Interim Report to the Minister of the Environment

Executive Summary

This *Interim Report* to the Minister of the Environment presents preliminary findings of research and analysis conducted by the National Round Table on the Environment and the Economy (NRTEE). This report is in response to a request from the federal government for advice on targets and scenarios for reducing emissions of greenhouse gases (GHGs) and air pollutants in Canada in the medium- and long-term.

The report reflects economic analysis conducted by NRTEE on the costs associated with various GHG and air pollutant reduction targets. It does not, however, provide any detailed analysis of the benefits – economic, environmental, or social –that might accrue from such reductions. Nor is the NRTEE in a position to comment on what the costs of inaction might be, if such targets are not achieved.

The preliminary analyses on GHG and air pollutant targets and pathways to achieve the targets were conducted using an integrated, energy-economy equilibrium model. The model uses an emission "price" in the scenario analyses. An emissions "price" is a price placed on carbon emissions through the implementation of an emissions cap and permit trading scheme, and/or an emissions tax.

The *Interim Report*:

- summarizes the scope and methodology of the NRTEE's work to date;
- provides key initial findings of commissioned research under GHGs, air pollutants (sulphur dioxide, particulate matter, nitrogen oxides, and volatile organic compounds) and integrated approaches; and,
- identifies research questions and next steps in the NRTEE's work.

Specifically, this report provides initial findings on scenarios that examined 45% and 65% GHG emission reductions (below 2003), as requested by the Minister. Further to these scenarios, the NRTEE is currently examining deeper emission reductions in the order of 80% (below 2003 levels).

A final report, with conclusions and recommendations, will be provided to the Minister in the Fall of 2007.

GHG Emissions Reductions

The NRTEE has examined the implications of long-term GHG emissions reductions of 45% to 65% (below 2003 levels) by 2050. This report provides cost estimates of these two targets, expressed as dollars per tonne of CO_2 equivalent. Our intention in providing these estimates is to help the government – and Canadians – make informed decisions on medium- and long-term GHG policy. To attain a 45% reduction target, the price is estimated at \$160 and \$200/tCO_2e in 2050. To attain a 65% reduction target, price estimates are \$270 and \$350/ tCO_2e in 2050. The difference in prices is attributed to the GHG price path scenarios — "fast" versus "slow". A "fast" start implies relatively higher emissions prices in the near term and lower prices in the longer term; whereas a "slow" start implies relatively lower emissions prices in the near term and higher prices in the longer term. The higher prices are associated with a "slow" start.

In addition to these cost estimates, the NRTEE's research finds that:

- In order to meet deep GHG emission reduction targets, the immediate implementation of a clear, consistent, and long-term policy (such as an emissions price) by the government is critical. Such a policy needs to place a price on carbon, which could be implemented, for example, through an emissions cap and permit trading scheme, and/or an emissions tax.
- Establishing and reaching medium-term targets is critical if the long-term targets of 45% and 65% reductions by 2050 are to be achieved. Any delay in the implementation of the GHG price may put some long-term GHG targets beyond Canada's reach and will mean that future emission prices will need to rise significantly.
- Medium and long-term targets should be set in combination to account for reductions of cumulative emissions between now and 2050.
- Canada's contribution to the international effort to reduce GHG emissions has not yet been determined, but could end up calling for a "faster and deeper" reductions path than currently envisioned by the Government of Canada.

Air Pollutant Emission Reductions

Reducing emissions of sulphur dioxide, nitrogen oxides, and volatile organic compounds by up to 50% is achievable with a relatively modest emissions price, but reductions beyond this level require the price to rise considerably. The one key exception to this general conclusion is PM, where the high process emissions in several industries make reductions in the order of 50% prohibitively expensive.

Integrated Approach for Emission Reductions

Even without an integrated approach, there can be significant co-benefits in terms of local air pollution from policies that produce deep GHG reductions, and vice versa.

There are important enhanced benefits that can be realized when addressing GHG and air pollutant policies at the same time, with significant opportunities for co-pollutant reductions when policies are designed and implemented concurrently.

1 Introduction

1.1 Purpose

This *Interim Report* to the Minister of the Environment presents preliminary findings of research and analysis conducted by the National Round Table on the Environment and the Economy (NRTEE) in response to a request from the federal government for advice on targets and scenarios for reducing emissions of greenhouse gases (GHGs) and air pollutants in Canada.

The *Interim Report*:

- summarizes the scope and methodology of the NRTEE's work to date;
- provides key initial findings of commissioned research under GHGs, air pollutants and integrated approaches; and
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A final report, with conclusions and recommendations, will be provided to the Minister by Fall 2007.

1.2 The Problem of GHGs and Air Pollutants

The impacts of greenhouse gases (GHG) and air pollutants (known as criteria air contaminants, or CACs) are a global concern. Scientific research is increasingly certain that anthropogenic GHG emissions are creating a discernable impact on the Earth's climate. Central to this certainty is the observation that the atmosphere's concentration of carbon dioxide (CO_2), the principal GHG, is about 35% higher than its pre-industrial concentration of 280 parts per million by volume [ppmv]. Further, the current concentration of CO_2, about 380 ppmv, has not occurred for hundreds of thousands, and perhaps even millions, of years. CO_2 emissions have grown between 1970 and 2004 by about 80%, and represented 77% of total anthropogenic GHG emissions in 2004.[1] The largest growth in global GHG emission between 1970 and 2004 has come from the energy supply sector (an increase of 145%). A main conclusion flowing from international scientific research is that in the absence of significant action to reduce GHGs emissions, atmospheric concentration of carbon will continue to increase, potentially causing "dangerous climate change"; typified by disruptions in the Earth's temperature, precipitation, sea levels, ocean currents, biodiversity, and other natural systems.[2]

Canada continues to add to the atmospheric stock of GHGs. Canada's emissions grew by 27% between 1990 and 2004, and were approximately 2% of global GHG emissions in 2004. Furthermore, Canada's per capita emissions are among the highest in the world and continue to increase.[3] As NRTEE members wrote in their advice to the government in advance of the

1 Total GHG emissions include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and hydrofluorocarbons (HFCs).

2 For a summary of global climate change science, see: Intergovernmental Panel on Climate Change (IPCC). 2007. "Climate Change 2007. The Physical Science Basis – Summary for Policymakers," World Meteorological Organization / United National Environment Program, New York: Cambridge University Press.

3 Details on Canada's GHG emissions by sector and by region are available from: Government of Canada, 2006, "Canada's Greenhouse Gas Inventory, 1990-2004". Ottawa: Environment Canada.

international Conference of the Parties hosted by Canada in 2005 (COP-11): "We believe that the current and projected impacts of climate change constitute a significant threat to Canada's national interest. Without deliberate global action to address GHG emissions, an accelerating rate of climate change will result in impacts that will threaten the sustainability of Canada's economy and environment and the high quality of life that Canadians enjoy".

There is increasing pressure, both nationally and internationally, to take strong and immediate action to reduce GHG emissions. To date, much of the national and international focus on climate change mitigation has been on short-term emission reduction targets, as articulated in the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). More recently, focus has shifted somewhat towards taking a longer-term view of emission reduction targets looking beyond 2012. However, no internationally agreed-upon quantitative long-term goal for GHG stabilization exists. The UNFCCC (through the Intergovernmental Panel on Climate Change (IPCC)) provides some guidance as to the form of an appropriate long-term goal: "to achieve the stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[4]

CACs, including volatile organic compounds (VOCs), sulphur oxides (SO_x), nitrous oxides (NO_x), carbon monoxide (CO)[5], and particulate matter (PM)[6] (individually or in combination as smog and acid rain) have been shown to cause adverse health and environmental impacts. Notably, scientific evidence indicates a positive correlation between ambient air concentrations of the pollutants and significantly adverse effects on human health, ranging from chronic bronchitis to premature death and increased mortality. From an environmental perspective, smog has been linked to reduced plant productivity resulting in reduced agriculture crop yields and forest growth. Acid rain and acid deposition from SO_x and NO_x emissions also present a well known threat to ecosystems, notably lakes and forests.

