Amherst traffic. The HA-800 freight represents 23% of the total Nova Scotia for-hire trucking freight, including intra-provincial freight.

Relative tonnage of major commodities is shown in Table 6. For imports, the three largest commodity groups are unclassified freight, non-perishable food products, and fabricated materials. For exports, the three largest groups are non-metallic minerals and products, rubber tires and tubes, and fabricated materials.

Table 7 presents major destinations for HA-800 export freight. Seventy-five percent goes to Canada and the Northeast U.S, and 20 percent goes to other U.S. regions.

Table 30. HA-800

Commodity Group	Imports		Exports	
	Tonnes	% of total	Tonnes	% of Total
General or Unclassified Freight	193,117	16.5%	82,133	12.3%
Rubber Tires and Tubes			109,505	16.5%
Non-metallic minerals/products	49,445	4.2%	124,097	18.6%
Pulp, paper, crude wood materials			77,132	11.6%
Non-perishable food products	312,074	26.6%	67,012	10 %
Perishable Foods/food products	39,456	3.4 %	74,678	11%
Fabricated Materials	182,180	15.5%	103,166	15.5%
Crude materials, waste and scrap	24,771	2%		
Metals and metal fabricated products	146,611	12.5%		
Chemicals and related products	34,393	2.9%		
Machinery and Equipment	29,942	2.6%		
Vehicles and parts	22,713	1.9%		
Equipment	25,722	2.2%		
Medical supplies	16,887	1.4%		
Total percent of tonnage		92%		95.5%

Source: Statistics Canada 1999.

Table 31. Major Destinations: For-Hire Trucking HA-800 Exports

Region	Tonnes	Destinations Receiving Largest Amounts
Canada	403,683	Quebec (52%); Ontario (45%)
Northeast US	161,154	MA (37%); NY (31%); ME (15%)
West US	68,681	South Dakota 93%
South US	59,272	TN (67%); TX (11%); Georgia (6%)

Midwest US	19,359	82% to Michigan, Indiana, Wisconsin

Statistics Canada 1999.

Provincial Government Revenues

1.1.1.4 Rail

Since privatization of CN Railways, the only government revenues from CN Rail operations are from locomotive fuel tax, property tax and “Other Sales & Excise Tax.” Grants in lieu of property taxes are paid to municipalities on commercial buildings and rail yards. The right-of-ways are not taxed. Roger Cameron (Railway Association of Canada, pers. comm.) estimates the total property taxes paid by CN in Nova Scotia in 1997 to be in the range of one million do1lars, which translates into 0.118 cents per tonne-km.

“Other sales and excise taxes” (listed in Railway Association of Canada 1998) are not included in this study’s total government revenues, either for truck or for rail. Locomotive fuel taxes paid by CN for operations along HA-800 are estimated from fuel taxes reported in Railway Trends (Railway Association of Canada 1998) and from statistics on diesel fuel usage in Nova Scotia from Rail in Canada 1996 (Statistics Canada 1997). Rail in Canada 1996 reports that 65% of diesel fuel used in Nova Scotia was used by CN Rail. Total diesel tax reported in Nova Scotia in 1997 was $494,000. Diesel tax paid for HA-800 freight was therefore estimated at 65% of this total, or $321,110. With 842, 006,127 tonne-km., this amounts to a fuel tax rate of .038 cents per tonne-km. Property tax and diesel fuel tax paid result in a total government revenue rate of 0.157 cents per tonne-km.

1.1.1.5 Truck

Vehicle registrations for interprovincial trucking are regulated by the Canadian Agreement on Vehicle Registration under the Motor Vehicle Act. This agreement allow provinces to prorate vehicle registration based on kilometres and tonnage transported by province. The total collected for vehicle registrations in Nova Scotia for all heavy commercial trucks (>5001 kg) travelling interprovincially in 1997 was $2.3 million for 3,506 vehicles (pers. comm., Nancy Craig-Noddin, N.S. Department of Business and Consumer Affairs).

Since it is not possible to obtain this figure for trucks travelling only the Halifax-Amherst Route, this figure is pro-rated according to the estimated proportion of tonnes of freight transported along the Halifax-Amherst route to the total estimated tonnes of freight in all of Nova Scotia. Total freight transported by for-hire trucking in Nova Scotia in 1997 (Statistics Canada 1997) is estimated at 8,332,452 tonnes, and total freight on the HA-800 is 1,921,333 tonnes. As shown in Table 8, the percentage of Nova Scotia freight that is HA-800 is therefore 23%, and the vehicle registration fees for HA-800 are estimated at $529,000.

In June 1997, a total of 15,893 Class I drivers were registered in Nova Scotia. The fee for this class of license is $69 for a five year-period, or $13.80 per year. Based on this number of drivers registered, total income from Class I licenses is estimated at $219,323. Based on the above proportion of freight, the proportion of this fee relevant to the Halifax-Amherst Route is $50,444, as shown in Table 8.

Table 32. Government Revenue from HA-800 Trucks: Registration and License Fees

	All of Nova Scotia: For-hire trucking	HA-800: For-hire Trucking	HA-800 percent of total	HA-800 Cents per tonne-km
Total Freight (tonnes)	8,332,452	1,921,333	23%	
Vehicle Registrations	$2,300,000	$529,000	23%	0.12
Class I Licenses	$219,323	$50,444	23%	0.01

Diesel fuel taxes paid by commercial trucks along this route are based on the 1996-97 Nova Scotia rate of $.154 per liter. The number of liters consumed is based on rates of diesel fuel usage of 52.02 tonne-km per litre (Khan 1991). In the absence of data, it was assumed that 50% of this diesel fuel is purchased in Nova Scotia. On this basis, the estimated amount paid for diesel fuel tax on HA-800 in 1997 is $607,867, or 0.148 cents per tonne-km (Table 9).

Table 33. Government Revenues from HA-800 Trucks: Diesel Fuel Tax

Diesel Fuel Usage Rate (Khan 1991) = 0.0192 litres per tonne-km	
Total Diesel Fuel Usage for HA-800: 411,165,262 tonne-km.	7,894,373 litres
Estimated Diesel Fuel Purchased in N.S. (50%)	3,947,187
Estimated Diesel Fuel Tax for HA-800 @0.154 per litre	$607,867
Estimated Diesel Fuel Tax for HA-800: cents per tonne-km	0.1478

Toll fees paid by trucks on the Halifax-Amherst Route are estimated at $6,000,000 per year, based on 600,000 truck trips per year and a charge of $2 per axle, or, on average, $10 per truck. The number of truck trips reported amounts to an average of 32 trucks per hour, which would indicate a heavy burden of truck traffic on this highway. The average truck is a five-axle truck, and 2% of the fleet are B-trains with eight axles (Highway 104 Western Alignment Corp., pers. comm.). Toll charges were apportioned for HA-800 at 47% of the total (percent of western imports/ exports that travel over 800 km). This produces an estimate of $2,820,000 for 1997, or 0.686 per tonne-km. This estimate is high, since it does not consider the trucks travelling within the province that pay toll fees. A summary of provincial government revenues for HA-800 truck and rail freight is presented in Table 10. For trucks, toll fees represent 71% of total government income.

