# AN ASSESSMENT OF THE ECONOMIC AND ENVIRONMENTAL IMPLICATIONS FOR CANADA OF THE KYOTO PROTOCOL

**ANALYSIS AND MODELLING GROUP**

**NATIONAL CLIMATE CHANGE PROCESS**

**November 2000**

November 29th, 2000

David Oulton
Co-Chair
NAICC-CC
Suite 600, 55 Murray Street
Ottawa, Ontario K1N 5M3

John Donner
Co-Chair
NAICC-CC
10th Floor, 9915 - 108th Street
Edmonton, Alberta T5K 2G8

Dear David and John:

On behalf of all the members of the Analysis and Modelling Group (AMG), we are pleased to forward its report *An Assessment of the Economic and Environmental Implications for Canada of the Kyoto Protocol*. This report summarizes the analytical approach, the assumptions, the results and the main learnings of the AMG work over the past two years.

The report was prepared in accordance with the mandate approved by the NAICC-CC in mid-1998. This mandate directed the AMG to conduct an integrated analysis of the economic, social, health and environmental implications of the Kyoto Protocol.

All AMG members agree that this document is an accurate reflection of the analytical work to date. While there remain some differences of interpretation in certain areas, there is general consensus on the main learnings.

In the Main Learnings, several issues for further analysis are identified. Moreover, the AMG has acquired important insights about the analytic and consultative processes. If required by NAICC, the AMG will provide its recommendations on both the substance and structure of future analytic effort.

Best regards,

Charles Lester
AMG Co-Chair
Newfoundland and Labrador Dept. of Mines and Energy

Neil McIlveen
AMG Co-Chair
Natural Resources Canada

On behalf of:

Shelley Murphy
British Columbia Ministry of Employment and Investment

Grant Hilsenteger
Alberta Environment

David Hanly
Saskatchewan Energy and Mines

Wilf Falk
Manitoba Bureau of Statistics

Than Nguyen
Ontario Ministry of Energy, Science and Technology

Thomas Storring
Ontario Ministry of Finance

Roger Corbeil
Ministère des Ressources naturelles du Québec

Claude Sauvé
Ministère de l'Environnement du Québec

George Foote
Nova Scotia Department of Natural Resources

Anna Soininen
Dept. of Resources, Wildlife & Economic Development, Northwest Territories

Stephen McClellan
Environment Canada

Jay Barclay
Environment Canada

Réjean Casaubon
Natural Resources Canada

Nick Marty
Natural Resources Canada

# Table of Contents

# List of Charts

# Acknowledgments

In undertaking the "roll up" analysis, the Analysis and Modelling Group (AMG) has benefitted enormously from the advice and assistance of a large number of individuals and organizations from the research, consulting and stakeholder communities.  The professionalism, dedication and cooperative spirit exhibited by these individuals and organizations were critical to the completion of this extraordinarily complex task.  With apologies to anyone inadvertently omitted from the list, the AMG wishes to express its appreciation to the following:

- Richard Loulou, Amit Kanudia and their colleagues at HALOA.

- Mark Jaccard, John Nyboer, Alison Bailie and the staff at M.K. Jaccard and Associates/ERG.

- Carl Sonnen and his associates at Informetrica Ltd.

- Jeremy Rudin, Philip Bagnoli, Aled ab Iorwerth, Tony Peluso and Yazid Dissou from the Department of Finance modelling team

- Doug Bruchet, Al Howatson, Abha Bhargava, Morgan Macrae, Stacey Schorr, Erin Down, Brian Guthrie, Stephen Dobson and the rest of the Climate Change Economic Analysis Forum team

- Peter Sol and Nick Macaluso of Environment Canada

- The Issue Table liaisons, in particular Jack Belletrutti, Darcie Booth, Matthew Bramley, Graham Campbell, John Dillon, Chris Feetham, Michel Francoeur, Rick Hyndman, John Lawson, Tony Lempriere, Bob Redhead, Randolph Seecharan and Ed Wojczynski

- Cathy Wilkinson of Global Change Strategies International Inc., Angelo Proestos of Cheminfo Services Inc., Robert Caton of Alchemy Consulting Inc., Jacek Kamininski of ARM Consultants and Mike Moran of Environment Canada.

- All the members of the Environmental and Health Impacts Subgroup and the Stakeholder Advisory Group

- John Sargent of the Department of Finance and the Tradeable Permits Working Group

- Philippe Crabbé of the University of Ottawa
- André Plourde of the University of Alberta
- Ian Hayhow of Natural Resources Canada
- Former AMG members Warren Bell, Lynn Berthiaume, Trevor Dark, Duncan Ferguson, Tony Harras, Linda Hutchinson, Luis Leigh and Dean Stinson O'Gorman

Two special acknowledgments are warranted:

- The former co-chairs of the AMG, Sue Kirby of Natural Resources Canada and Dan McFadyen of Saskatchewan Energy and Mines, whose vision and leadership were instrumental in establishing the framework in which we worked
- The AMG Secretariat, Catherine Roberts and Nancy Roberts of Natural Resources Canada, who, in addition to their substantive contributions to the analytic effort, accomplished miracles of organization to keep the process on track

# Executive Summary

In April 1998, federal, provincial and territorial Ministers of Energy and Environment launched the National Climate Change Process (NCCP), a wide-ranging inquiry into the feasibility and implications of Canada's Kyoto Protocol commitment. The centrepiece of the NCCP was the establishment of a number of Issue Tables and Working Groups to address and make recommendations concerning various dimensions of the challenge posed by the Kyoto commitment.

The Analysis and Modelling Group (AMG) is one of these working groups. It is comprised of officials and analysts representing two federal departments (Natural Resources Canada and Environment Canada) and the governments of the provinces and territories. The AMG's principal task is to undertake the so-called "roll up" – the integrated assessment of the economic and environmental consequences, for Canada, of achieving the Kyoto target. In undertaking the roll up, the AMG was instructed to use as the key inputs the options, associated analysis and other insights developed by the Issue Tables – in particular, from those such as Agriculture, Buildings, Electricity, Forest Products, Industry, Municipalities and Transportation which focussed on specific sectors – and by the Tradeable Permits Working Group (TPWG). Further, the AMG was to conduct its analysis in a transparent, step-by-step process to ensure broad stakeholder review of the results.

This report describes the analytic approach developed by the AMG, presents the main results and findings, notes the limitations of the analysis and suggests areas for further research. The purpose of this executive summary is to provide the highlights of the report. Before doing so, however, it is important to spend a few paragraphs to situate the report and its findings – to indicate what they are and what they are not.

The AMG roll up has been usefully described as "range finding." Its primary objective is to provide policymakers with "order of magnitude" guidance on some fundamental issues related to the achievement of the Kyoto target, including:

- the economic implications of different broad policy approaches, such as using various combinations of a suite of specific measures and a major economic instrument - the consequences of requiring each sector to achieve a common target versus an overall national target;

- the potential benefits and costs of greater access to the Kyoto flexibility mechanisms;

- the sectoral and regional distributions of emissions reductions and costs of achieving the target;
- the degree to which Canada's competitive position might be affected by the achievement of the Kyoto commitment;
- the relative importance of the co-benefits of greenhouse gas (GHG) mitigation, in particular those related to improvements in air quality; and
- areas or actions which appear to offer large potential for emissions reductions and, conversely, areas or actions for which the potential seems to be limited.