Due to the serious health and environmental impacts of CAC emissions, governments in Canada have a long history of developing policies to address these issues. However, despite small improvements in CAC emissions in recent years, local air pollution in many parts of the country continues to cause significant health and environmental impacts, and therefore remains a focus of government policy.

Given the twin air emission pressures of GHGs and CACs, the Government of Canada is developing a coordinated regulatory approach for addressing both.[7]

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4 United Nations, United Nations Framework Convention on Climate Change. New York: United Nations, 1992, accessed from http://unfccc.int/resource/docs/convkp/conveng.pdf, June, 2005.

5 Carbon monoxide is an important indoor air pollutant, but was not considered as part of this work.

6 Airborne particulate matter (PM) consists of many different substances suspended in air in the form of particles (solids or liquid droplets) that vary widely in size. PM_{10} includes particulate matter with a mass median diameter of less than 10 μm; whereas PM2.5 has a mass median diameter less than 2.5 μm. The size of PM particles determines the extent of environmental and health damage caused.

7 Available at: http://www.ecoaction.gc.ca//news-nouvelles/20070426-1-eng.cfm.

1.3 The Government's Clean Air Act Reference

In October 2006, the federal government introduced *Canada's Clean Air Act* to Parliament, along with the *Notice of Intent to Develop and Implement Regulations and Other Measures to Reduce Air Emissions*. The Act and the Notice set out the government's proposed plan to develop regulations for air emissions in key industrial sectors. Section 10 of the Notice identified a role for the NRTEE. This role was reiterated and enhanced through a Letter of Reference from the Minister of the Environment to the NRTEE Chair in November 2006. The Reference asks the NRTEE to provide advice on the following:

GHG Emissions

- Medium-term emissions reductions targets for 2020-2025 for GHG emission reductions for a number of specified industry sectors, recognizing the government's intention to build upon the emissions-intensity approach with targets that are ambitious enough to translate effectively into a fixed cap on absolute emissions; and,
- The national emissions target that should be adopted within the range for a 45% – 65% reduction from 2003 levels by 2050, and scenarios for how this target could be achieved.

Air Pollutants

- National objectives for ambient air for particulate matter and ozone for the periods of 2020-2025 and 2050; and
- National emission reduction targets for 2050 for total emissions of sulphur dioxide, nitrogen oxides, gaseous ammonia, volatile organic compounds, and particulate matter, for a number of specified industry sectors.

The NRTEE was also directed to draw on experiences from other industrialized countries that are also looking at targets and policy approaches for GHG and air pollutant emissions reductions.

Since directing the Reference to the NRTEE, the Government of Canada released the *Regulatory Framework for Air Emissions* (April 2007), in which it committed to reducing GHG emissions by 60% to 70% below 2006 levels by 2050. In its final phase of work the NRTEE will expand the scope of its analysis to address the implications of three GHG reduction targets: 45%, 65% and 80% (below 2003).

2 NRTEE's Approach

2.1 Organizing the Reference

In developing its overall approach, the NRTEE first organized the government's Reference into three distinct, though related, elements: *objectives*, *targets* and *pathways*:

- *Objectives* are essentially those outcomes that Canada is trying to achieve as a nation. For GHGs they can be expressed as long-term ambient concentrations of CO_2 that are set based on an understanding of how emissions ultimately adversely impact sensitive climate, ecosystem and human receptors. For GHGs, the objective is likely Canada's share of global emissions that stabilize atmospheric concentrations of CO_2 at a level that avoids "dangerous climate change". The Reference does not specifically request advice on a GHG objective for Canada. However, the NRTEE has concluded that a clearly articulated national objective linked to stabilizing atmospheric carbon levels can help the government evaluate the likely effectiveness of possible emission reductions targets.

  Air pollution is a real concern to Canadians and their natural environment. For air pollutants, the overall objective is to have clean air. Objectives, while set at a national level, are best expressed as regional and local targets that will have a direct and real effect on the health of Canadians and ecosystems. The ambient air quality objectives are often specified as annual average concentrations for particulate matter and ozone.

- *Targets* are the emission reductions that contribute to the attainment of the objectives. These targets can differ in timing and scope.

- *Pathways* (or scenarios) are the preferred trajectories of emission reductions that achieve the national emission reduction targets. Policies that achieve the preferred pathway are based on a consideration of a range of factors such as environmental effectiveness, economic efficiency, political acceptability, distribution and competitiveness. Other considerations such as technology, GDP growth and structural change in the economy also influence the preferred pathway.

These elements provide the overarching framework of the NRTEE's approach to delivering the Reference advice. A number of activities were then developed to address the work elements:

- First, the NRTEE commissioned a number of research studies for this initial work. The research covers a range of topics, including pathways for long-term reductions in emissions of GHGs and air pollutants, economic implications, co-benefits of GHG and air pollutant emission reductions, and comparative international approaches and the question of Canada's "share" of global reductions.[8] Further research studies are underway and planned for the coming months (see Section 6).

- Second, the NRTEE has engaged expert advisory groups to validate its research approach, findings, and recommendations throughout the development of its advice to the Minister. The advisory groups include individuals from industry, academia, government and non-governmental organizations.

8 See Appendix 1 for a list of the commissioned research studies.

- The NRTEE plans to discuss the research findings and its preliminary recommendations with a broader group of stakeholders in the summer and fall. While the research findings and advice are likely to be of great interest to many Canadians, time constraints will limit the extent of the NRTEE's wider consultations in this phase.
- Finally, the findings and recommendations will be the subject of thorough review and dialogue by NRTEE members. The final report will represent a consensus of the members.

2.2 Scope of the Preliminary Analysis

The preliminary analyses on GHG and CAC targets and pathways to achieve the targets were conducted using CIMS, an integrated, energy-economy equilibrium model.[9] CIMS has a detailed representation of technologies that produce goods and services throughout the economy and attempts to simulate capital stock turnover and choice between these technologies realistically. It also includes a representation of equilibrium feedbacks, such that supply and demand for energy intensive goods and services adjusts to reflect policy (or "price").[10] CIMS uses an emissions "price" in the scenario analyses. An emissions "price" is a price placed on carbon emissions through the implementation of an emissions tax and/or an emissions cap and permit trading scheme. The emissions price is the highest price required to reduce carbon to a level that achieves the medium-term and long-term objectives, but recognizes that most if not all emission reductions occur at a price that is lower. The emissions price pathways that are modeled capture the strength of a market-based price required to achieve a given level of emissions reductions. For both GHG and CAC emissions, there is substantial momentum internationally towards market-based systems, such as emissions taxes, or emissions cap and permit trading schemes. Taxes have been applied extensively in Europe to address air pollutants while emissions cap and permit trading markets are operational in both the United States and Europe for air pollutants and carbon respectively. This research is a quantitative exploration of these market-based GHG and CAC policies.

The scope of the analysis is limited to "energy-related" GHG and CAC emissions. These are the emissions of GHGs (primarily CO_2, but also methane and nitrous oxide) that result from the production and consumption of fossil fuels. Approximately 82% of GHG emissions in Canada originate from energy-related sources. The remaining non-energy emissions[11] are beyond the scope of this study. CIMS covers nearly all CACs in Canada except those from open sources (like forest fires, soils, and dust from roads).

In summary, the GHG emissions reductions modeled in CIMS can be realized through energy efficiency, fuel switching, carbon capture and storage (CCS), and overall demand reduction. Similarly, the CAC emissions reductions can occur though these actions, as well as through tailpipe controls. The full report of the modeling analysis is available.[12]

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9 For a full description of the CIMS model refer to "Pathways for Long-term Greenhouse Gas and Air Pollutant Emissions Reductions". Report by J&C Nyboer and Associates for the NRTEE. April 2007.