Table 34. 1997 Estimated Provincial Government Revenue for HA-800 Truck and Rail Freight (cents per tonne-km)

Type of Revenue	Rail	Truck
Property Tax	0.118	
Diesel Fuel Tax	0.038	0.1478
License Fees		0.01
Registration Fees		0.12
Toll Fees		0.686
TOTAL	**0.157**	**0.974**

Provincial Government Costs

1.1.1.6 Rail

Because of privatization of rail, provincial governments bear no costs for operations or maintenance of Right-of-Ways. Although in 1997 there were federal grants of $169,400 to improve safety at two Nova Scotia crossings (Railway Association of Canada 1998b), these expenditures were not routine and were not made by the provincial government.

1.1.1.7 Truck

1.1.1.7.1 Infrastructure

Capital costs for the relevant highways for 1974-1976 were obtained from Mr. Kent Speiran, N.S. Department of Transportation and Public Works. While the length of time before re-paving of Nova Scotia 100-series highways is estimated at 12 years, the lifetime of a highway (time before reconstruction) is estimated at 20-25 years. The capital costs must also include the cost of borrowing on the capital (Litman 1997). The primary reason for including borrowing costs (Lee 1995) is that there is an opportunity cost to capital sunk into highway investments, which could be earning interest. The Nova Scotia Government, however, expenses its capital expenditures and therefore does not show the exact rate of borrowing on the capital expenditures. In order to estimate the cost of borrowing, it was assumed that the government does borrow on highway capital expenditures for a 20-year term. Mr. Roy Spence (NS Department of Finance) recommended that since the Nova Scotia borrowing rates are very complicated, it would be more feasible to use Government of Canada long-term borrowing rates. These rates were available from 1976 to present. Total capital costs per year and estimates of the cost of borrowing are shown in Table 32 in the Appendix. The average annual payment of capital expenses for the Halifax-Amherst route is $9,259,023.

Maintenance costs average $6,900 per 2-lane km for 100-series highways (pers. comm., Kent Spearin, N.S. Dept. of Transportation and Public Works), or a total of $2,953,200.

As mentioned in Section 3, the procedure for apportioning infrastructure costs to vehicle type is a subject of controversy. This study apportions 41.1% of these costs to heavy trucks (from U.S.

study, cited in Transport Concepts 1993). Table 11 summarizes estimated annual provincial government costs for infrastructure for HA-800.

1.1.1.7.2

1.1.1.7.3

1.1.1.7.4 Policing Costs

Policing costs for HA-800 were calculated using a percentage of total provincial policing costs for 1997. The total policing bill was $143,300,000 (Statistics Canada 1999a and b). Based on Transport 2001 (Litman 1997) estimates, 10% of this figure is apportioned to traffic costs. The result is further apportioned to HA-800 by multiplying by 23%, which is the ratio of HA-800 tonnage to total Nova Scotia tonnage. Table 12 shows the results: a value of 0.8 cents per tonne-km for HA-800.

Table 35. Annual Average Provincial Costs for Infrastructure on HA-800

MAINTENANCE COSTS:	
Total 2-lane km on HA-800	428
Tonne-km Hauled on HA-800 in 1997	411,165,262
Average Maintenance Cost per 2-lane Km of 100-series Highway	$6,900
Total Maintenance Cost for Halifax- Amherst Series 100 Hwy	$2,953,200
Maintenance Costs Attributable to Trucks (@ 41.1%)	$1,213,765
Highway Maintenance Costs Attributable to HA-800 Trucks (@ 47%)	$570,469
Maintenance Costs for HA-800 Trucks: cents per tonne-km.	0.139
CAPITAL COSTS:	
Average Annual Payments on Capital Expenditures for Halifax-Amherst 100-Series Hwy	$9,259,023
Payments on Capital Exp. Attributable to Truck (@ 41.1%)	$3,805,458
Payments on Capital Expenditures Attributable to HA-800 Trucks (@ 47%)	$1,788,565
Annual Payments on Capital Expenditures for HA-800 Trucks: cents per tonne-km.	0.435

Table 36. Estimates of Annual Policing Costs for HA-800

Total cost of policing for Nova Scotia, 1997	$143,300,000
Amount apportioned to Traffic costs (10%)	$14,330,000
13.3. Amount apportioned to HA-800, based on 23%	$3,295,900
Total annual cost of policing on HA-800 (cents per tonne-km)	0.802

1.1.1.7.5 Administrative Costs

Because in Nova Scotia transportation and public works are combined into one department, it is difficult to accurately determine total administrative costs for transportation. A rough estimate has been made, however, based on Main Estimates for the Fiscal Year 1998-99, which included actual year-end figures for 1996-97 (Government of Nova Scotia 1998). Table 13 shows the totals and the estimates for HA-800. Administrative expenses which likely were included in the above infrastructure expenses were omitted. Expenses of the Department of Transportation and Public Works related to highways are listed in Table 13 (pers. commun. Kevin Malloy, NS Dept. of Transportation and Public Works). Allocating on the basis of 23% of total costs, the cost for HA-800 is 3.54 cents per tonne-km.

Table 37. Estimated Annual Administrative Expenses for HA-800

Government Administrative Costs 1996-97 (from Provincial Estimates)		
Category	TOTAL	HA-800 share @ 23%
Senior Management	$1,046,000	$240,580
Corporate Services Unit	$7,648,000	$1,759,040
Policy and Planning	$914,000	$210,220
Field Administration	$20,779,000	$4,779,170
Contract Employee Benefits	$7,341,000	$1,688,430
Specialized Support Services	$4,130,000	$949,900
Capital Development & Engineering	$4,990,000	$1,147,700
Registry of Motor Vehicles	$16,492,000	$3,793,160
TOTAL	$63,340,000	$14,568,200
HA-800 cents per tonne-km		3.54

Air Pollution Costs and Climate Change Costs

The major air pollutants from the burning of diesel fuel are carbon dioxide (CO_2); nitrogen oxides (NOx); volatile organic compounds (VOC); sulphur dioxide (SO_2); carbon dioxide (CO_2), and particulate matter (PM). The environmental impacts of carbon dioxide are discussed in "Costs of Climate Change." Nitrogen oxides are a health problem, primarily in urban areas, where they contribute to smog and cause respiratory irritation and increased susceptibility to respiratory infections. VOCs react with NOx to produce ground-level ozone, a major constituent of smog. Some VOCs, such as benzene, are carcinogenic. SO_2 emissions cause respiratory irritation, reduced visibility, reduced agricultural production, and acid rain. CO converts to ground-level ozone and also converts to methane, a very strong greenhouse gas. Exposure to high concentrations can cause impaired perception and thinking, slow reflexes, drowsiness, and unconsciousness. Particulate matter of a size range of less than 10 millimicrons (PM_{10}) can penetrate human, animal, and plant tissue.

Previous estimates of emissions per tonne-km of these pollutants for rail and truck are shown in Table 14. These figures are based on a 1995 study of freight emissions in Ontario (Transmode Concepts 1995), which included the following steps:

1) baseline goods movement by vehicle type were established;
2) energy consumed by vehicle type was assessed;

3) emissions were calculated based on unit emissions per unit of energy consumed;
4) emission totals were adjusted to account for the emissions created during the extraction, refinement and distribution of the fuels to produce life cycle estimates of emissions.

Over the years, emissions from rail freight have improved considerably. Hydrocarbons (HCs) are reported, rather than VOCs. Since VOCs are included in HCs, the values for HC is used as that for VOC. This results in a conservative estimate - higher than actual estimate for VOCs. To some degree, the improvements in emissions are a result of fuel efficiency , which increased from 175 tonne-km per litre in 1993 to 187 tonne-km per litre in 1997 (calculated from Railway Association of Canada 1999). In addition, the maximum allowable axle load is being increased on many lines, which improves efficiency of freight movement. Low-idle applications, which allows the diesel engine to idle at reduced speed, and automatic start/stop systems, which automatically shut down and restart the diesel when it is not in use, have also contributed to lowered emissions.