It should be clear from the above that the roll up results should not be viewed as a plan of action. The resolution of the findings is too coarse and many of the major assumptions are too speculative for such an interpretation. Three examples underscore this point. First, both Canada's decision, and probably that of the United States as well, to ratify the Kyoto Protocol will obviously be predicated on the outcome of negotiations on the structure of the various flexibility mechanisms (most importantly, an international emissions trading system, Joint Implementation (JI) and the Clean Development Mechanism (CDM)). At time of writing, there is little information concerning the outcome of these negotiations. Thus, the assumptions in the AMG roll up concerning the likely shape of the Kyoto mechanisms and the response of Canada's trading partners, in particular the United States, to them are no more than educated guesses. The analysis will need to be refined as more information concerning the negotiations becomes available.

The second example relates to the estimated impacts on industry. Although the various models all indicate that there will be considerable variability in the impacts across industries, there is not agreement on which industries will be most affected. The differences in the rankings reflect different assumptions about the capacity of particular industries to adjust and different emphases on the importance of the impacts on suppliers, customers and competitors on a given industry. Although the AMG has made some progress in examining the competitiveness issue, further industrial analysis, perhaps focussing on specific measures, will be required to gain more confidence in the industry impacts.

The third example relates to the application of a domestic emissions trading system. The Tradeable Permits Working Group made significant progress in examining the principles and features associated with such a system. It did not, however, agree on a method to allocate the permits. The roll up required that some assumption (for example, grandfathering, auction with or without recycling of proceeds) be made concerning allocation. As noted in the report, the method – allocation of permits to households – chosen by the AMG, solely for analytic reasons, results in inflationary pressures. The point, however, is that each allocation method will produce its own unique set of consequences.

Until there is a proposed approach to allocation, the AMG's findings concerning the implications of a tradeable permit system should and must remain preliminary and provisional.

## Analytic Approach

The analytic approach to the roll up has three main components: a series of policy packages, referred to as "Paths"; a set of framework assumptions, the most important of which are the international scenarios describing the likely shape of the Kyoto mechanisms and the response of the United States to them; and a modelling structure within which to examine systematically the various path-scenario combinations or other sensitivities. Each component is described briefly below.

*The Paths*

The National Air Issues Coordinating Committee (NAICC) directed the AMG to examine five policy packages or Paths. Although somewhat complex in terms of their specification, the Paths are differentiated by different degrees of reliance on specific measures and tradeable permit systems and by the imposition of sectoral versus national targets. The Issue Tables' options are present in all Paths, either explicitly or implicitly, in the sense that the underlying actions are available for selection if they meet certain cost effectiveness criteria. The five Paths are:

**Path 0**: the integrated summation of the Issue Tables' options.

**Path 1**: each sector achieves a minus 6 percent target using the Table's options, supplemented by a tradeable permit system for electricity generation and a motive fuel tax in transportation.

**Path 2**: an optimized approach in which the minus 6 percent target is established nationally and measures and actions are taken in order of cost effectiveness. As one of the options proposed by the Tradeable Permits Working Group (TPWG), a tradeable permits system is established jointly for large emitters (essentially electricity generation and large industry which account for roughly 35 percent of total emissions). Other sectors employ specific measures based on lowest abatement costs.

**Path 3**: employs the same permit system as in Path 2, but the joint cap is fixed at 6 percent below 1990 levels. All other sectors employ the specific measures used in Path 1.

**Path 4**: based on the alternative TPWG proposal, a tradeable permit system is established over the largest portion of the economy as practical. The resulting system covers about 85 percent of emissions. The remaining sectors, such as landfills, agriculture and non-combustion emissions related to oil and gas production, use specific measures to achieve the required emissions reduction.

As can be seen, the Paths move, more or less progressively, through increasing reliance on a major economic instrument to achieve the Kyoto target. As well, Paths 1 and 3 explore the implications of an equivalent target for each sector while Paths 2 and 4 examine, through different mechanisms, a broad national target and measures and actions based on cost-effectiveness.

*The Kyoto Scenarios*

A simulation analysis of this complexity requires a large number of external assumptions each of which must be carefully considered in light of available evidence. The most important of these are the Kyoto Scenarios.

The Kyoto Protocol incorporates a number of flexibility mechanisms that allow countries to discharge a portion of their obligations internationally. At the time of writing, the form of these mechanisms is not well articulated and is the subject of ongoing international negotiations. Nonetheless, it is important to understand the implications of potential outcomes of these negotiations for Canada’s capacity to meet its Kyoto target. Equally important is the likely response of Canada’s trading partners, in particular the United States, because of the repercussions, principally through trade, on Canadian economic activity.

In order to cover a range of responses three scenarios were developed. In the Canada Acts Alone Scenario, Canada is assumed to be the only country to undertake its Kyoto commitment. This Scenario was developed primarily to show the impact of Canadian emissions reduction policies in isolation from the potential effects that may occur as a result of the policies of other countries. It is not, admittedly, a likely scenario.

The two remaining Scenarios were developed from a 1998 study by the Energy Information Administration (EIA) of the U.S. Department of Energy. The EIA study analysed several cases in which the United States achieved its Kyoto target using different combinations of domestic and international permit trading. Two such cases, referred to in this report as *Kyoto Loose* and *Kyoto Tight*, were selected.

Kyoto Loose posits a situation in which, by 2010, there is a well-established international permit trading system with low transaction costs, buy-in by some developing countries and plentiful JI and CDM opportunities. Under such circumstances, the EIA study suggests that the U.S. can discharge 75 percent of its obligations internationally at an international permit price of C$24 per tonne of $CO_2$. This outcome approximates the Clinton Administration's preferred position.

By contrast, Kyoto Tight assumes that the international permit trading system is not as well developed, with consequently higher transactions costs, that participation by developing countries is limited and that CDM and JI opportunities are constrained. This results, according to the EIA study, in the U.S. discharging only one-third of its obligations internationally, meeting the rest through domestic action. The resulting permit price is C$58 per tonne of $CO_2$. Kyoto Tight can be interpreted as the minimum conditions for U.S. ratification.

The primary purpose of using the EIA study is to obtain a credible range of international carbon prices to incorporate in the domestic analysis. An additional benefit is that the study also provides a comprehensive analysis of the assumed U.S. actions on energy prices, energy imports and economic activity with which to frame the domestic analysis.

*The Modelling Structure*

To evaluate the various path-scenario combinations systematically, the AMG linked together a number of specialized models available from the private sector or within government into an overall modelling structure. The approach is to use the outputs of one set of models as inputs to the others. The three sets of models are:

Micro models: These models evaluate the direct impacts - required investment, changes in energy flows and GHG emissions reductions - associated with path-scenario combinations under the deliberately imposed assumption that economic activity remains largely unchanged. Two energy-technology models – the Market Allocation Model (MARKAL) and the Canadian Integrated Modelling System (CIMS) - were selected for this purpose to capture different modelling perspectives. MARKAL is an optimizing model that provides the lowest financial cost solution to the achievement of a constraint, such as a stipulated emissions target. CIMS, by contrast, incorporates evidence concerning actual consumer and producer experience and allows for responses to the proposed policy that take into account non-financial considerations. Other things equal, MARKAL should produce a lower cost outcome than CIMS. MARKAL and CIMS also differ in their approach to energy pricing. The former employs marginal cost pricing so that the price of carbon is determined by the last tonne abated. CIMS assumes average cost pricing, so that only the average cost of all the emissions reduced is incorporated in the price. The distinction is not particularly important for the pricing of oil products or natural gas. It is, however, crucial to the pricing of electricity. The emissions profile and other circumstances in agriculture are so different, compared to other sectors, that special models maintained by Agriculture Canada were employed and their results were combined with the CIMS and MARKAL results.