10 See Appendix 2 for a description of the key attributes of CIMS.

11 CIMS does not include agroecosystems, the waste sector, solvent, or hydrofluorocarbon emissions.

12 Pathways for Long-term Greenhouse Gas and Air Pollutant Emissions Reductions. Report by J&C Nyboer and Associates for the NRTEE. April 2007.

For GHG emission reductions, four different scenarios were evaluated, incorporating two different reduction targets (45% and 65% below 2005 levels by 2050) and two different GHG price path scenarios ("fast" and "slow"). A "fast" start implies relatively higher emissions prices in the near term and lower prices in the longer term; whereas a "slow" start implies relatively lower emissions prices in the near term and higher prices in the longer term.

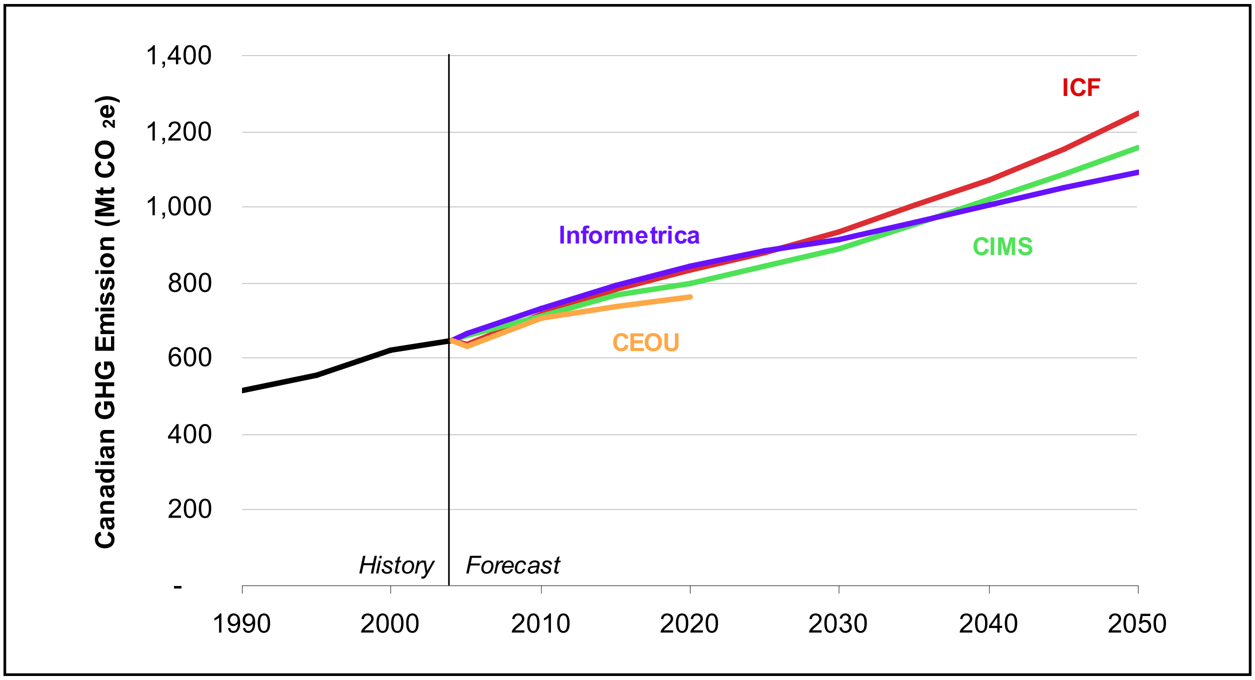
For CAC emissions (SO_x, NO_x, VOCs, and PM), reductions of 50% and 99% from 2005 levels by 2050 were initially evaluated. However, reductions of 99% were unable to be achieved in the model. Instead, targets of 50% and 80% reductions by 2050 for all the CAC emissions were analyzed.

A key aspect of the government's *Regulatory Framework for Air Emissions* is to address both GHG and air pollutant emission reductions in an integrated manner. Therefore, the research underway is also exploring the potential reductions that can be achieved when policies addressing both types of reductions are implemented concurrently.

3 Initial Findings – Greenhouse Gas Emissions

In the absence of government interventions, substantial increases in Canada's GHG emissions can be expected through 2050, primarily as a result of natural resource development and economic growth. GHG emissions in 2020 could be in the order of 65% greater than 1990 levels and will be more than double 1990 levels by 2050, according to some estimates (Figure 1). While there are slight differences between the forecast the NRTEE used and other established forecasts, the overall magnitude of each forecast is quite comparable, suggesting that the conclusions, relating to GHG growth in the "business as usual" (BAU) scenario, are sound.

Figure 1: Comparison of "business as usual" forecasts for Canadian GHG emissions



Notes: ICF forecast comes from NRTEE, 2006, "Advice on a Long-term Strategy on Energy and Climate Change", Ottawa: NRTEE. Informetrica forecast comes from Informetrica, 2007, "Projection of Total GDP for the Long-term". CEOU forecast comes from Analysis and Modelling Division, 2006, "Canada's Energy Outlook: The Reference Case 2006", Ottawa: Natural Resources Canada.

3.1 Long-term GHG emissions reductions of 45% to 65% (below 2003 levels) by 2050 are achievable.

The NRTEE has examined the implications of long-term GHG emissions reductions of 45% to 65% (below 2003 levels) by 2050. Our estimates of the cost implications of these targets tests the trade-off between environmental objectives and economic impacts, in order to help Canadians make informed decisions.

The primary finding from the NRTEE's research undertaken to date is that reducing GHG emissions by 45 to 65% below 2003 levels by 2050 is achievable. Such reductions would require significant use of energy efficiency, fuel switching, renewables, and CCS. This finding is consistent with many other studies (including a recent study by the NRTEE[13]).

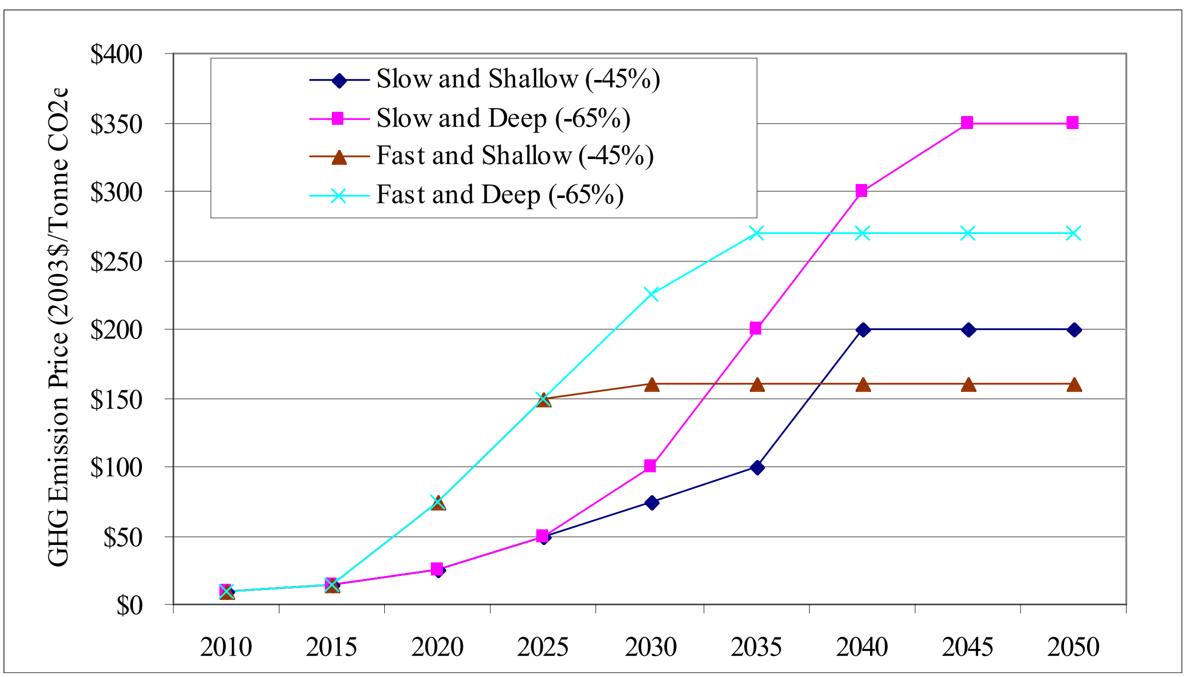
Four GHG reduction scenarios were evaluated with two different targets (45% and 65%), and two different GHG price path scenarios (Table 1). Alternative GHG emissions price trajectories were simulated in order to stimulate GHG reductions corresponding to these targets. Figure 2 and Table 2 show the GHG emissions price trajectories used to reach the targets identified in each scenario.[14]