Total emissions (Table 14) were calculated by multiplying the tonne-km by the emission rates. According to Jaques (1997), the CO_2 emissions calculated here for trucks amount to six percent of total 1995 emissions from heavy-duty diesel vehicles. Emissions from rail amount to 40% of total 1995 emissions from rail. On the assumption that improvements in fuel efficiency and emission control technologies will be comparable in rail and truck in the period 1995-2010, projections of future emissions were based on the emission rates in Table 14.

Table 38. Total Estimated Emissions (kilotonnes) from Truck and Rail: AH-800 in 1997

TRUCK		**CO_2**	**NOx**	**VOC**	**SO_2**	**PM**
Grams per Tonne-km. →		115.2	1.99	0.2	0.24	0.13
	Tonne-km	Tonnes				
Imports	251,145,906	28,932	500	50.2	60.3	33
Exports	160,019,356	18,434	318	32.0	38.4	21
TOTAL	411,165,262	47,366	818	82.2	98.7	53
RAIL						
Grams per Tonne-km. →		17.38	0.353	0.018	0.016	0.009
	Tonne-km	Tonnes				
Imports	475,613,073	8,266	168	8.6	7.6	4.3
Exports	366,393,005	6,368	129	6.6	5.9	3.3
TOTAL	842,006,127	14,634	297	15.2	13.5	7.6

Sources: IBI Group 1995 and Railway Association of Canada 1999.

1.1.1.8 Cost of emissions

The second step in estimating the cost of emissions is to apply costs to each of the air pollutants. With the exception of CO_2, discussed in Section 2, the costs of one tonne of each of the air pollutants is fairly straightforward. The IBI Group considered five studies that estimated these costs, based upon the cost of controlling, or reducing, the emissions. IBI chose values in the middle of the ranges presented by the other studies. They also used a value of $100 per tonne. Klein (1997) used generally lower values to cost these externalities for a study of gas turbine cogeneration and district energy plants on the prairies in Western Canada. He does point out that these values may change with location and geography. Since air pollution is a much more serious problem in Atlantic Canada than on the prairies, it is reasonable to choose higher values for Atlantic Canada. Klein also mentions that as society's concern over the effects of climate change rises, higher externality values in the $20-$40 per tonne range may be more appropriate. The current study used the IBI values, as well as additional values for CO_2, converted to C$1997 (Table 15), as discussed in Section 3. Table 16 summarizes values used in the current study in terms of cents per tonne-km.

Table 39. Comparison of Environmental Externality Values (dollars/tonne)

Pollutant	Royal Commission on National Passenger Transportation (1991)	Ontario Externalities Collaborative (Tellus Institute 1994)	Klein (1997)	IBI Group (1995)
Carbon Dioxide	$32.7	$40	$10	$34
Carbon Monoxide	-	$1,400		0
Sulphur Oxides	-	$2,100-4,800	$1,000	$6,000
Nitrogen Oxides	$5,000	$8,500-$15,000	$1,000	$7,000
Volatile Organic Compounds	$5,000	$3,000-$7,500		$5,000
Particulate Matter	-	$13,200-$16,400	$2,000	$4,000

Source: IBI 1995, p. 4.3.

Table 40. Cost of Emissions Used in Present Study (1997 C$ per Tonne)

Pollutant	Cost Per Tonne	Cost in 1997 C$ Per Tonne	Cents Per Tonne-km	
			Rail	Truck
CO_2	$34 C$1995 (IBI)	$35	0.061	0.403
	$20-$50 US$1990 (Cline 1996)	$96	0.167	1.106
	$10 C$1997 (Klein 1997)	$10	0.017	0.115
SO_2	$6,000 C$1995 (IBI)	$6,240	0.010	0.150
NOx	$7,000 C$1995 (IBI)	$7,280	0.257	1.449
VOC	$5,000 C$1995 (IBI)	$5,200	0.009	0.104
PM	$4,000 C$ 1995 (IBI)	$4,160	0.004	0.054

1.1.1.9 Truck

Accident rates for trucks were taken from the 1996 Nova Scotia Traffic Safety Report. Rates for trucks over 5000kg and semi-trailer power units were used (Table 17). The proportion of truck accidents in Nova Scotia that should be attributed to AH-800 was estimated at 23%, the ratio of HA-800 tonnage to total Nova Scotia tonnage. As mentioned earlier, this ratio was chosen on the assumption that accident costs are related to traffic intensity and that tonnage is a reflection of traffic intensity. Estimated compensation costs per accident were based on those listed in Transport Canada's 1997 Annual Report (Transport Canada 1997). The results are shown in Table 17.

Table 41. Estimated Annual Accident Costs for Trucks HA-800

1996 Only	Property Damage	Personal Injury	Fatality	Total
Est. Cost Per Accident (1997$) (Transport Canada 1997)	$5,712	$28,560	$1,591,200	
Trucks over 5,000kg.	308	93	3	404
Semi-Trailer Power unit	190	48	3	241
TOTAL	498	141	6	645
Portion attributable to HA-800 (23%)	114.54	32.43	1.38	148.35
Total Cost HA-800	$654,252	$926,201	$2,195,856	$3,776,309
Cents per tonne-km HA-800				0.92

Source: Nova Scotia Traffic Safety Report 1996.

1.1.1.10 Rail

Because rail accidents are so infrequent, a three-year average of rail accidents in Nova Scotia was used. The same costs were applied that were used for truck. The results are shown in Table 18.

Table 42. Estimated Annual Accident Costs for Rail HA-800

Average 1995-1997	1995	1996	1997	Average	Estimated Cost
Total	7	20	11	12.67	
Fatal	0	2	0	0.67	$1,060,800
Serious Injury	0	1	2	1.00	$28,560

Assumed Property Damage	7	17	9	11	$62,832
TOTAL					$1,152,192
Cost per tonne-km					0.14

Transportation Safety Board of Canada 1998.

Cost of Fossil Fuel Depletion

To determine an estimate for the cost of fossil fuel depletion, a proxy value is based on the estimate of the cost to replace fossil fuel with alternative energy sources. As mentioned in Section 3, a value of $124 per tonne of CO_2 has been estimated, although this estimate is for energy sources not currently available (Cline 1996). The U.S. G.P.I. Group has estimated a value of $100 per barrel of ethanol fuel derived from corn (value was $75 1988 US $). At 158.9 litres per barrel of diesel, the fuel usage rate allows the calculation of the replacement cost per tonne-km.

Table 43. Cost of Fossil Fuel Depletion Based on Value of $100 per Barrel (or $0.63 per liter) of Corn-based Ethanol

Mode	Tonne-km Per Liter Diesel Fuel	Liters Diesel Fuel Per Tonne-km	Replacement Cost (cents per tonne-km)
Rail	187	0.005	0.315
Truck	52.02	0.019	1.197

Employment Benefits From Truck and Rail Freight

Exact figures on numbers of employees and remuneration in the rail and truck freight industries in Nova Scotia were not obtainable from either the employment by Industry figures of from the employment by occupation figures Statistics Canada 1996 Census). While estimates of numbers of employees were not available, estimations of remuneration rates per tonne-km were made from estimates in Trucking in Canada and Rail in Canada for 1996, as shown in Table 20.