Macro models: Macro models evaluate the overall economic consequences - changes in economic activity, employment, trade and competitiveness and government balances - from a policy shock. Two models were also employed for this purpose - the Informetrica Model (TIM) operated by Informetrica Ltd and the Canadian Sectoral General Equilibrium Model (CaSGEM) developed by the Department of Finance. Both models contain considerable sectoral detail and can produce results at a provincial level. They differ, however, in approach. TIM focuses on the adjustment process as the economy responds to the new policy and, therefore, allows for transitional under or over-employment of capital and labour. CaSGEM employs a general equilibrium framework and focuses on the long-term result of the policy change after all adjustments have taken place. CaSGEM is also more of a hybrid model, incorporating both micro and macroeconomic features. It can provide, therefore, a fully integrated solution covering both the changes in economic activity and the emissions consequences of those changes. Thus, while CaSGEM does incorporate some of the results from the micro models, it is probably best to think of it as providing an complementary view to the complex of MARKAL/CIMS - TIM results.

Environmental and health models: To address the environmental and health consequences of the policy options, in particular the changes to health resulting from the reduction in criteria air contaminants associated with the GHG policies, the AMG relied on a suite of models maintained by Environment Canada. The spreadsheet model estimates the changes in atmospheric pollutants – $SO_X$, $NO_X$, VOC, particulates and carbon monoxide – associated with the various path-scenario combinations, using the energy change results from the micro models as input. Several specialized models then translate these changes in emissions levels into changes in ambient air quality. These results in turn provide input to the Air Quality Valuation Model (AQVM) which estimates both the physical impacts on health – mortality risk, hospital visits, etc. – and assigns a monetary value to these impacts. The latter are based on estimates in the health literature concerning willingness-to-pay for the avoidance of such risks.

In sum, the basic approach is to use the micro models to aggregate the direct impacts of the various path-scenario combinations and then to use these results as the inputs to both the macro and environmental and health models. To accomplish this sequencing, the AMG imposed the assumption on the micromodelling approach that economic output (i.e., tonnes of steel, volumes of chemicals, production of oil and gas) does not change. The limited exception to this constraint concerned some aspects of transportation, such as kilometres driven, because the policy intent of the measures was, in fact, to reduce this item.

The constant output assumption has generated considerable concern from the stakeholder community and requires some further explanation. The constraint was not imposed because the AMG believes that economic activity will be unaffected by GHG reduction policies – it is almost axiomatic that it will. The reasons for the constraint are twofold. First, the energy-technology models do not provide a good representation of the total economy and the many complex linkages among sectors. They concentrate, quite appropriately, on energy-intensive processes, industries and activities. The macro models, by contrast, incorporate all the major linkages and can address trade, competitiveness and fiscal and monetary policy issues. An industry which uses little energy may be largely unaffected by the direct impacts of the emissions reduction policies. It may, however, be greatly affected by the impact that those policies have on either its suppliers or its customers. The macro models capture these important second-round effects.

The second reason for the fixed output constraint is that the roll up analysis is extraordinarily complex. If only the final impacts were reported, it would be impossible for stakeholders to ascertain whether the initial measures had been incorporated correctly or what their consequences might be. Keeping the output constant for the micro analysis reduces the complexity and allows an interim “reality check” on the results before moving on to the macro analysis.

**Main Learnings**

The AMG was asked to address the question "what are the economic and environmental consequences, for Canada, of achieving the Kyoto target?" While not a definitive answer, the analysis provides some important insights into this question. These Main Learnings are as follows:

- At the national level, attainment of the target results in sustained, long-term, negative economic impacts. In the long run, the reduction in gross domestic product (GDP), relative to the business-as-usual case, ranges from 0 to 3 percent depending on the path-scenario combination.

  It is important to provide perspective on these estimates. For example, a reduction in GDP of 3 percent in 2010 means that, over the decade, the economy will grow by about 26 percent instead of 30 percent as projected in the reference case. This is equivalent to the loss of roughly one year's growth, or, viewed in absolute terms, in 2010, the loss in annual economic output of approximately $40 billion (or $1100 per capita).

- The overall GDP impacts vary over time. Initially, economic activity increases modestly in response to increased investment in emissions reducing technologies. Thereafter, however, higher production costs, deterioration in competitiveness and lower incomes combine to reduce GDP below business-as-usual levels. The analysis also suggests that the adjustment process may not be completed until after 2010.

- The provincial GDP impacts are generally within 1.5 percentage points of the national average impact. The relative ranking of each province typically varies by Scenario. In the Canada Acts Alone Scenario, Newfoundland, Prince Edward Island, Quebec and British Columbia are less affected, relative to the national average, whereas Ontario and Saskatchewan are more negatively affected. The impact on Alberta is close to the national average. The results for Nova Scotia, New Brunswick and Manitoba vary between the studies.

  In the International Scenarios, Newfoundland, Prince Edward Island and British Columbia remain in the "less affected" category and are joined by Manitoba. Saskatchewan remains in the "more affected" category, which now includes Alberta and New Brunswick. By contrast, Ontario's GDP impact is smaller than under Canada Acts Alone, becoming close to the national average. Quebec's position is largely unchanged across the Scenarios, although one study indicates that its GDP would be consistently higher than in the business-as-usual case. For Nova Scotia, one study indicates impacts that are greater than the national average, while the other suggests the opposite.

- The findings suggest the potential for substantial variability in GDP impacts across industries. Unfortunately, it is not possible to identify unambiguously the sectors that would be negatively or positively affected, since industry variation is not uniform across models and Paths.

- The greatest potential for emissions reduction appears to reside in the electricity generation sector – between 40 and 60 percent of the reduction. Two actions – capture and storage of $CO_2$ in aquifers in Alberta and Saskatchewan and enhanced interprovincial hydro-electricity trade, in particular from Manitoba and Quebec to Ontario – account for the bulk of this potential.

- Policies to reduce greenhouse gases will both reduce energy consumption and encourage switching from more to less carbon-intensive fuels. All of the analysis suggests some declines, relative to business-as-usual, in oil product and coal consumption. Interestingly, natural gas consumption also declines largely because the capture and storage of $CO_2$ and enhanced hydro electricity trade reduce the attractiveness of gas-fired electricity generation. Were these options not fully available, natural gas demand would increase.

- The industrial sector, particularly the oil and gas industry, and the transportation sector face significant challenges in achieving large emissions reduction.

- Were Canada to act alone in achieving its Kyoto target, the marginal cost of abatement in 2010 could range from $40 to $120 per tonne of $CO_2$. Were these costs to be incorporated in energy prices, gasoline prices would increase by 13 to 35 percent, natural gas prices (for residential use) by 30 to 75 percent, and average coal prices by 300 to 800 percent.

- The outcome of the negotiations concerning forestry and agriculture sinks is an important factor in the cost to Canada of achieving the Kyoto target. According to one estimate, a pessimistic assumption concerning this outcome, the effect of which widens the gap by about 20 percent, results in an increase in the marginal cost of abatement from $57 to $100 per tonne of $CO_2$. This result also suggests that the Canadian emissions abatement cost curve, constructed from the analysis and insights of the Issue Tables, becomes increasingly steep as the target is approached.

- The analysis supports the contention that competitiveness – measured by changes in productivity - will be adversely affected by the achievement of the Kyoto target. The impact is somewhat attenuated if Canada's trading partners are also committed to attaining their targets and Canada has access to flexibility mechanisms. However, under this Scenario, Canada's trading partners will also face reductions in economic activity, with adverse consequences for Canadian export performance. At the national level, the net impact of these two forces is to reduce the GDP loss by about 0.5 percentage points.

- The analysis strongly supports the conclusion that moving from individual sector targets to an economy-wide target will achieve the desired objective at significantly lower cost. Moreover, sector specific emissions targets do not distribute the economic burden evenly across sectors.