Table 1: Scenarios modelled for GHG emissions reductions

Scenario	Long-term goal (2050)	Medium-term goal (2020 – 2025)
Shallow GHG reductions; ***slow*** start	-45% GHG	Stabilize Emissions
Deep GHG reductions; ***slow*** start	-65% GHG	Stabilize Emissions
Shallow GHG reductions; ***fast*** start	-45% GHG	Reduce Emissions
Deep GHG reductions; ***fast*** start	-65% GHG	Reduce Emissions

Regardless of pathway, the analysis firmly concludes that a very strong price signal is required to stimulate deep GHG reductions by 2050. To reiterate, in the cases modeled here, this is a price that applies throughout the economy and begins immediately.

Figure 2: GHG emission price trajectories for each policy scenario



13 National Round Table on the Environment and the Economy, 2006, "Advice on a Long-term Strategy on Energy and Climate Change", Ottawa: NRTEE.

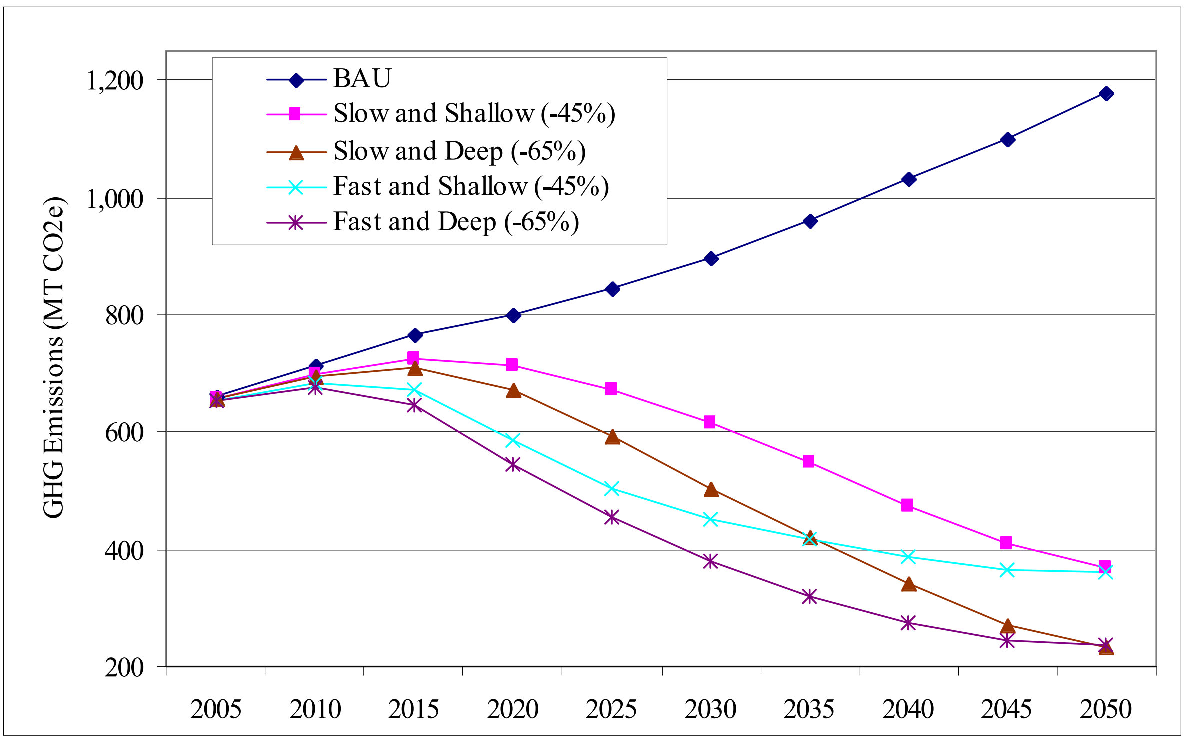
14 The price trajectories that are shown here represent only four of many possible paths for reaching the desired medium and long-term targets.

Table 2: GHG Emission Prices for each GHG Emission Reduction Scenario (2003$/tonne CO2)

Scenario	2010	2015	2020	2030	2040	2050
Slow and Shallow (-45%)	$10	$15	$25	$75	$200	$200
Fast and Shallow (-45%)	$10	$15	$75	$160	$160	$160
Slow and Deep (-65%)	$10	$15	$25	$100	$300	$350
Fast and Deep (-65%)	$10	$15	$75	$225	$270	$270

Using the trajectories shown in Figure 2, the modeling projects the impact on GHG emissions in Figure 3. As illustrated, it is possible to attain long-term targets with either a "fast" or "slow" start. However, the "slow" start requires a significantly higher emissions price in the latter years to compensate for the low emissions price in the beginning years, which allow emissions to grow more. Regardless, however, the modeling shows that the emission reductions targets are achievable.

Figure 3: GHG emissions forecasts in business-as-usual and the alternative prices scenarios



Estimated Effects on GDP

The modeling done for this analysis provides estimates of lost GDP associated with each scenario, which must be compared against a baseline forecast for context. We have compared these estimates against the NRCan CEO/Informetrica Ltd. forecast used to provide the primary drivers for the modeling (Table 3). BAU GDP in 2011 is estimated to be 1.27 trillion, and is expected to grow by 1.83% per year (cumulative) to 2.61 trillion in 2050. In our GHG reduction scenarios, GDP grows by rates ranging from 1.79% to 1.82%, leading to GDPs in 2050 ranging from 2.58 trillion to 2.60 trillion. This translates into lost growth from 2011 to 2050 of 0.9% to 2.9% as a percentage of growth in the BAU forecast. Put another way, it takes Canada between 0.5 and 1.6 years longer to get to the same GDP level as it would have had in BAU in 2050. These results indicate small reductions in the size of the economy under all four scenarios.

Fast and Shallow causes the least lost growth (0.9%, or 0.5 years), while Slow and Deep causes the most (2.9%, or 1.6 years). Comparing the deep reduction runs, Fast and Deep costs roughly half as much as Slow and Deep to get to the same reduction target (1.6% vs. 2.9%, or 0.9 years vs. 1.6 years).

Table 3: Comparison of changes in total GDP from 2010- to 2050 ($1997)

	GDP - 2011 (trillion)	2011-50 Compound Growth rate	GDP - 2050 (trillion)	Lost growth 2011-2050, as a percent of BAU	"Years of lost growth"	Average annual losses as % of BAU
BAU	1.267	1.83%	2.613			
Slow and Shallow		1.81%	2.591	1.6%	0.9	-0.90%
Fast and Shallow		1.82%	2.600	0.9%	0.5	-1.05%
Slow and Deep		1.79%	2.574	2.9%	1.6	-1.31%
Fast and Deep		1.81%	2.591	1.6%	0.9	-1.44%

The annual reductions in GDP are not even between 2011 and 2050; the most adjustment occurs from 2030 to 2045, with the economy re-stabilizing on its new less GHG intense path by 2050. While the annual reduction in GDP for the four scenarios lies between 0.90% and 1.44% of BAU GDP per year, when averaged over the forty year period, the individual yearly costs over the period varying from 0.1% to 2.3% per year (Table 4). The reader should note these costs are NOT cumulative – they are subtracted from potential GDP in the year in question, while the underlying potential GDP continues to grow at an average of 1.83% per year from 2011 to 2050 (which results in GDP growing in BAU from 1.27 trillion in 2011 to 2.61 trillion in 2050).