Table 44. Estimates of National Rates of Remuneration per Tonne-km

Mode	Estimated Total Annual Compensation (1996)	Estimated Total Annual Tonne-km (1996)	Estimated Rate of Compensation (cents per tonne-km)
Truck (for-hire >$1million annual revenue)	$3,472,100,000 (Trucking in Canada 1996, p. 23)	120,459,000,000 (Trucking in Canada 1996 p. 34)	

Converted to 1997 dollars	$3,541,542,000		2.9
Rail (CN)	$2,491,734,000 (Rail in Canada, 1996 p. 13)	282,488,814,000 (Rail in Canada 1996, p. 13)	
Converted to 1997 dollars	$2,541,568,680		.9

Although trucking employs nearly one-third of all transportation sector workers, the average annual wage is less than that in the rail industry. While an average annual wage was not available for the trucking industry as a whole, in 1995 in Nova Scotia, 6,585 truck drivers were employed (3,090 full-time and 3495 part-time), at an average annual wage of $24,082 ($29,446 full-time; $19,340 part-time) (Statistics Canada 1996 Census).

CN Rail has increased productivity and decreased numbers of employees but increased average rate of remuneration (CN Rail 1998). In 1997, the rail industry employed an average of 46,174 people, with an average annual wage of $54,580 (Railway Association of Canada 1997).

13.4. Projections to 2010

Discount Rate

As discussed in Section 2, no discount rate is used for this study, which infers that in terms of environmental concerns, the future value of the dollar is equal to the present value. To demonstrate the impact of discount rates on the calculations, cost projections for a 10% discount rate were determined and are presented in the Results section.

Freight Projections

Projections of tonnage to the year 2010 are based on percentage increases cited in "Freight Transport Trends & Forecasts to 2010 (Transport Canada 1998). Overall freight shipments in Canada are expected to increase by an annual average of 1.4% between 1996 and 2010. Canadian exports to the U.S. are expected to grow by an annual average of 1.4% during this period, much of which will be driven by an intermodal component from ports in Eastern Canada. Imports are expected to increase by an annual average of 2.3%.

Table 21 summarizes projected annual increases in rail and truck freight in Nova Scotia. Rail loadings (exports) in Nova Scotia are expected to increase by an average annual rate of 1% between 1998 and 2005, and by 1.1% between 2006 and 2010. Interprovincial truck loadings are expected to increase by an average annual rate of 2.3% between 1998 and 2005 and by 1.7% between 2006 and 2010. These projections are low, compared with those of Gardner-Pinfold (1997) for cargo demand. For the period 1998-2007, Gardner-Pinfold predicted an increase of 36.9% for rail and 38.9% for truck, whereas the cumulative increases over this same time period calculated from Transport Canada projected rates of increase are 9.96% increase for rail and 16.3% increase for truck. It is not known whether the Gardner-Pinfold estimates were based on the addition of the post-Panamax Terminal at the Port of Halifax.

Table 45. Average Annual Percentage Increases in Freight Tonnage in Nova Scotia 1998-2010

Import/Export	Truck		Rail	
	1998-2005	2006-2010	1998-2005	2006-2010
Import	1.4	0.6	1.1	1.1
Export	2.3	1.7	1.0	1.1
Average	1.85	1.15	1.05	1.1

Transport Canada 1998.

Table 22 demonstrates how CO_2 emissions will increase if these freight projections are accurate. For truck, this amounts to a cumulative increase of 22% and for rail, 19%.

Table 46. Projected CO_2 Emissions 1997-2010 from HA-800 Truck and Rail Freight

Year	Rail			Truck			Total
	tonnes	tonne-km	tonnes CO_2	tonnes	tonne-km	tonnes CO_2	
1997	3,153,581	842,006,127	14,634	1,921,333	411,165,262	47,366	62,000
1998	3,186,694	850,847,191	14,788	1,956,878	418,771,819	48,243	63,030
1999	3,220,154	859,781,087	14,943	1,993,080	426,519,098	49,135	64,078
2000	3,253,965	868,808,788	15,100	2,029,952	434,409,701	50,044	65,144
2001	3,288,132	877,931,281	15,258	2,067,506	442,446,281	50,970	66,228
2002	3,322,658	887,149,559	15,419	2,105,755	450,631,537	51,913	67,331
2003	3,357,545	896,464,629	15,581	2,144,711	458,968,220	52,873	68,454
2004	3,392,800	905,877,508	15,744	2,184,388	467,459,132	53,851	69,595
2005	3,428,424	915,389,222	15,909	2,224,800	476,107,126	54,848	70,757
2006	3,466,137	925,458,503	16,084	2,250,385	481,582,358	55,478	71,563
2007	3,504,264	935,638,547	16,261	2,276,264	487,120,556	56,116	72,378
2008	3,542,811	945,930,571	16,440	2,302,441	492,722,442	56,762	73,202
2009	3,581,782	956,335,807	16,621	2,328,919	498,388,750	57,414	74,036
2010	3,621,182	966,855,501	16,804	2,355,702	504,120,221	58,075	74,879
Cumulative			219,587			743,088	962,675

14. Results

14.1. Summary of Input Data

Table 23 presents a summary of the values used to estimate revenue, costs, and emissions of rail and truck freight. The values demonstrate that, when external costs are included, truck freight is almost 13 times more expensive than rail freight, on a per tonne-km basis. The values are compared with those from the IBI (1995) report. Government Revenue values for rail and freight are higher than those of IBI because 1) government revenues in the IBI study only included fuel taxes and license fees, whereas in the current study, property taxes, registrations, and toll fees are also included. Government costs are lower than those of IBI for rail are and higher than IBI for truck. When the IBI study was done, there was still some government subsidy to railways, whereas in the current study, there is none.

Government costs for truck are higher because costs were allocated to trucks at 41.1% of total road costs, whereas IBI allocated 25% of total road costs to truck. With regard to accident costs, it is difficult to analyze why present study costs are so much higher than those of IBI. The present study uses specific provincial accident records and therefore produces a more accurate value than a national value. Other studies (Transport Concepts 1993) have produced a range of values for accident costs from 0.06 to 0.23 cents per tonne-km for rail and 0.59 to 4.52 cents per tonne-km for truck (all 1994 dollars). Fossil fuel replacement costs were not included in the IBI study. Costs of air emissions are very similar between the two studies, since the same costing methods were used. IBI did not analyze the contribution of the two modes to employment remuneration.

Table 47. Input Values for Estimating Costs and Emissions for HA-800

Parameter	Values			
	Rail		Truck	
HA-800 1997 Freight (tonnes)	3,153,581		1,921,333	
HA-800: Total km in route (including spurs)	267		214	
HA-800: Total Tonne-km Freight	842,006,127		411,165,262	
	Cents/Tonne-km.			
		IBI 1995		IBI 1995
GOVERNMENT REVENUE	0.1569	0.06	0.97462	0.36
GOVERNMENT COSTS				
Government Capital Costs	0		0.43500	
Government Maintenance Costs	0		0.13874	
Policing Costs			0.80160	
Administrative Costs			3.54315	
TOTAL GOVERNMENT COST	0	0.014	4.91849	0.76
NET GOVERNMENT COSTS	-0.1569		3.94387	
EXTERNAL COSTS				
Accidents	0.1368	<0.01	0.92000	0.04
Fossil Fuel Replacement Costs	0.315		1.19700	
Climate Change and Air Pollution Costs				
CO_2	0.061	0.07	0.40300	0.39
NOx	0.257	0.3	1.44900	1.39
VOC	0.009	0.01	0.10400	0.1
SO_2	0.01	0.02	0.15000	
PM	0.004	0.01	0.05400	0.05
Total External Cost of Emissions	0.341	0.41	2.160	2.08
TOTAL EXTERNAL COSTS	0.7928	0.41	4.27700	2.12
TOTAL NET COSTS	0.6359		8.2209	
EMPLOYMENT BENEFITS				
Employment Remuneration	0.82		2.90	

14.2.