- Based on preliminary modelling of some characteristics of emissions permit trading, this instrument can be viewed as cost-effective mechanism for achieving emissions reductions in the industrial and electricity sectors. However, the analysis to date underscores the importance of the design of such an instrument, in particular the permit allocation mechanism. Each allocation method carries with it different distributive effects on the economy.

- Measures and actions to achieve the Kyoto target will also result in the reduction of sulphates, ozone and other atmospheric pollutants. These reductions will lead to ancillary benefits from improved air quality and improvements in human health. These co-benefits are immediate, local and reasonably certain and can make a significant contribution to the attainment of clean air goals as enunciated in the Canada-Wide Standards Initiative.

- The analysis indicates that the societal benefits of these improvements in human health are in the range of $300 to $500 million per year. Most of this value derives from reduced risk of mortality. These societal benefits represent the value that Canadians place on these co-benefits, as determined by estimates of their willingness-to-pay to achieve these avoided impacts. They are not comparable to the GDP impacts noted above. These estimates do not cover the full spectrum of pollutants and do not include sulphate reductions in western Canada.

- Although increased reliance on the international mechanisms to reduce greenhouse gases lowers the cost of achieving the Kyoto target for Canada, it also reduces the domestic clean air benefits. The analysis suggests that this reduction in societal benefits is on the order of $200 million per year.

Analysis is most useful when it succeeds in resolving issues. Even when it fails to do so, however, it is still valuable if it points to gaps in our understanding. The AMG has identified the following areas where future analysis should yield useful insights:

- Much greater effort is required to measure welfare benefits and costs. Attention should focus on the welfare implications of transportation and “life style” change initiatives.

- Some progress has been made in identifying competitiveness impacts, but a much more sophisticated understanding of this issue is required. In particular, there is a need to evaluate the importance of the so-called “leakage” issue: the possibility that some industries will lose market opportunities and investment to developing countries not subject to emissions reduction targets.

- Much more analysis of the implications of the various approaches to the design of an emissions trading system is required. The suggested priority area is the allocation mechanism.

- More province-specific analysis is needed. The current macroeconomic models develop provincial impact estimates by distributing the national results according to the industrial mix in each province. This approach is reasonable if the characteristics of an industry are similar across provinces, but questionable if this is not the case. More refinement of this assumption is required.

- The assumptions concerning how the United States might address the Kyoto Protocol requirements are too simplistic to comprehend the complex ways in which that country’s climate change policies could affect both Canada’s economy and our policy options.

- The analysis, to date, has not comprehensively modelled how Canada’s other trading partners might respond to their commitments under the Kyoto Protocol.

- Despite considerable progress, the quantitative co-benefits analysis requires further development.

## Concluding Remarks

In focussing on the substance of AMG analysis, this executive summary has perhaps given insufficient attention to how the task was accomplished. The AMG deliberately created a transparent, interactive process involving the stakeholder and modelling communities. Largely through the multi-stakeholder workshops organized by the Climate Change Economic Analysis Forum (CCEAF), the various phases of the analysis were presented, reviewed and critiqued. The dialogue generated by these discussions and the network of expertise established via this process are important achievements, providing a solid basis for further cooperative analytic effort as Canada develops its strategy on climate change.

In the above context, it is important to obtain feedback from the stakeholder community on the process. Therefore, at the request of the AMG, CCEAF surveyed the stakeholder and modelling communities concerning their views on the analytical process and suggestions for the future. The results of that survey are contained in an annex to this report. The results provide a useful counterpoint to the main body of the report and will be of considerable value to the AMG as it prepares its recommendations to NAICC concerning the priorities for and organization of the post-JMM analysis.

In addition to this report, the AMG has generated a large number of studies focussing on the microeconomic, macroeconomic and environmental and health phases of the roll up analysis. These, in turn, are supported by numerous reports, prepared by CCEAF and others on specific topics. The AMG believes that this research will form a valuable base for further climate change analysis.

# Chapter 1
# Introduction

In December 1997, in an international agreement known as the Kyoto Protocol, Canada agreed to reduce its greenhouse gas emissions by 6 percent on average, relative to 1990 levels, over the period 2008-2012. At the same time, other industrialized countries made similar commitments, albeit for differing percentages, with an overall average reduction of 5.2 percent.

Shortly after the conclusion of these negotiations, First Ministers, meeting in Ottawa, instructed federal, provincial and territorial Ministers of Energy and Environment (Joint Ministers) to develop a process to achieve "a thorough understanding of the impact, the costs and the benefits of the Protocol's implementation and of the various implementation options open to Canada."

In April 1998, the Joint Ministers announced a process for the establishment of the National Climate Change Process (NCCP). The centrepiece of the process was the creation of fifteen Issue Tables, comprised of experts from governments and the stakeholder community, to provide advice on various aspects of the implementation strategy. Some of the Issue Tables were to address cross-cutting issues such as public education and outreach, enhanced voluntary action and the Kyoto mechanisms.[1] Other Tables - Agriculture, Buildings, Electricity, Forest Products, Industry, Municipalities and Transportation - were asked to focus on the development of options to achieve at least the 6 percent reduction within the sector they represented.

The April 1998 announcement also created the Analysis and Modelling Group (AMG), a federal, provincial and territorial organization with the overall responsibility for the quantitative analysis of the economic and environmental consequences of the potential avenues to achieving Canada's Kyoto target. This responsibility included the development of a reference outlook to frame the work of the Tables and guidance to the Tables on critical methodological issues. The AMG's central task, however, is to conduct the integrated analysis of the economic, social and environmental implications for Canada of achieving its Kyoto commitment. This is referred to as the *roll-up analysis*.

---

[1] Kyoto mechanisms include International Permit Trading, Joint Implementation (JI) and the Clean Development Mechanism (CDM).

The primary objective of this report is to present the findings based on the results of the *roll-up analysis* undertaken by the AMG. In essence, the roll-up involves the evaluation of the integrated impact of the Options Packages analyzed by the Issue Tables, along with other "paths" for the attainment of the Kyoto objective specified by the National Air Issues Coordinating Committee (NAICC). The analysis also considers the impacts, under different "scenarios," concerning the likely shape of the Kyoto flexibility mechanisms and the consequent response of Canada's trading partners, in particular the United States.

To undertake this analysis, the AMG has created an integrated modelling structure which links together a number of detailed energy-technology (microeconomic), agriculture, macroeconomic and air quality-health models. Two energy-technology models, reflecting different modelling perspectives, optimizing versus behavioural, have been employed. The agriculture emissions were modelled using the Canadian Economic and Emissions Model for Agriculture maintained by Agriculture Canada. The macroeconomic analysis was undertaken with an econometric model. A fourth model, using general equilibrium principles, which combines elements of the energy-technology and the macroeconomic models provided another perspective to the analysis. Environmental and Health Impact (EHI) modelling was undertaken using Environment Canada's Air Quality Valuation Model. Also, working largely through the Climate Change Economic Analysis Forum (CCEAF), the AMG has developed a set of framing assumptions on which to base the analytical efforts. These assumptions help to define key variables such as the concept of the Kyoto mechanisms, the response of the United States and impacts on international energy prices.

This analysis should not be construed as a plan to achieve the Kyoto target because:

- the international negotiations to define the Kyoto mechanisms are too fluid to allow much more than educated guesses concerning the likely outcome. As well, the responses of Canada's trading partners, particularly the United States, which are predicated on the outcome of the negotiations, are uncertain.

- the reference case, although developed with a high degree of consultation, is one view of the future. The results depend on the assumptions incorporated in that outlook.