Table 4: Reduced Size of the Economy under the Four Scenarios

	Reduction in GDP in a given year as a % of forecasted BAU GDP							
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Slow and Shallow	-0.1%	-0.6%	-0.8%	-0.9%	-1.1%	-1.6%	-1.4%	-0.8%
Fast and Shallow	-0.5%	-1.2%	-1.6%	-1.5%	-1.3%	-1.1%	-0.7%	-0.5%
Slow and Deep	-0.3%	-0.5%	-0.7%	-1.1%	-1.9%	-2.3%	-2.2%	-1.5%
Fast and Deep	-0.5%	-1.1%	-1.7%	-2.1%	-2.2%	-1.7%	-1.3%	-0.8%

A caveat must be made that the GDP forecast upon which this analysis is based, and to which our GDP costs are compared, is fundamentally driven by population, labour force participation, labour productivity, savings rates, the relative attractiveness of Canadian investment and capital productivity. This analysis was not set up to automatically adjust these key parameters within the GDP forecast in response to climate policy costs, mainly because they are more sensitive to a broader spectrum of drivers, especially long term political decisions regarding immigration, education and labour and capital taxation. These variables were taken as being unchanging between BAU and the scenarios in this analysis.

Finally, it should be noted that these preliminary estimates of GDP effects should be treated with care. Although GDP is used as a measure of the change in economic activity, it is not direct measure of the change in human welfare. GDP is roughly analogous to the sum product of the price of all goods and services consumed multiplied by the physical output of these goods and services. In the results of the modeling undertaken for the NRTEE, the price of many of these goods and services has increased to pay for the cost of reducing their GHG intensity, and overall physical consumption of these goods and services has fallen in response to the price increase. This implies some welfare loss associated with reduced consumption. However, GDP does not fall significantly, because the remaining consumption is multiplied by a higher price.

3.2 Clear, consistent, and long-term communication by the government of GHG prices is critical if the targets are to be achieved.

When businesses and individuals make investments with a long lifetime, they implicitly or explicitly consider the financial performance of those investments over the expected life of the investment. The analysis conducted for the NRTEE assumes that the government clearly communicates to businesses and individuals a schedule for GHG prices well in advance and inspires confidence in firms and consumers that the policy will be enduring. As a result, businesses and individuals have some expectation of a future GHG price, and use this knowledge to make decisions about carbon-reducing technology investments. This type of clear communication can dramatically improve the effectiveness of a policy.

Conversely, if the government neglects to clearly communicate the GHG price schedule well in advance, it risks causing serious economic dislocation when it actually implements each increase in the price, because society's capital stocks will not be well prepared for the abatement effort required. GHG reductions would then be smaller for the same GHG price.

In essence, inadequate and delayed communication by the Government of a GHG "price" could lead to substantial long-term economic costs. Notably, the recent Stern review[15] concluded that "the costs of climate change for developed countries could reach several percent of GDP", and that delay of action would result in higher costs.

15 *The Economics of Change: The Stern Review.* N. Stern, 2007. Cambridge University Press.

3.3 *Establishing and reaching medium-term targets is critical if the long-term targets of 45% and 65% reductions by 2050 are to be achieved. Any delay in the implementation of the GHG price may put some long-term GHG targets beyond Canada's reach and will mean that future emission prices will need to rise significantly.*

The 45% reduction target is likely achievable if emissions are at least stabilized at 2003 levels in 2025. However, the 65% target may not be achievable if emissions are only stabilized at 2003 levels in the 2020 to 2025 period. This "non-attainment" risk exists since there is a high rate of capital stock turn-over in the 2020 to 2025 period and therefore an opportunity to shift the economy onto a lower emissions path. If this opportunity is missed and investment decisions do not result in the deployment of lower emitting technologies, the economy will become locked into a future emissions path from which reductions to the 65% level will either be too costly or simply unattainable. To attain the 65% target by 2050, reductions below 2003 levels on the order of 10% to 30% are necessary by 2025. Table 5 summarizes the medium–term GHG targets that can be attained.

Table 5. Medium-term targets for GHG emission reductions

Scenario	GHG Emissions Reductions in 2020	GHG Emissions Reductions in 2025
BAU	+21%	+28%
Slow & Shallow (-45% GHGs in 2050)	+8%	+2%
Slow & Deep (-65% GHGs in 2050)	+2%	-9%
Fast & Shallow (-45% GHGs in 2050)	-11%	-23%
Fast & Deep (-65% GHGs in 2050)	-17%	-31%

Regardless of the medium-term target chosen, if emissions reductions are pushed into future periods, the overall costs of achieving the reductions will rise.

A later start implies that the GHG price signal eventually has to reach higher levels to produce the same level of GHG reductions, and that a very late start will jeopardize reaching any deep reduction target at all. The modeling undertaken for the NRTEE considered not only different long-term GHG targets for Canada, but also different trajectories (that is, different GHG prices pathways) that aimed to reach the long-term targets. The results of this modeling suggest that the earlier a strong GHG price is implemented, the lower the ultimate price needs to be to reach a given level of emissions reductions. Importantly, the modeling concluded that a delay in the implementation of a GHG price may mean that some long-term GHG targets will be beyond Canada's reach.

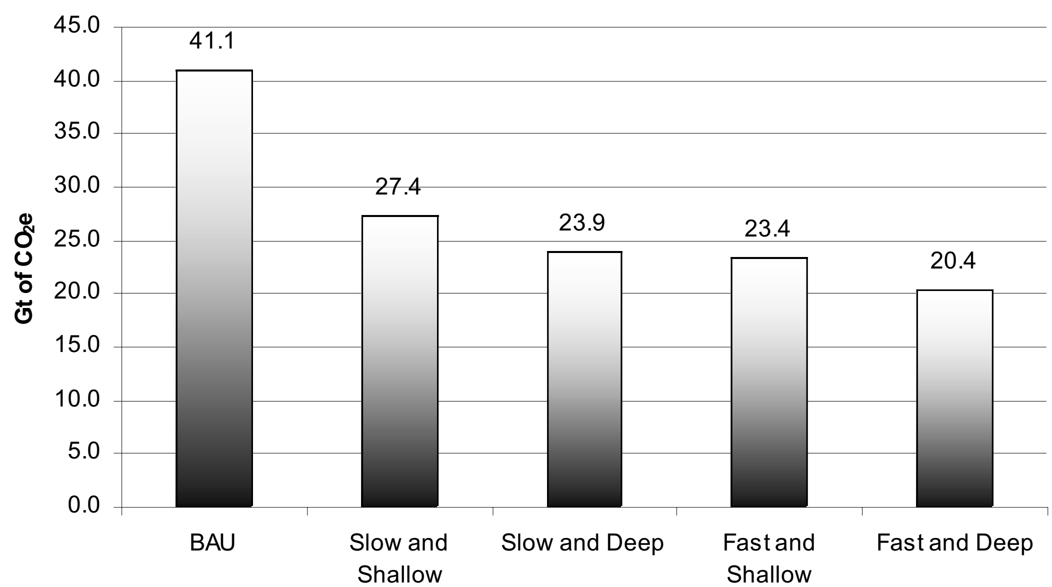
3.4 *Medium and long-term targets should be set in combination to account for reductions of cumulative emissions between now and 2050.*

While annual targets in the medium and long-term are important, it is critical to keep in mind that the cumulative emissions between now and 2050 will remain in the atmosphere for at least 100 years (hence the reference to GHGs as a "stock" pollutant).