14.3. Costing of HA-800 Rail and Truck Freight Transportation for 1997

The input values shown in Table 23 were used to estimate total transportation costs for the current situation and for different modal mixes of truck and rail freight for 1997. The effect of varying the discount rate and the value used for one tonne of CO_2 were examined. Finally the impact of modal freight shift on employment remuneration was considered, and a new modal mix was recommended. Table 24 shows the total transportation costs for the existing situation. External costs account for the majority of the costs. Table 25 shows the total emissions for the current situation.

Table 48. Total Transportation Costs for HA-800 Freight in 1997

	Rail	Truck	Total
Kilotonne-km	842,006.13	411,165.26	1,253,171.40
Percent of total Kilotonne-km	67.19%	32.81%	
COSTS: C$ 97 (' 000)			
A. Government Costs			
- Government Revenues	1,321.11	4,007.31	5,328.42
- Government Costs	0	20,223.138	20,223.13
NET GOVERNMENT COSTS	-1,321.11	16,215.828	14,894.72
B. External Costs			
- Local Air Pollution	2,357.62	7,224.17	9,581.79
- Climate Change (@ \$35/ tonne CO_2)	513.62	1,656.99	2,170.16
- Accident Costs	1,151.86	3,782.72	4,934.58
- Fossil Fuel Depletion Costs	2,652.32	4,921.65	7,573.97
TOTAL EXTERNAL COSTS	6,675.42	17,585.54	24,260.96
TOTAL NET TRANSPORTATION COSTS	\$5,354.31	\$33,801.36	\$39,155.67

Table 49. Total Air Emissions for HA-800: Existing Situation (1997)

Pollutant	Tonnes		
	Rail	Truck	TOTAL
CO_2	14,634.06	47,366.27	62,000.33
NOx	297.23	818.22	1,115.45
VOC	15.16	82.23	97.39
PM	7.58	53.45	61.03

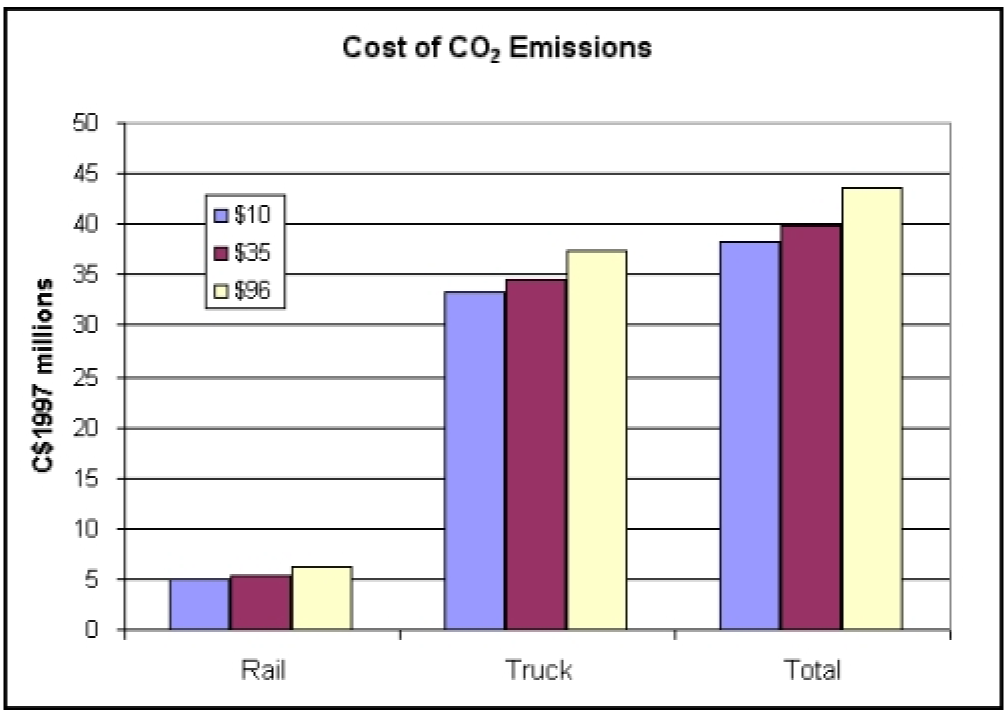
Effect of Varying Dollar Value of CO_2

Three values for the cost of one tonne of CO2 were used: \$10; \$35; and \$96. Table 26 and Figure 1 show how the total costs change when different values are used. The difference in total transport costs between the $10 value and the $96 value is $5.3 million annually. The impact on rail freight is much less than that on truck freight. The current study uses the $35 figure in all subsequent calculations.

Table 50. Effect of Value of One Tonne CO_2 on Total Transportation Costs for HA-800: Current Situation (1997)

CO_2 Cost/tonne	Total Cost (C$97 ' 000)		
	Rail	Truck	Total
$10	$4,990	$33,300	$38,290
$35	$5,353	$34,485	$39,839
$96	$6,250	$37,370	$43,620

Figure 30. Costs of Carbon Dioxide Emissions



Effect of Varying Discount Rate

The decision to use a zero discount rate is a philosophical one, based on intergenerational equity.

Recommended Modal Shift

Table 27 presents the potential export tonnage that would be suitable for a shift from truck to rail. The maximum potential transferable is 578,903 tonnes, which represents 77% of HA-800 truck and rail exports and 30 % of total HA-800 freight. These are commodities that are not perishable or particularly time-sensitive. Very small shipments were excluded, as were the unclassified, mixed cargo, and freight forwarding commodities. Since specific origin and destination were not considered in the scope of the study, there may be other reasons why certain shipments cannot be transferred to rail.

Table 51. Potential Export Truck Freight to be Shifted to Rail for Ha-800 (1997)

Commodity Group	Truck (tonnes)	Rail (tonnes)
Potentially Transferrable to Rail:		
Forestry Products: lumber, newsprint, building materials,		
Pulp	77,132	516,267
Rubber tires and tubes	109,505	
Non-metallic minerals: crude and basic products	124,097	
Base metals, iron & steel, ores	21,306	88,074
Fabricated Materials	103,166	
Equipment & Machinery	18,079	
Household and personal equipment	14,888	
Motor Vehicles, engines, parts, aircraft, ships, boats	9,876	17,733
Food preparations and feeds	12,212	7,605
Non-perishable food & beverage products; oils, fats, waxes	67,973	
Containers & Closures	8,681	
Crude animal & Vegetable products and waste	3,699	
Chemicals	5,104	28,168
Photographic goods and office supplies; printed matter	1,847	
Miscellaneous end products, firearms, apparel, rec. equip.	1,338	
1.1.1.10.1.1Total Potentially Transferrable to Rail	578,903	
Commodities Probably Not Transferrable to Rail:		
Plastics		2,866
Fertilizers, potash		28,122
Gypsum, sand, clay, cement, rock salt		29,570
Unclassified; mixed carload; freight forwarder; and other	91,525	636,004
Medical Supplies	2,069	
Perishable food products	74,678	
Petroleum Products	232	17,850
Small retail items	347	
1.1.1.10.1.2Total Commodities Probably Not Transferrable to Rail	747,754	1,372,259
Total Potential Transfers	**578,903**	

Potential Transfer: Percent of Total	77.42%	

Table 28 presents the total transportation costs, CO_2 emissions, and employment remuneration for different modal mixes. The maximum potential transferable tonnage results in a mode mix of 77% rail and 23% truck freight. This mix is recommended as the best modal mix for decreasing total costs and decreasing CO_2 emissions. This modal shift will bring about a decrease in overall employment remuneration, however. Total remuneration is reduced by 12.3%, and trucking remuneration is reduced by 30%.