- the modelling structure does not have sufficient resolution to analyze specific policies.

- there are a large number of inter-locking assumptions. While it is believed that these assumptions are reasonable, it is clear that changing any one of them will alter the results, possibly in a major way.

- the analysis assumes a certain timing and penetration of the measures; variations from this could have a significant effect on some of the results.

This analysis employs the best available models with sound analytical groundings. The objective is to provide a plausible range of outcomes and to provide insights on, and general guidance concerning the following issues:

- the relative economic impact of two of the more significant policy approaches - a combination of specific measures and the use of a major economic instrument.
- identification of options that appear to offer significant emissions reduction potential and conversely, those where the potential seems to be limited and/or costly.
- the implications of applying common sectoral targets as opposed to an overall national target.
- the benefits Canada might derive from access to the international flexibility mechanisms to meet, at least, a part of its commitment.
- key areas of uncertainty, such as the future degree of inter-provincial trade in the electricity sector, the amount of carbon that can be absorbed by sinks and the potential for capture and storage of $CO_2$, for which different assumptions can dramatically alter the results.
- information concerning the potential distribution of the regional and sectoral costs and benefits and their economic impact of achieving the national target.
- the potential health impacts associated with the reduction of air pollutants that may result from a GHG reduction strategy.

The rest of this report is organized as follows:

- Chapter 2 reviews the options packages developed by the Issue Tables and the Paths used in the analysis.
- Chapter 3 provides an overview of the analytic approach. It includes descriptions of the modelling structure employed in the analysis, and of the framework assumptions. As well, there is a discussion pertaining to understanding the results and some caveats concerning the results.
- The microeconomic (energy-technology) results for the various path-scenario combinations are presented in Chapter 4. These results are the direct implications associated with the policy packages, on the assumption that the level and composition

of economic activity is largely unaffected by their introduction. The microeconomic estimates from Chapter 4 and the options packages from the Issue Tables provide the input to the macroeconomic and environmental and health impacts of Chapter 5 and 7 respectively.

- Chapter 5 presents the results of the macroeconomic analysis. The macroeconomic analysis examines the consequences, at the national, sectoral and regional levels, for economic performance, employment, trade, competitiveness and government finance of the various path-scenario combinations.

- Chapter 6 provides a complementary view of the macroeconomic aspects of the analysis using a general equilibrium model developed by the Department of Finance.

- Chapter 7 explores the environmental and health implications of the some of the path-scenario combinations. The analysis largely focuses on the changes in criteria air contaminants ($SO_X$, $NO_X$ and particulates) associated with the various GHG reduction approaches. It provides estimates of the physical effects and the value of these changes on human health and environment. The chapter also provides a qualitative assessment of the implications of GHG reductions on other pollutants.

- Chapter 8 summarizes the main findings and conclusions from the analysis, notes its limitations and suggests the most important areas for future research.

- Annex I contains the executive summary of the report prepared by CCEAF, at the request of the AMG, on the views if the analytic process to date and the priorities for future climate change analysis.

- It is recognized that there is a wealth of information contained in the modelling reports and that analysts will continue to use this information to gain further insights, refine the issues and examine the uncertainties. The background studies and detailed reports from the modellers are listed in the bibliography.

# Chapter 2
# Option Packages and Paths

This chapter describes the development of the Issue Tables' options to reduce GHG emissions, which are the cornerstone of the roll-up analysis, and will define the analytical paths requested by the NAICC.

## 2.1 Issue Table Options

As noted earlier, the NCCP announcement created 15 Issue Tables, including several specialized task groups, consisting of over 450 experts from a broad cross-section of government, industry, the academic community, environmental groups and non-governmental organizations. The objective of the Tables is to develop options, examine and analyze their impacts, costs and benefits, within their sphere of expertise, to reduce GHG emissions. Tables representing the main sectors of the economy were requested to develop options to achieve at least a 6 percent reduction in GHG emissions, below the 1990 levels, in their particular sector. The options, as presented in the Issue Tables' Option Reports, are the foundation of the AMG roll-up analysis. For this analysis, the most important of these Option Packages were developed by: Buildings; Municipalities; Industry; Electricity; Transportation; Agriculture; and Forest Products. In addition, the roll-up analysis explores suggestions from the Tradable Permits Working Group (TPWG).

## 2.2 Option Packages

The Option Packages reports proposed a wide range of measures and actions[2] such as regulations, information programs, financial incentives and partnerships. The AMG worked closely with the Tables' representatives to ensure consistency of the analysis, without changing the meaning and intent of the Option Packages.

In the case of the Industry and Forest Product Tables, although a large number of actions were examined, these tables were unable to develop measures that would motivate the

[2] A measure is a combination of a specific GHG reduction action and the policy instrument that implements it.

actions. With the assistance of the AMG, a set of generic options,[3] including enhanced voluntary action, cogeneration and subsidies was constructed.

In total, 106 measures were used in the roll-up analysis (Chart 2.1). About one third of the measures relate to Buildings, which covers both the residential and commercial sectors. The Municipalities Table proposed eight direct measures and five enabling measures.[4] In the roll-up analysis, these measures were assigned to the commercial and transportation sectors. As noted above, the Industry and Forest Product Tables agreed with the generic measures as estimated by the AMG. Underlying these generic measures are about 100 other actions that were examined by the Industry sub-Tables.

**Chart 2.1**
**Issue Table Options for the Roll-Up**

| Table | Number of Options | Remarks |
|---|---|---|
| Buildings | 34 | A and B packages. Exceeds target. |
| Municipalities | 8 | Included landfill gas. Meets target. |
| Industry | 3 | Includes generic measures. Does not meet target. |
| Electricity | 2 | Does not meet target without permit trading. |
| Transportation | 48 | Meets target. |
| Agriculture | 10 | Meets target, if soil sinks included. |
| Forestry | 1 | Included with Agriculture. |
| Total | 106 | |

The Electricity Table provided two specific measures. Without endorsing specific targets for reducing GHG emissions, the main recommendation of the Electricity Table was that the most efficient way to achieve substantial GHG reductions would be to set emission caps and allow firms to meet targets by trading emission permits. It also proposed a 2.5 cents per KWh subsidy for renewable technologies. This Table also undertook a review of actions available to reduce greenhouse gas emissions in the sector, such as fuel switching, expansion of inter-provincial trade and the capture and storage of $CO_2$ in deep aquifers. This research was used to inform the roll-up analysis.

The Transportation Table proposed a large number of measures with the majority being described “most promising” and “promising.” However, measures in these two categories were not sufficient to reduce emissions to meet the Kyoto target in the transportation sector. Therefore, on the advice of the Transportation Table, four “less promising” measures were added to meet the target. In addition, the Transportation Table undertook an extensive analysis of motive fuels taxes, but did not suggest this option as part of a general package.

The Options Package from the Agriculture and Agri-Food Table includes 10 measures. These generally pertain to farm management practices (no-till, summerfallow and grazing strategies)

3 *The Industry Challenge*, ERG/M. J. Jaccard and Associates, November 1999

4 These measures include education and suasion.

and agro-forestry activities. Several of these measures are predicated on the inclusion of soil sinks in the final version of the Kyoto Protocol. The Afforestation measure, recommended by the Forest Products Table, is included with the agriculture and other sector.

The TPWG provided advice on the extent of the coverage for the sectors that may participate in an emissions trading systems.

### 2.3 The Paths

The AMG roll-up analysis is designed to explore a range of policy directions to achieve the Kyoto target. The main issues to be explored are the attainment of sector targets versus an economy-wide target and a set of specific measures versus a major economic instrument. The NAICC specified five approaches, referred to as Paths, to understand these issues.