Figure 4 illustrates the cumulative GHG emissions from 2006 to 2050 in the BAU scenario and each of the four policy scenarios. (Note that in the table emissions are measured in "gigatonnes of CO_2e", a thousand-fold increase over the million tonnes CO_2e unit of measure typically used in discussions of emissions.) In the most aggressive scenario – the "fast and deep" scenario – cumulative emissions are reduced by about 50% compared to BAU levels. GHG prices that increases quickly ("fast pathway") reduce cumulative GHG emissions significantly more than the pathways where the start is delayed. As a result, even though the "fast" and "slow" pathways can be designed to reach the same target for annual GHG emissions in 2050, the overall environmental improvement from the "fast" pathways will be greater than for the "slow" pathways for the same target.

However, the research also suggests that the "fast price" pathway combined with the shallow target results in about the same cumulative emissions reductions as the "slow" pathway with a deeper target.

Figure 4: Cumulative emissions in BAU and the alternative GHG emissions prices



3.5 Canada's contribution to the international effort to reduce GHG emissions has not yet been determined, but could end up calling for a "faster and deeper" reductions path than currently envisioned.

Long-term objectives for global GHG emissions reductions are being set internationally, based on atmospheric stabilization goals that avoid dangerous climate change. International goals for GHG stabilization range between concentrations of about 450 and 650 ppmv CO_2e[16], based on differing interpretations of "dangerous" human interference with the climate system.[17] Regardless of the level ultimately selected, it is clear that stabilization of atmospheric GHG concentrations during the 21st century at a level to minimize climate change impacts will require a significant departure from current emission trends. Global emissions will need to decline substantially compared to today, dropping below current emissions and declining to almost zero over time. The earlier the emissions peak and decline, the lower will be the stabilized concentration level, leading to a lower level of climate change impacts at a global level. The atmospheric GHG concentration at stabilization will be determined by the time taken to reduce emissions to near zero, and by the cumulative emissions released during the transition.

The question of Canada's contribution (burden) to this global GHG emissions reduction effort involves consideration of the following factors:

- the choice of stabilization level (between 450 and 550 ppmv);
- the choice of burden-sharing approach;
- the starting point of emissions in 2008-2012 which is used as a basis for emission allowances afterwards; and
- Canada's national circumstances.

A singular focus on climate change prevention suggests that Canada's emission reductions in 2050 may need to be in the order of 75% to 95% below 2003 levels in 2050, well beyond the government's announced target of 60% to 70%. If such a long-term target is accepted, then this suggests that a "fast" start is critical, and the medium-term (2020) target will have to be greater than stabilization at 2003 levels.

Further analysis is needed in order to identify a range of allowances that reflect Canada's national circumstances. The NRTEE will further investigate what these national circumstances could involve, and will present its findings in the final report.

16 For comparison purposes, GHG emissions are reported in units of carbon dioxide equivalent (CO_2e). CO_2 equivalent is a unit used to standardize measurements and facilitate emissions trading. For example, tonne for tonne, methane is a greenhouse gas that is 21 times more powerful than carbon dioxide in causing the global greenhouse effect. Therefore one tonne of methane represents 21 tonnes of CO_2 equivalent.

17 See IPCC (2001).

4 Initial Findings – Air Pollutant Emissions

Accurately forecasting the emissions, ambient concentration, and health effects of CAC emissions is much more challenging than for GHG emissions. As with GHG emissions, CAC emissions from humans result primarily from fossil fuel combustion. However, CAC emissions differ in three important ways. First, CAC emissions have the greatest effect in the local area around the emissions source. Second, most CACs have a fairly short residence period in the atmosphere, so impacts can vary significantly over time. Finally, while combustion-based GHG emissions can be linked closely to the amount of fossil fuel combusted, combustion-based CAC emissions can vary greatly depending on conditions, fuel quality and end-of-pipe emission controls.

As a result of these differences the forecasts generated in the modeling undertaken for the NRTEE should be considered indicators of overall trends, rather than absolute values.[18]

4.1 Reducing air pollutant emissions by up to 50% is achievable with a relatively modest emissions price signal, but beyond this level, the price must rise considerably.

For CAC emissions, reductions targets of 50% and 80% by 2050 were analyzed (Table 6).

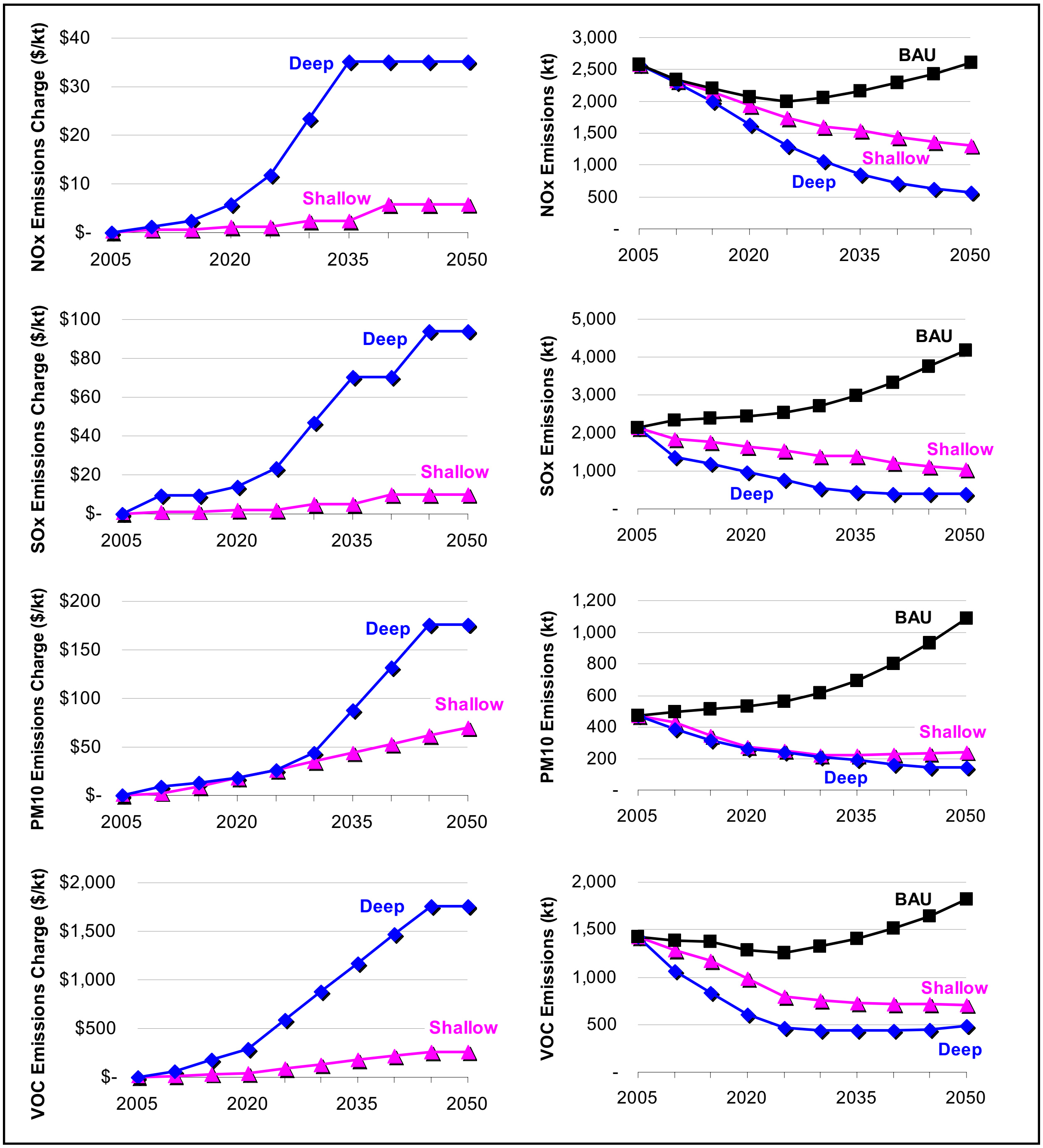
Table 6: Scenarios modelled for CAC reductions