Table 52. Total Transportation Costs, CO_2 Emissions, and Employment Remuneration with Different Modal Mixes (HA-800, 1997)

Percent of Total Tonne-Kilometres		CO_2 Emissions (Tonnes)	Total Transportation Costs (C$97 '000)	Total Employment Remuneration (C $97 '000)
Rail	Truck			
67.19 (current)	32.81 (current)	62,000.33	$ 39,136.5	$ 18,828.2
77	23	49,913.43	$ 30,260	$ 16,258.14
75	25	52,426.43	$ 32,250	$ 16,792.50
73	27	54,878.13	$ 34,200	$ 17,313.82
71	29	57,329.83	$ 36,140	$ 17,835.14
69	31	59,781.54	$ 38,080	$ 18,356.45

14.4. Costing of HA-800 Rail and Truck Freight Transportation, 1997-2010

Based on the projected annual percent increases in freight described in Section 4, total transportation costs and CO_2 emissions were calculated for the years 1997-2010. Table 29 shows the contribution of the recommended modal shift to the GHG reduction target for Nova Scotia, based on the Kyoto agreement. (*The targets presented are proportional to a six percent decrease from 1990 levels, as stated in the Kyoto Agreement. It should be emphasized that Nova Scotia has not set actual GHG reduction targets*.) By 2010, the modal shift would provide a decrease of 2.1 Kt from 1997 levels, which is 0.23% of the Nova Scotia target. Compared with the Business-as-Usual Scenario, the RMM provides an average reduction of 14.99 Kt annually by 2010.

Table 30 shows CO_2 emissions and total transportation costs for the Business-as-Usual scenario, assuming no change in modal mix and for the Recommended Modal Mix (77/23). According to these calculations, the recommended modal mix (RMM) would save roughly $150 million over the 14 years represented here. Figure 4 shows the projected total freight costs, and Figure 5 shows the projected CO_2 emissions for the "business as usual" scenario vs. the "recommended mode mix" scenario. The cumulative reduction in tonnes of CO_2 is estimated at 191,750. It is estimated that the annual CO_2 reduction would range from 12 kt to almost 15 kt. This would represent a decrease in total Nova Scotia GHG emissions (18,600 kt in 1995) of 0.23% of the targeted decrease. This means that a 10% shift of freight away from truck toward rail would

result in an average annual decrease in CO_2 of 13,696 tonnes at a net average annual social benefit of $10 million.
Table 31 presents a comparison of predicted transportation cost savings obtained through the recommended modal shift when varying costs per tonne of CO_2 are used. In this case, the climate change damage estimate of $1,000 recommended by Cline is also used. A roughly two-fold annual difference is observed between savings when CO_2 is valued at $10 per tonne vs. $1,000 per tonne. With the valuation of $1,000 per tonne, which considers a range of climate change damages, the cumulative savings with this measure from 1997-2010 is predicted to be $303 million.

Table 53. HA-800 Recommended Modal Mix: Contribution to Nova Scotia Target Annual GHG Emissions (2010), Based on Kyoto Agreement

Section	Annual Emissions	Target 2010 Emissions	Change	% Change
Nova Scotia 1995	18,600	17,672	-928.00	-5.0%
HA-800 BAU (1997)	62.00	74.88	12.88	20.8%
HA-800 RMM (1997)	62.00	59.89	-2.10	-3.4%
HA-800 RMM : percent of 2010 target		0.23%		

Table 54. Projected Transportation Costs and CO_2 Emissions for HA-800 Freight for Business-As-Usual (BAU) and for Recommended Modal Mix (RMM) 1997-2010

Year	Total Annual Costs (C$97 ' 000)			Total Annual CO_2 Emissions (tonnes)		
	BAU	RMM	Difference	BAU	RMM	Difference
1997	39,156	30,221	8,935	62,000	49,910	12,090
1998	39,837	30,727	9,111	63,030	50,070	12,960
1999	40,531	31,242	9,289	64,080	51,500	12,580
2000	41,237	31,765	9,472	65,140	52,320	12,820
2001	41,956	32,298	9,658	66,230	53,150	13,080
2002	42,687	32,840	9,847	67,330	53,990	13,340
2003	43,432	33,392	10,040	68,450	54,850	13,600
2004	44,190	33,953	10,237	69,600	55,720	13,880
2005	44,961	34,524	10,437	70,760	56,610	14,150
2006	45,475	34,918	10,558	71,560	57,250	14,310
2007	45,995	35,316	10,680	72,380	57,900	14,480
2008	46,521	35,718	10,803	73,200	58,550	14,650
2009	47,053	36,125	10,928	74,040	59,220	14,820
2010	47,591	36,537	11,055	74,880	59,890	14,990
Cumulative Difference			141,048			191,750
Average Annual Difference			10,075			13,696

Figure 31. Projected Total Freight Costs for Business as Usual and Recommended Modal Mix Scenarios

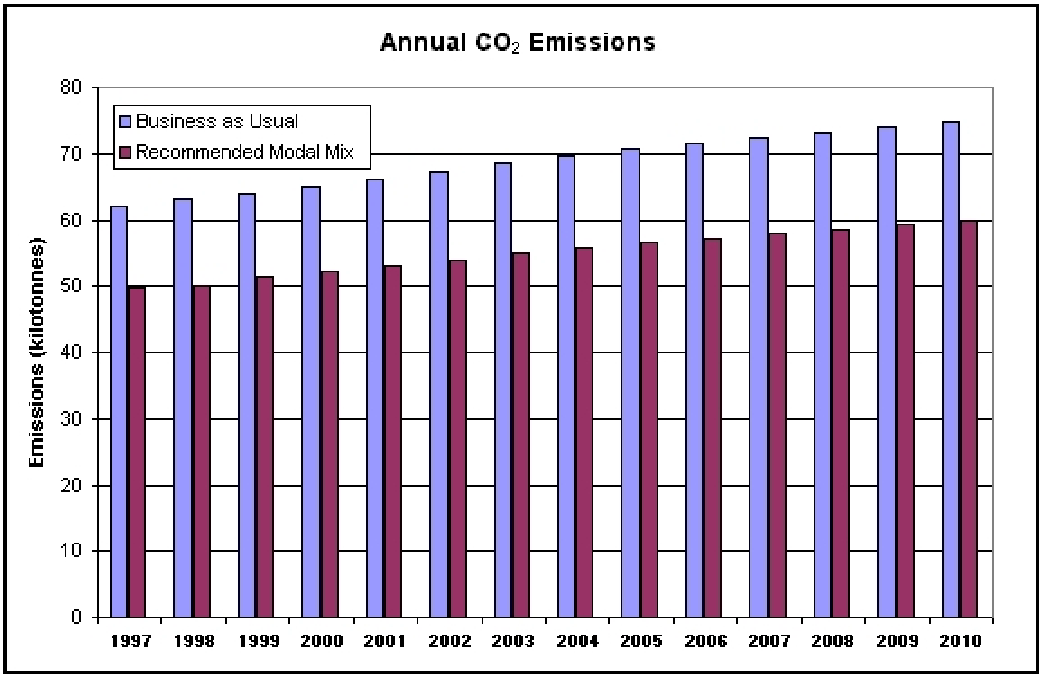


Figure 32. Projected Total Carbon Dioxide Emissions for Business as Usual and Recommended Modal Mix Scenarios