The Paths assess various combinations of specific measures, sector targets and emission trading.

> ***Path 0: Tables Measures.*** This Path is the aggregation of the all measures, including the four “less promising” Transportation measures, identified in the Options Packages by the Issue Tables. This aggregation is not a simple summation because of the interaction among the measures. It was apparent that the industry sector could not achieve its target, therefore, only the generic measures, costing up to $75 per tonne of $CO_2$ equivalent, were included. Since it was clear that this Path would not achieve the target it is referred to as Path 0.

> ***Path 1: Sectoral Targets.*** Each sector’s emissions (electricity, industry, residential, commercial, transportation and agriculture) for the period from 2008 to 2012, are limited to 6 percent below the 1990 levels. With the exceptions noted below, the Tables measures were employed to meet the target. In the Industry sector, generic measures were implemented up to a cost of $300 per tonne of $CO_2$ and the four “less promising” measures from Transportation were replaced by a motive fuels tax, sufficient to meet this sector’s cap. Consistent with the recommendation of the Electricity Table, sector-based emission trading is incorporated as a measure in the Electricity sector.

> ***Path 2: Permit Trading for Large Emitters and an Economy-wide Target.*** The main feature of this Path is that it replaces the sectoral targets with an economy-wide target of 6 percent below the 1990 level, allowing the selection of a least cost set of measures. All of the Tables’ measures are available for selection by the residential, commercial and transportation sectors based on their cost. This Path examines one of the proposals from the TPWG. The tradable permit system is applied to the Large

Final Emitters (LFE), which are defined as the Electricity sector and major industries, such as pulp and paper, iron and steel and cement.

**Chart 2.2**
**Extent of Permit Trading in Paths 2, 3 and 4**

| | Percent of Emissions Covered | |
|---|---|---|
| | **Paths 2 and 3** | **Path 4** |
| Oil Sands | 100 | 100 |
| Gas Pipelines | 100 | 100 |
| Petroleum Refining | 100 | 100 |
| Electricity | 95 | 100 |
| Chemicals | 80 | 100 |
| Pulp and Paper | 80 | 100 |
| Smelting and Refining | 80 | 100 |
| Cement | 80 | <100 |
| Iron and Steel | 80 | <100 |
| Other Industries | 55 | <100 |
| Gas Processing ($CO_2$ only) | 50 to 70 | 50 to 70 |
| Commercial | 0 | 100 |
| Residential | 0 | 100 |
| Road Transport | 0 | 100 |
| Air Transport | 0 | 100 |
| Rail Transport | 0 | 100 |
| Other Emissions | 0 | 100 |
| Landfills | 0 | 0 |
| Oil and Gas Processing ($CH_4$ only) | 0 | 0 |
| Oil Processing ($CO_2$ only) | 0 | 0 |
| **Total Coverage** | **35** | **85** |

Provided by the Tradable Permits Working Group

The extent to which these sectors and sub-sectors are allowed to use tradable permits was provided by the TPWG (Chart 2.2). About 35 percent of total national emissions are covered by the trading system. In this Path, some sectors reduce their emissions by more than 6 percent, while other sectors do not.

***Path 3: Permit Trading for Large Emitters and Sector Specific Targets.*** The coverage of the trading system is the same as Path 2. However, the LFE are capped at 6 percent below their 1990 level. Other sectors, not included in the emission trading system, such as residential, commercial, small firms and transportation, meet their respective 6 percent target using the Tables measures defined in Path 1, including measures valued up to $300 per tonne of $CO_2$ for small industry and a motive fuels tax in Transportation.

***Path 4: Broadest Practicable Permit Trading.*** This Path reflects the second major approach from the TPWG. The emission trading system, which caps the emissions at 6 percent below the 1990 level, is expanded to include all sectors for which permit trading is administratively feasible. The sub-sectors excluded from permit trading for administrative reasons are: carbon dioxide from conventional oil processing, methane from oil and gas processing, small firms and emissions from landfills. The sub-sectors achieve their target reductions through the Tables measures or generic measures costing up to $300 per tonne of $CO_2$. In this Path, about 85 percent of total emissions are covered by permit trading.

The operationalization of these Paths, for analytic purposes, involves a considerable amount of detail, which can obscure the policy direction that the Path is designed to examine. Chart 2.3 provides a summary of the policy intent of each Path, across the two dimensions: specific measures and permit trading and sectoral versus economy-wide targets (optimization). As the analysis moves through the Paths, defined measures are reduced, and permit trading is expanded to cover a larger segment of the economy. Path 1, and to a lesser extent Path 3, represent approaches in which each sector is required to achieve a common target. By contrast, Paths 2 and 4 examine less restrictive approaches in which least cost solutions are sought to achieve the Kyoto target. The main

**Chart 2.3**
**Summary of Paths by Policy Direction**

| | Emission Trading | Measures | Optimization |
|---|---|---|---|
| Path 0 | No | All | No |
| Path 1 | Electricity only | All Others | Electricity only |
| Path 2 | Large Emitters | All Others | Economy-wide, no sector targets |
| Path 3 | Large Emitters | All Others | For Large Emitters only, Sector targets for all others |
| Path 4 | Broad as Practical | Remainder | For Broad as Practical, with an Economy-wide target |

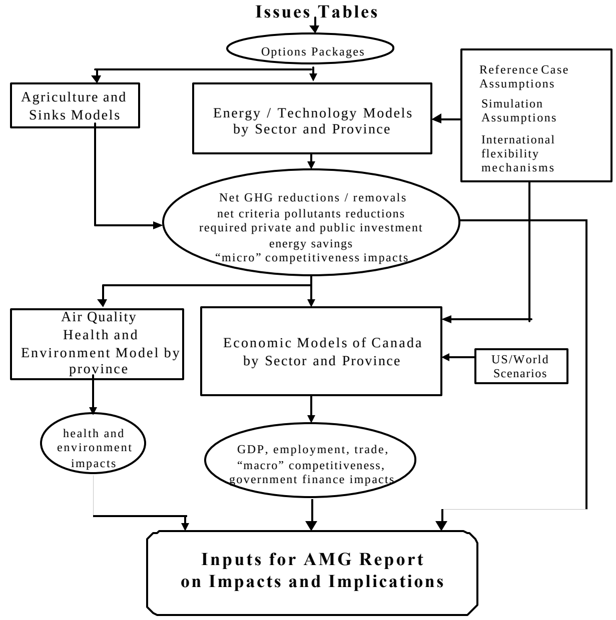
distinction between Path 2 and Path 4 is that, in the former, the lowest cost measures are selected, whereas in the latter, higher energy prices, owing to the cost of the permits, cause the action underlying the measures to occur. While the direct impacts of Paths 2 and 4 are generally similar, the question of who bears the cost of GHG reduction may have sectoral implications in the macroeconomic analysis.

# Chapter 3
# Analytical Framework

## 3.1 Overview

The roll-up is designed to capture many energy, economic and environmental dimensions of the Paths to the achievement of the Kyoto target. This task requires a comprehensive and systematic analytical framework. The framework constructed by the AMG comprises two components (Chart 3.1).