Scenario	Long-term goal (2050)
Deep NO_X Reductions	-80% NO_X
Shallow NO_X Reductions	-50% NO_X
Deep SO_X Reductions	-80% SO_2
Shallow SO_X Reductions	-50% SO_2
Deep PM Reductions	-80% PM_{10}
Shallow PM Reductions	-50% PM_{10}
Deep VOC Reductions	-80% VOC
Shallow VOC Reductions	-50% VOC

Reducing CAC emissions to 80% below 2003 levels by 2050 is possible, though requires a high price signal. Reducing emissions to 50% requires a much more modest price signal (Figure 5), except for PM which requires a considerably higher emissions price due to process emissions in a number of industries in which abatement options are not available. For both NO_X and SO_X, the emissions price required to reach the deep target is about six-to-ten times greater than the price required to reach the shallow target. This indicates that the costs of reducing NO_X and SO_X emissions increase substantially if policy makers wish to reduce CAC emissions to 80% below 2005 levels.

18 The national forecast that was used in this analysis provides a useful indicator as to potential health and environmental effects from CAC emissions, but is not sufficient to accurately measure these outcomes, which can only be determined by detailed anal

Figure 5: CAC prices (2003$) and emissions in the BAU and policy scenarios



Neither of the simulations to attain deep (80%) reductions in PM_{10} or VOC emissions reached their target. Rather, emissions of both PM_{10} and VOC reached a level where further increases in the emission price did not yield significant additional reductions. For PM_{10}, the level was reached at about 75% reductions, and for VOCs, just under 70% reductions.

There are two main reasons why the model's simulations did not attain the deep targets for PM_{10} or VOCs. First, a significant portion of PM_{10} and VOC emissions arise from processes over which businesses and consumers have little control if they are to continue pursuing the activity. For example, a large portion of PM_{10} emissions come from processes such as grinding clinker and limestone or blasting and quarrying rock, and a large portion of VOC emissions arise from equipment leaks and exposed oil sands in the upstream oil industry. Second, the model used does not include the abatement technologies required to attain a deep reduction in PM_{10} or VOC emissions. For example, new technologies or processes that may emerge as a result of a GHG price cannot be incorporated in the model. As a result, the modeling may underestimate the emissions reductions caused by emissions prices.

Finally, to achieve reductions in the order of 50% in PM, the modeling indicated that the only option was to reduce industrial output in some sectors, notably oil sands and mining. Reducing output is a very high cost option for reducing emissions, and explains the high PM costs for the 50% target in Figure 5.

5 Initial Findings – An Integrated Approach

Industrial emissions of GHGs and CACs each account for approximately 50% of Canada's total air emissions, and share many common sources. For these reasons, the Government of Canada is looking to coordinate its regulatory efforts to address emission reductions of GHGs and CACs in an integrated manner within the same time frame.

To explore the possible effects and feasibility of an integrated approach, the NRTEE commissioned research to analyze several policy scenarios that combined efforts to reduce GHG and CAC emissions concurrently. Scenarios involving deep and shallow target emission prices for GHGs were combined with shallow target (-50%) prices on CACs (Table 7).

Table 7: Scenarios modeled for integrated GHG/CAC reductions

Scenario	Long-term goal (2050)	Medium-term targets (2020-2025)
Deep and *fast* GHG reductions with 50% reductions in all CACs	-65% GHGs, -50% CACs	Fast start
Deep and *slow* GHG reductions with 50% reductions in all CACs	-65% GHGs, -50% CACs	Slow start

5.1 First, even without an integrated approach, there can be significant co-benefits in terms of local air pollution from policies that produce deep GHG reductions, and vice versa.

Reducing GHG emissions can affect CAC emissions – either positively or negatively – and vice versa (Tables 8 and 9). For example, GHG polices can induce:

- energy efficiency (which lowers the CACs associated with producing energy);
- fuel switching from higher CAC intense to lower CAC intense energy types (for example, coal to natural gas, or fossil fuels to biofuels); and
- the use of CCS, which virtually eliminates SO_2 and PM emissions.

Policies targeting CACs, especially SO_2, encourage fuel switching from relatively high sulphur (and GHG) intensive coal to less sulphur (and GHG) intensive natural gas and electricity.

Table 8: Summary of the effect of actions to reduce GHG emissions on CAC emissions

Response to Climate Policy	General Effect on CAC Emissions
Improve energy efficiency	Decrease CAC emissions
Decrease output	Decrease CAC emissions
Improved maintenance (e.g., to reduce fugitive emissions)	Decrease fugitive CAC emissions (especially NO_x and VOCs)
Fuel switching	Increase CAC emissions if the switch is from fossil fuels to biomass or from gasoline to diesel; decrease CAC emissions if the switch is to coal to gas or from fossil fuels to CAC-benign renewables
Change process technologies	Usually decrease CAC emissions (e.g., switch to inert anodes in aluminum production; switch to coal gasification)
Capture and sequester carbon dioxide	Decrease CAC emissions

Source: Adapted from Tisdale, M., 2003, "The Effect of Climate Policies on Local Air Pollution: Design and Application of a Canadian Modelling Tool", Simon Fraser University Resource and Environmental Management Master's Thesis No. 317.

Table 9: Summary of the effect of actions to reduce CAC emissions on GHG emissions

Response to CAC Policy	General Effect on GHG Emissions
End-of-pipe controls (e.g., selective catalytic reduction, precipitators, baghouses)	Increase fuel consumption and GHG emissions*
Reduce pollutant content in fuels (e.g., low sulphur diesel)	Increase fuel consumption and GHG emissions at refineries
Reduce output	Reduce GHG emissions
Reduce fuel consumption	Reduce GHG emissions
Fuel switching	Increase or decrease GHG emissions
Improved maintenance	Reduce GHG emissions

Table 10 shows the effects of GHG emissions prices on CAC emissions by comparing the growth rate of CAC emissions under the BAU and four policy scenarios (a negative value indicates that the emissions fall from 2005 to 2050). The research shows that high GHG emission prices reduce the growth of most CAC emissions because many actions that reduce GHG emissions also reduce CAC emissions. For example, improvements in energy efficiency or fuel switching to low emissions fuels such as natural gas also reduce emissions of CAC. The implementation of CCS eliminates most SO_X and PM emissions associated with combustion. Certain advanced types of gasification and combustion processes equipped with CCS also eliminate NO_X, as nitrogen is not present during combustion.

While the research shows that a high GHG emissions price will reduce SO_X, NO_X, and VOCs, it also shows that it may increase PM. Energy efficiency, fuel switching and CCS triggered by the GHG policy all reduce PM. At the same time, however, there is a potential for an increase in biomass consumption in the electricity generation and pulp and paper sectors when a high GHG price is implemented. The increase in biomass consumption in these sectors likely would increase PM emissions, offsetting the reductions from other actions (though it is likely that any dramatic increase in the use of biomass would be accompanied by strengthened regulations).

Table 10: Interaction between GHG prices and CAC emissions

	Emissions Growth (2005-2050) Relative to 2005				
	BAU from 2005	**Slow & Shallow From 2005 / From 2050 BAU**	**Slow & Deep From 2005 / From 2050 BAU**	**Fast & Shallow From 2005 / From 2050 BAU**	**Fast & Deep From 2005 / From 2050 BAU**
NO_x	+3%	-23%/-25%	-28%/-30%	-20%/-22%	-26%/-28%
SO_x	+110%	-30%/-60%	-41%/-72%	-27%/-65%	-42%/-72%
PM_{10}	+134%	+149%/+6%	+148%/+6%	+147%/+6%	+149%/+6%
VOC	+26%	+12%/-11%	+8%/-15%	+13%/-11%	+8%/-15%

5.2 There are important enhanced benefits that can be realized when addressing GHG and air pollutant policies at the same time, with significant opportunities for co-pollutant reductions when polices are designed and implemented concurrently.