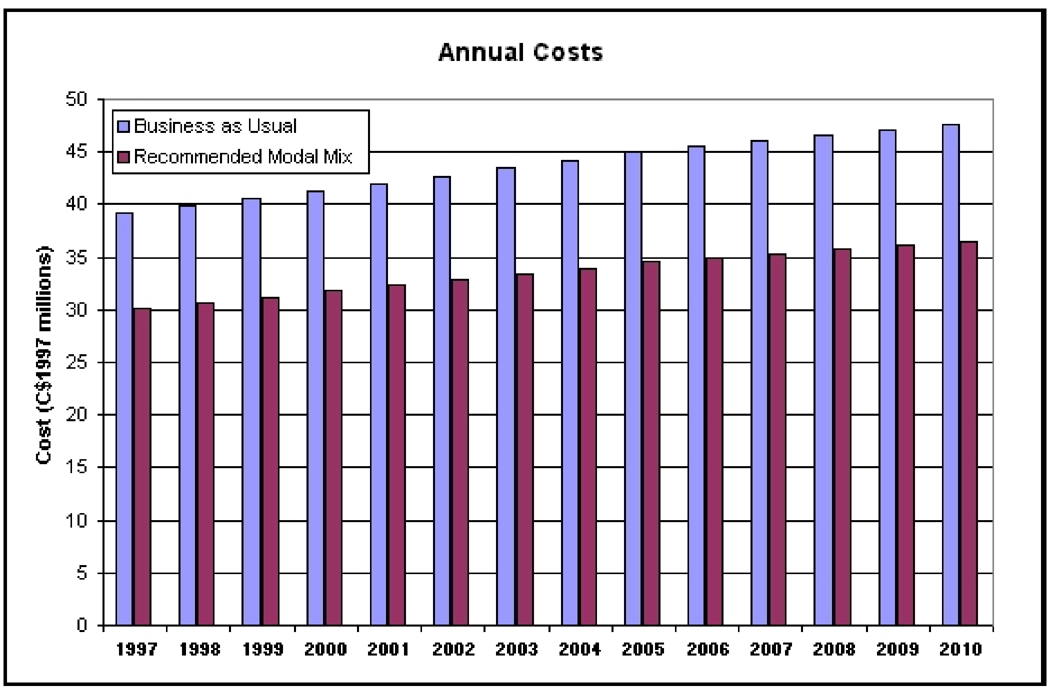


Table 55. Total Transportation Costs Savings with RMM with Varying Values for Cost of CO_2 per Tonne (C$97 million)

CO_2 $/tonne	1997	2010	Cumulative (1997-2010)
$10	8.66	10.71	145.30
$35	8.93	11.05	141.05
$96	9.59	11.87	151.47
$1,000	19.37	24.12	307.20

14.5. Additional User Costs Required to Implement Modal Shift

Based on the freight demand factor discussed in Section 3, an increase in trucking costs of 1% is required to effect an increase in rail tonnage of 0.5%. This amounts to a 2:1 ratio in that a 2% increase in trucking costs would result in a 1% increase in rail freight. The required increase in rail tonnage for the recommended modal mix is 577,339 tonnes, or an 18% increase over the current rail tonnage. If the shift is effected by additional user costs, this would require an increase in trucking costs of 36% over current costs.

Since it is assumed this government would implement the shift, the costs to be increased would be the government revenues. Current total government revenue from HA-800 truckers is estimated at $4,007,311. Increasing the costs by 36% would produce a total annual cost to truckers (in the form of government revenue) of $1,442,632.

14.6. GHG Mitigation Index for HA-800 Freight

The GHG Mitigation Index is a measure of the cost to reduce CO_2 by one tonne. The GHG Mitigation Index (GMI) as defined here is the extra cost required to bring about the reduction minus the costs or benefits that result from the reduction. A negative GMI indicates a net social benefit for a given proposed GHG reduction option. In this case it does not include any government administrative costs that may be incurred in increasing the cost of trucking. In the case of the long-haul freight transportation industry in Nova Scotia, the total annual reduction of CO_2 in 1997 resulting from the recommended modal shift is 12,090 tonnes, and the cost is estimated at $1,426,910, which is a cost of $118 per tonne). The average annual economic benefit of the modal shift is $10,074,863, or $833 per tonne of CO_2. Therefore, the GMI for the HA-800 Route is $118 minus $833, or $-715, or a net social benefit of $715 for every tonne of CO_2 reduction.

15. Conclusions

Because of the nature of the data on which the study is based, caution must be applied in drawing conclusions from the study. General conclusions that can safely be drawn are discussed here.

15.1. Magnitude of CO_2 Reduction Available

In order to meet the Kyoto commitments, Nova Scotia would need to reduce its GHG emissions to six percent below the 1990 level, which would result in a target of 17,672 Kt per year. This would require a reduction of 928 Kt from the 1995 levels of 18,600 Kt. The HA-800 freight modal shift allows the reduction of CO_2 by 2100 tonnes by the year 2010, or 0.23 percent of the overall annual target. While this is a modest share of the overall reduction target, in terms of the cumulative impact, it should be emphasized that this reduction is accompanied by a reduction in overall transportation costs of $11 million annually by 2010. Even without including the costs of climate change, savings in 1997 from the modal shift would have been $8.5 million. As compared with the "Business-as-Usual" scenario, the CO_2 reductions are more dramatic, resulting in a decrease of 191.7 Kt by 2010. While it is clear that a modal shift alone will not accomplish the required reduction in GHG emissions for Nova Scotia, it would make a significant contribution. The modal shift would have significant economic benefits and therefore may be considered a "No Regrets" measure.

15.2. Usefulness of GPI Approach in Analyzing GHG Reduction Strategies

This study has shown that the GPI approach is quite useful in analyzing the potential benefits and costs of a general type of GHG reduction strategy. By including "externalities", a more complete picture of costs and benefits is obtained. The GHG Mitigation Indices would be extremely helpful in comparing strategies across different sectors to determine the greatest reductions at the least cost.

15.3. Successful Strategies in Other Jurisdictions

In Sweden, environmental costs have been partly included in the tax on petrol and diesel fuel (Kageson 1993). A 1988 policy which substantially increased mileage tax on heavy vehicles has been somewhat eroded by subsequent measures to harmonize Sweden's taxes with other EU countries.

No jurisdictions in Canada have implemented user fees specifically to include environmental costs or to encourage use of rail freight over truck freight. The Ontario Freight Movement Study (Transmode Consultants 1995) did analyze in great detail options for GHG reduction in the Ontario freight transportation sector. New technologies providing greater customer service and efficiency may attract more freight to intermodal. If all long-haul freight in Ontario were shifted to intermodal, this would accomplish a reduction of 2% below 1990 levels in 2005 and an increase of 6% over 1990 levels in 2010. This is compared with an increase of 35% over 1990 levels under a business-as-usual scenario. The authors concluded that there are not enough options in the freight transport industry to reduce GHG emissions to a degree that would offset increased emissions from projected increases in traffic growth. They suggest that the answer to reducing GHG emissions in the freight transport industry may be more regionalized production facilities, leading to a lower demand for freight transport. In order to implement an intermodal shift, the authors recommend pricing of energy use to reflect environmental cost of emissions and improved response of rail to customer service demands.