Chart 3.1
The Roll-up Framework



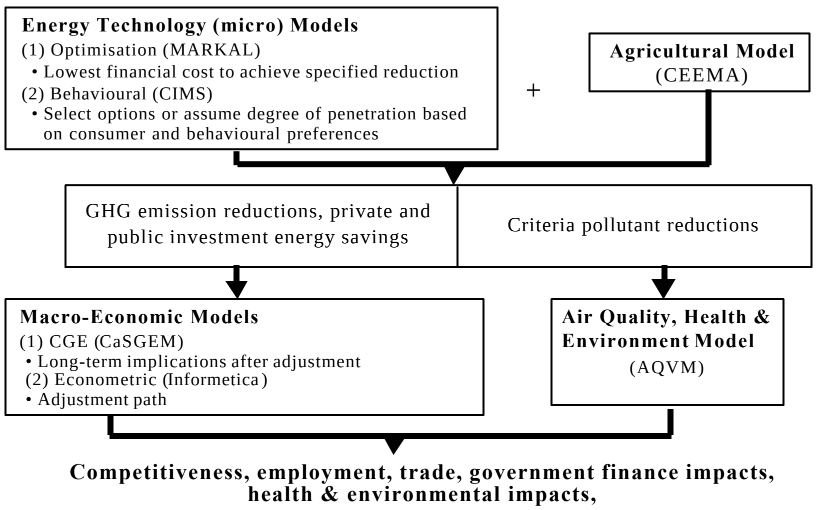

An integrated system of energy, agriculture, macroeconomic and environmental-health models to analyze systematically the Paths. The approach uses specialized energy and agriculture models to evaluate the direct consequences of the investments, energy prices, the level and mix of energy and the resulting emissions reduction in each sector and each Path. These results were then used to assess the impacts on the whole economy and on environment and health.

A set of assumptions to frame the domestic analysis. These assumptions, which were largely developed through extensive stakeholder consultations, include a reference case against which to estimate the impacts, considerations of the likely shape of the Kyoto mechanisms, the extent to which they may be used by Canada and the consequent responses of Canada's trading partners, particularly the United States.

The Options Packages from the Issue Tables provide the principal input to the energy-technology models, which in turn generate direct investments, fuel cost savings and fuel mix. The direct investments and savings are inputs to the macroeconomic models which also use information from the Options Packages. The fuel use estimates from the energy-technology models are inputs to the EHI models.

### 3.2 The Models

**Chart 3.2**
**The Modelling Structure**




The modelling structure (Chart 3.2) comprises four parts: energy-technology (microeconomic), agriculture, macroeconomic and environmental and health impacts.

A complete description of these models is contained in the detailed reports from each of the modellers.

***Energy-Technology Models***

The energy-technology or microeconomic models examine the choices that individual economic agents, such as consumers and businesses, make in the purchase and use of energy. These models focus on the influence of various factors, such as energy prices and government policies on the choices that the individual agents make. The models integrate the implications of combining multiple GHG reducing measures. Summing the separate impact of measures, in isolation, may not yield consistent results. For example, a measure to improve lighting efficiency and a measure to reduce the use of coal in electricity generation will not have the same effect when combined than when treated separately. The energy-technology models are designed to represent these interactions.

These models simulate the impact of changes in policy or market conditions against a reference case. The main outputs consist of changes in energy use, energy prices, GHG emissions, the investment cost and potential cost savings resulting from the policy change. While the models provide the cost of GHG abatement, they do not assign the payment of that cost to any particular part of the economy. These results are important to identify the direct effects of GHG reduction policies. Also, the investments and savings are inputs to the macroeconomic analysis, which assess the impact of those investments and monetary flows on the whole economy. The change in energy mix, provided by the energy-technology models, is a primary input to the EHI modelling.

There are two distinct perspectives in energy technology modelling. The first, known as optimization, assesses options solely on the basis of financial cost. Given a specific objective, such as a stipulated emissions target, an optimizing model will choose the measures in order of lowest financial cost. By contrast, a behavioural model incorporates evidence concerning consumer preferences (i.e., less tangible non-financial considerations, such as quality or the type of technology) in determining which option to select or the degree of penetration of a particular technology in the market place. In order to ensure that these two perspectives receive full expression in the analysis, the AMG has selected two models for the microeconomic analysis: the optimizing Market Allocation Model (MARKAL) operated by HALOA Inc. from McGill University and the behavioural model Canadian Integrated Modelling System (CIMS) developed the Energy Research Group from Simon Fraser University.

MARKAL is an optimization model that integrates production, trading, transformation and the end-use of various energy forms. It computes a regional equilibrium based on the long-term, least total cost for the entire system. It assumes that the markets are fully competitive. It also assumes that all agents (producers and consumers) minimize their own long-term costs under the following conditions:

- Each agent has perfect information of all other agents over the model horizon of 40 years.
- Each agent adopts the long-term view to optimize its financial cost.
- All agents use the same discount rate.
- Electricity is priced using marginal costs, reflecting a fully competitive market.

By contrast, CIMS is a behavioural model that uses competitive attributes tempered with the prospective behaviour. Behaviour may be the result of financial or non-financial factors, such as quality. However, the perception of cost, by the purchaser, is the prime determinant of the market share of a given technology; that is, technological characteristics give the relative position of one technology to another and behaviour gives the market share of the technologies. CIMS is also an equilibrium model that integrates decisions regarding specific technologies, in the five major sectors, and decisions concerning energy prices, supply and demand. The CIMS producers and consumers:

- Make decisions on limited information about the future.
- Make decisions for reasons other than financial cost.
- Use different discount rates reflecting their payback period and their perceived risk.
- Use electricity prices based on average costs, reflecting a cost of service approach.

The different pricing philosophies have important implications for the results, particularly for electricity. In the CIMS model, the price is determined by the average cost of producing electricity. The end-users pay an incremental price for electricity which just covers the total cost of investments to reduce greenhouse gases. In MARKAL, electricity producers set the price to reflect the marginal (incremental) cost of producing output. The marginal cost price generated by MARKAL is significantly higher than the average cost price determined in the CIMS model. In the MARKAL model, users of electricity are charged a price as if the cost of all emission reductions are as costly as the last emission reduction action implemented. The result of marginal cost pricing is that the electricity producing sectors receive extra profits because the additional revenue is greater than the total cost of emission reduction policies. In reporting results for MARKAL, the extra profits are assumed to stay with the electricity producers and are reflected as a cost to the energy end-use sectors.

Both MARKAL and CIMS have a similar regional breakdown: six provinces and a combination of the four Atlantic provinces into one region which were subsequently estimated for the individual provinces by the AMG. The economic sectors, represented in the models, are: electricity, upstream and refining, industry, residential, commercial and transportation. The industrial sector comprises 10 major industries. MARKAL is particularly strong in modelling the electricity generation industry, whereas CIMS' strength is its representation of the industrial sector. Both models include all GHG except hydro-fluorocarbons. However, neither model incorporates the non-energy emissions from the agriculture sector.

The strength of both models is the detailed representation of energy technologies such as space heating, industrial processes and electricity generation. The models' databases describe the technologies in terms of installed capacity, unit cost and efficiency on regional and sectoral basis. Options for future improvement, such as retrofitting or replacement of existing technologies and fuels are included and used by the model, when economically viable.

### *Agriculture Models*

The Agricultural scenarios were analyzed using the Canadian Economic Emissions Model for Agriculture (CEEMA) which consists of two major sub-models.

The first component of CEEMA is the Canadian Regional Agricultural Model (CRAM). CRAM is a static model that optimizes the net benefits to producers and consumers. The model integrates all sectors of primary agriculture on a regional basis. Supply response is determined by the relative profitability of alternative crops. The model allows for both inter-provincial and international trade in primary and processed products. It can also incorporate the effects of government programs and policies.

The GHG emissions component of CEEMA links the activity levels generated by CRAM to emission coefficients, in order to estimate emissions of $CO_2$, $CH_4$ and $N_2O$ from primary production resulting from changes in land use and management practices. Emissions from the production of farm inputs, food processing and off-farm transportation are also estimated. The coefficients from the CENTURY model[5] were used to measure the rate of soil carbon sequestration.