The research concludes that an integrated approach substantially lowers the GHG price required to achieve the 65% GHG reduction target, compared to when a GHG price is implemented on its own. The reduced emission price is realized because the CAC emission prices encourage investment in higher efficiency and lower emissions technologies, and therefore the GHG price does not have to be as strong to reach the target. The preliminary research suggests that under an integrated approach, with concurrent GHG and CAC policy signals, the GHG price could be about $110/ t CO_2e less than it would otherwise need to be under the “slow price” path, and about $50/t CO_2e less under the “fast price” path.

The research also demonstrates that greater reductions in CAC emissions may be achieved through an integrated approach, at a given emissions price. For each of the CAC emissions, the integrated simulation attains greater reductions compared to when the CAC emissions price is implemented alone. For example, the SO_X price that attains a 50% reduction when implemented alone attains a reduction of 82% when implemented in conjunction with the other CAC and GHG emissions prices.

6 Next Steps

This report represents the NRTEE's initial findings in response to the government's Reference, focusing on the possible effects of a range of target reductions for GHGs and CACs.

The NRTEE is continuing to work on exploring the questions and issues surrounding national and sectoral emission reduction targets for GHGs and CACs. As noted previously, the Government of Canada in April 2007 released the *Regulatory Framework for Air Emissions*, in which it committed to reducing GHG emissions by 60% to 70% below 2006 levels by 2050. In its final phase of work the NRTEE will expand the scope of its analysis to address the implications, in terms of GHG prices, pathways and economic effects, of three reduction targets: 45%, 65% and 80%. Furthermore, the NRTEE's final report will focus its research, recommendations and options on the policy pathways (or scenarios) that could allow Canada to attain a range of emission reduction targets.

This work over the next several months will include:

- exploring policy scenarios to achieve medium-term GHG emission reduction targets, including an examination of GHG prices;
- further analyzing the question of Canada's 'burden' of the global effort to reduce GHGs, in the context of Canada's national circumstances;
- examining how an emissions intensity approach can translate effectively into a fixed cap on absolute emissions;
- further evaluating the potential effects of emission reduction actions on GDP; and,
- examining the issue of a national ambient air quality objective for PM and ozone.

In the summer of 2007, the NRTEE will conduct a limited number of meetings with stakeholders and experts, to discuss the draft findings and recommendations, before submitting a draft final report to the government in September. Following this, the NRTEE will conduct outreach sessions with Canadians in the fall to solicit feedback on the report; these views will be reflected in a final version of the report to the Minister in late fall.

APPENDIX 1

Research Commissioned by the NRTEE in the period February to April 2007, relevant to the Reference.

1. *Pathways for Long-term Greenhouse Gas and Air Pollutant Emission Reductions.* J&C Nyboer and Associates.
2. *Demographic and Population Projections to 2050.* Informetrica Ltd.
3. *Transitioning an Emissions Trading System from Intensity Allocations to a Binding Cap.* Margaree Consultants Inc.
4. *Understanding Canada's Emission Reduction Requirements Under Alternative Climate Stabilization Objectives and Burden-sharing Approaches Submitted.* Ecofys Germany.
5. *International Experiences in Setting Medium and Long-Term Emission Reduction Targets.* Wrangellia Consulting.
6. *Emissions of Greenhouse Gases and Air Contaminants in Canada – Toward Harmonized Strategies.* ICF International.

APPENDIX 2

Key Attributes of the Energy Economy Model: CIMS

The CIMS model, developed by the Energy and Materials Research Group at Simon Fraser University, simulates the technological evolution of fixed capital stocks (mostly equipment and buildings) and the resulting effect on costs, energy use, emissions, and other material flows. The stock of capital is tracked in terms of energy service provided (m2 of lighting or space heating) or units of physical product (metric tons of market pulp or steel). New capital stocks are acquired as a result of time-dependent retirement of existing stocks and growth in stock demand. Market shares of technologies competing to meet new stock demands are determined by standard financial factors as well as behavioural parameters from empirical research on consumer and business technology preferences. CIMS has three modules — energy supply, energy demand, and macro-economy — which can be simulated as an integrated model or individually. A model simulation comprises the following basic steps:

1. An exogenous base-case macroeconomic forecast initiates model runs. If the forecast output is in monetary units, these must be translated into forecasts of physical product and energy services.
2. In each time period, some portion of existing capital stock is retired according to stock lifespan data. Retirement is time-dependent, but sectoral decline can also trigger retirement of some stocks before the end of their natural lifespans. The output of the remaining capital stocks is subtracted from the forecast energy service or product demand to determine the demand for new stocks in each time period.
3. Prospective technologies compete for new capital stock requirements based on financial considerations (capital cost, operating cost), technological considerations (fuel consumption, lifespan), and consumer preferences (perception of risk, status, comfort), as revealed by behavioural-preference research. Market shares are a probabilistic consequence of these various attributes.
4. A competition also occurs to determine whether technologies will be retrofitted or prematurely retired. This is based on the same type of considerations as the competition for new technologies.
5. The model iterates between the macro-economy, energy supply and energy demand modules in each time period until equilibrium is attained, meaning that energy prices, energy demand and product demand are no longer adjusting to changes in each other. Once the final stocks are determined, the model sums energy use, changes in costs, emissions, capital stocks and other relevant outputs.

The key market-share competition in CIMS can be modified by various features depending on the evidence about factors that influence technology choices. Technologies can be included or excluded at different time periods. Minimum and maximum market shares can be set. The financial costs of new technologies can decline as a function of market penetration, reflecting economies of learning and economies of scale. Intangible factors in consumer preferences for new technologies can change to reflect growing familiarity and lower risks as a function of market penetration. Output levels of technologies can be linked to reflect complementarities. Personal mobility provides an example of CIMS' operation. The future demand for personal mobility is forecast for a simulation of, say, 30 years and provided to the energy demand module. After the first five years, existing stocks of personal vehicles are retired because of age. The difference between forecast demand for personal mobility and the remaining vehicle stocks to provide it determines the need for new stocks. Competition among alternative vehicle types (high and low efficiency gasoline, natural gas, electric, gasoline-electric hybrid, and eventually hydrogen fuel-cell) and even among alternative mobility modes (single occupancy vehicle, high occupancy vehicle, public transit, cycling and walking) determines technology market shares. The results from personal mobility and all other energy services determine the demand for fuels. Simulation of the energy supply module, in a similar manner, determines new energy prices, which are sent back to the energy demand module. The new prices may cause significant changes in the technology competitions. The models iterate until quantity and price changes are minimal, and then pass this information to the macro-economic module. A change from energy supply and demand in the cost of providing personal mobility may change the demand for personal mobility. This information will be passed back to the energy demand module, replacing the initial forecast for personal mobility demand. Only when the model has achieved minimal changes in quantities and prices does it stop iterating, and then move on to the next five-year time period.

CIMS' technology data is collected and reviewed in collaboration with the Canadian Industrial Energy End Use Data Analysis Centre (CIEEDAC), an independent data collection and analysis agency co-funded by the Canadian federal government and industry associations, and the other residential, commercial and transportation sectors DACs across Canada. CIMS' technology competition behaviour parameters are researched and established in cooperation with the Energy and Material Research Group of Simon Fraser University; the key parameters in CIMS are set using revealed and stated preference discrete choice studies, and literature review where necessary.

Please visit the Energy and Materials Group website for further documentation of CIMS, *www.emrg.sfu.ca*.