An Australian study (BTCE 1996) examined the effect of rail infrastructure improvement to decrease rail freight transit time, increase operating efficiencies, decrease overall rail freight cost, and thereby effect a shift of freight traffic from truck to rail. The study concluded that although shifting of freight from truck to rail is only of minor significance in its potential to reduce GHG emissions, this strategy remains a “No Regrets” measure.

15.4. Recommendations for Nova Scotia

In light of the limited scale of GHG reduction in the HA-800 freight, the conclusions drawn by Transmode Consultants (1995) merit particular consideration. Their recommendation of regionalization of manufacturing leading to lower freight demand may be applicable to the Atlantic Region. One option would be for provincial governments to encourage investment in industries that are less freight intensive.

While a modal shift of freight from truck to rail in Nova Scotia may not be the most efficient method of reducing GHG emissions, it is a “No Regrets” measure, as demonstrated by the Net GHG Mitigation Index of -$715 per tonne of CO_2. Considering the poor performance of the CN line in Nova Scotia as compared to lines in Canada and the U.S., it may be necessary for the provincial government to provide a business environment that encourages rail freight. Otherwise, the province may lose the line altogether. The suggestion by the APTC of establishing a regional rail network may be worthy of further consideration. Because the Highway 104 Toll fee has only been recently implemented, it may be wise to determine the impact of this change on the trucking industry before initiating other changes. The impacts of any shift of freight from truck to rail on competitiveness of Nova Scotia and of Canada must be considered. In addition, the upheaval caused by a decrease in trucking employment would have to be addressed. This situation may require new ways of thinking about the trucking industry in Nova Scotia and Atlantic Canada so that new means of employment could be found within the trucking industry through intermodal and regional centres.

15.5. Recommendations for Further Study

Enhancement of Present Study

1. Conduct a Shippers' and Receivers' Survey to determine
    1. Actual freight being shipped on HA-800
    2. Shippers' willingness to pay for alternate modes
    3. Degree of intermodal shipments already occurring
    4. Freight and mode projections based on shipper's plans
    5. Analyze structure of shipping rates for truck, rail, and intermodal shipments
2. Obtain cooperation of CN Rail for more exact figures and projections based on their market and their plans
3. Use current model for price cross-elasticities to more accurately determine increases in trucking rates required to effect a particular modal shift
4. Examine future of CN Rail Halifax-Montreal line.
5. Obtain data from Statistics Canada input-output database to determine impacts on the economy as a whole (including spin-offs) of a modal shift.

Studies of Other GHG Reduction Strategies

It is recommended here that future cost-benefit studies of GHG reduction strategies focus on those strategies most likely to produce net benefits for society. Such "no regrets" measures are those that can reduce net greenhouse gas emissions levels, but whose total social cost is zero or negative over a specified time period. This does not mean that some individuals or groups do not incur losses, but that society, as a whole, will gain, which allows compensation for those with losses.

1.1.1.11 Additional Transportation Studies

Before delving into policy initiatives, it may be worthwhile to look at various transport combinations of modal transportation shifts in order to determine which combinations provide the greatest GHG reductions at the least cost. These could include shifts from car to bus; car to rail; and truck to rail.

In the transport sector, previous studies internationally have focused on the following areas as potential "no regrets" measures. Nova Scotia may wish to examine the implications of these for local conditions and circumstances:

1) Road user charges
2) Reduced urban public transit fares and improved public transit services
3) City-wide parking charges
4) Fuel-efficiency labelling of cars
5) Carbon taxes on fuels.

An Australian study (BCTE 1996) found that introduction of all five of these measures would reduce total transport sector emissions between 1996 and 2015 by up to 10%. The measures would also produce substantial social benefits in reduced congestion, accidents, noxious emissions, and other costs. The framework of the present study on modal freight shifts is particularly applicable to an examination of the potential for modal shifts in passenger transportation and to transportation in the entire province.

1.1.1.12 Forest Sector

A further area for future study, which is in accord with the GPI natural resource accounts, is exploration of the potential for enhancing carbon sinks. Investments in restorative forestry and tree planting were found by the Australian study (BCTE, 1996) to be a low cost measure capable of absorbing all CO_2 emissions from the transport sector in the long term.

1.1.1.13 Energy Sector

The GPI approach would be applicable to the study of renewable energy sources and for comparing total costs of existing energy sources.

In sum, because the GPI approach attempts to assess the economic costs and benefits of social and environmental variables as well as direct inputs on the economy, it may be a helpful tool for future studies assessing the viability of different GHG reduction strategies.

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17. Appendix

Table 56. Annual Capital Costs for HA-800

Yr.	Average Annual Rate	Total Capital Hwy 102	Annual Payments New Loans	Annual Cumulative Payments	Total Capital Hwy 104	Annual Payments New Loans	Annual Cumulative Payments
1976	9.61	$7,243,500	$828,283	$828,283	$35,600	$4,071	$4,071
1977	9.15	$2,169,500	$240,207	$1,068,490	$74,200	$8,215	$12,286
1978	9.57	$1,235,000	$140,829	$1,209,319	$457,600	$52,181	$64,467
1979	10.5	$8,631,900	$1,048,718	$2,258,036	$325,300	$39,522	$103,989
1980	12.82	$2,839,200	$399,806	$2,657,842	$878,500	$123,707	$227,696
1981	15.59	$5,198,800	$857,806	$3,515,648	$0	$0	$227,696
1982	14.75	$3,963,600	$624,485	$4,140,133	$61,600	$9,705	$237,401
1983	12.08	$4,336,200	$583,439	$4,723,571	$593,900	$79,910	$317,311
1984	12.92	$2,184,100	$309,421	$5,032,992	$1,787,300	$253,206	$570,517
1985	11.2	$3,385,100	$430,658	$5,463,651	$2,079,300	$264,532	$835,049
1986	9.3	$2,359,300	$264,001	$5,727,652	$691,900	$77,422	$912,472
1987	9.75	$142,500	$16,453	$5,744,105	$359,100	$41,462	$953,934
1988	10.05	$1,843,600	$217,288	$5,961,394	$798,000	$94,053	$1,047,987
1989	9.66	$4,287,600	$491,983	$6,453,377	$2,589,400	$297,122	$1,345,109
1990	10.69	$1,204,300	$148,176	$6,601,553	$4,357,200	$536,105	$1,881,214
1991	9.72	$2,155,300	$248,340	$6,849,892	$8,700,700	$1,002,519	$2,883,734
1992	8.77	$200,800	$21,638	$6,871,530	$22,263,600	$2,399,055	$5,282,788
1993	7.86	$100,000	$10,079	$6,881,609	$38,374,400	$3,867,886	$9,150,675
1994	8.69	$1,076,700	$115,355	$6,996,964	$35,861,300	$3,842,075	$12,992,750
1995	8.41	$8,961,750	$940,799	$7,937,762	$16,619,900	$1,744,746	$14,737,496
1996	7.75	$2,362,100	$236,127	$7,345,606	$30,466,200	$3,045,545	$17,778,971
1997	6.66	$4,431,950	$407,354	$7,512,753	$28,047,900	$2,577,971	$20,348,726
Average Annual Payments				$5,081,007			$4,178,015
Total Average Annual Payments				$9,259,023			

Note: Assumes 20-year lifetime & 20-year loan term at Govt. of Canada Benchmark Bond Yields. Long-Term Rates (Bank of Canada 1999)