### *Macroeconomic Models*

Macroeconomic analysis integrates consumption, investment, production and trade decisions in the whole economy. This analysis captures not only the interaction among industries, but also the implications for changes in producer prices, relative final prices and income. Also detailed are government fiscal balances, monetary flows, interest and exchange rates. The AMG decided to use an econometric model which incorporates the frictions and rigidities of the economy and therefore, provides insights to the adjustment path. The Informetrica Model (TIM), provided by Informetrica Ltd of Ottawa was selected for this analysis.

TIM analyzes the macroeconomic impacts at the national level and then distributes these as sector effects across the provinces. For goods producers, the national model provides detail to distinguish impacts provincially. Service industry output is then determined by the requirements of the provincial goods producers, population and household incomes. In this analysis, the regional differences in electricity generation and other energy production are captured by detailed analysis that is reflected in the energy-technology models.

TIM is a dynamic econometric model of the Canadian economy. It has interdependent relations between demand, industrial performance, cost of production and price formation. It represents the spending of households, business and non-business. The effect of GHG

---

5 A model that predicts the accumulation of soil carbon.

reduction policies on business investment, consumption and other sources of demand directly affect the operations of the supplying businesses. Their requirement for materials and services indirectly affects all other businesses. Consequent changes to the income of labour and business along this chain of supply induces further spending to provide multiplier effects. The induced spending is also sensitive to consequent changes to unit costs of production, and to Kyoto-related changes such as taxes, subsidies and the trading system, as these are reflected in prices. Producer selling prices are detailed for the industries represented in the model, which are used to determine the prices of final demand. TIM incorporates input-output tables to link final demands to industrial output, thereby representing the interdependence of industries and to determine selling prices used in the calculation of final demand. To reflect changes in fuel-using technology, the results reported by the energy-technology models are used.

TIM models these effects as an "adjustment" over time and, as such, the system is not always in equilibrium. As a result, there may be periods of under/over-capacity, higher unemployment and imbalances in government current account and other-sector savings.

TIM has 750 categories of final demand and represents 133 industries at a provincial and territorial level. It also has an international component to account for exports and imports, which are detailed for approximately 100 commodities.

For the roll-up analysis, TIM uses the results from the energy-technology models, in particular capital investment, energy savings and emission permit prices, as input to calculate the impacts on economic activity, competitiveness, trade and government fiscal position. Complementary, and consistent impacts on current spending are drawn from the Issue Tables.

To develop a complementary macroeconomic view, the AMG used a general equilibrium developed by the Department of Finance (Economic Studies and Policy Analysis Division). This economic model includes some of the energy-technology features of CIMS and MARKAL and some of the macroeconomic features of TIM, although not to the same level of detail.

The Canadian Sectoral General Equilibrium Model (CaSGEM) is a static,[6] computable general equilibrium model of the Canadian economy. Relative price changes are the main factor causing behavioural changes. Therefore, the elasticities - the relationship between price changes and the changes in supply or demand - are critical to the functioning of the model. The model is made up of 51 sectors which, together, produce 59 different goods and services. The public sector collects taxes and transfers money in addition to providing

[6] A static model produces a single result after the adjustment period when the model has reached equilibrium. It does not provide any insights as to when this equilibrium may occur.

goods and services. International trade is also represented. In the model, consumers interact with producers through the relative price mechanism until the price-quantity relationship is in equilibrium. Taxes are collected and redistributed through the government part of the public sector. The model assumes perfect competition. Its output includes: fuel prices and demand, gross domestic product and the marginal cost of GHG abatement.

***Environmental-Health Models***

The Environmental and Health Impacts were examined in both quantitative and qualitative terms, using a number of approaches and analytical tools.

The quantitative assessment involves the following steps:

the use of a spread sheet model that defines the relationship between energy use and criteria air contaminant (CAC) emissions to estimate changes in CAC for the reference case and the Paths analyzed.

these results are used to estimate changes in ambient concentrations of pollutants (air quality).

the Air Quality Valuation Model (AQVM) estimates the physical health and environment impacts associated with the changes in air quality and estimates the economic value of the effects that would be avoided by reducing emissions.

AQVM evaluates the costs and benefits of proposed climate change initiatives on air quality. It is based on the damage function approach in which projected reductions in the ambient air concentration of certain air pollutants are used to estimate reductions in various human health and environmental effects. Economic values are then applied to these physical impacts, largely using the concept of willingness-to-pay, based on wage differential studies. Benefits estimates, produced by AQVM, provide a view of the value that individuals place on avoidance of these negative health and environmental impacts.

The qualitative assessment examines the relative environmental and health impacts across the Paths and Scenarios.

## 3.3 The Framing Assumptions

The analysis of the Paths requires a context, which is provided by the framework assumptions. The two principal components of this framework are a reference case and a set of views regarding the shape of the Kyoto Mechanisms with the consequent reactions of Canada’s principal trading partners. These elements are discussed below. There are other framing assumptions required which are germane to specific phases of the analysis. These are discussed in later chapters with the corresponding results.

***The Reference Case***

A reference case provides a policy-as-usual base against which to evaluate the impact of the Paths. In May 1999, the National Air Issues Coordinating Committee on Climate Change (NAICC) requested that the AMG provide this reference case. The AMG decided to update the previous reference case[7] incorporating new methodologies and data, as well as insights from the Issue Tables and other stakeholders.

The new report, *Canada's Emissions Outlook - an Update* (CEOU), was released in December 1999. This report projects that, in a "policy-as-usual" environment, GHG emissions will rise from 601 Megatonnes (Mt) of $CO_2$ equivalent in 1990 to 764 Mt in 2010. For a consistent evaluation of the Paths, all the economic models were calibrated to the assumptions and results of the CEOU.

Canada's Kyoto target is to reduce its GHG emissions to 565 Mt in 2010, 6 percent below the 1990 level. Based on this projection, the required reduction, in 2010, is 199 Mt which is 26 percent below the reference case. The CEOU did not include estimates of agriculture and forestry sinks because the estimates are contingent upon the outcome of the international negotiations regarding the accounting for land use changes and forestry in GHG inventories. At this time, there is considerable uncertainty regarding the definition of forestry sinks and the inclusion of agricultural sinks. However, for analytic purposes an estimate of agriculture and forestry sinks is required. Based on advice from the Sinks and Agriculture Issue Tables, it is assumed that the negotiations will permit the use of 10 Mt for Forestry sinks and 6 Mt for Agricultural soil sinks. Under these conditions, the emissions in 2010 are reduced form 764 to 748 Mt, hence the gap is reduced to 183 Mt.

***The Scenarios***

The Kyoto Protocol incorporates a number of flexibility mechanisms which allow countries to discharge a portion of their obligations internationally. At this time, the form of these mechanisms is not well articulated and is the subject of future international negotiations. It is important to understand the implications of potential outcomes of these negotiations. Equally important is the likely response of Canada's trading partners, in particular the United States. The United States' response will, because of the strong trade links, have repercussions on Canadian economic activity. In order to cover a range of responses, three Scenarios were developed by the AMG. The first Scenario, Canada Acts Alone, assumes that Canada meets its Kyoto target solely by domestic emission reduction actions and no

---

[7] Natural Resources Canada, *Canada's Energy Outlook 1996 to 2020.* April 1997.

other country effects any emission reduction initiatives. Export prices and export demand are maintained at the same level as in the CEOU. This Scenario is designed to show the impact of Canadian GHG policy in isolation from the potential effects which may occur as a result of implementation of GHG policies in other countries. The two International Scenarios assume that GHG reductions can be achieved using different degrees of the application of international mechanisms.

The AMG requested CCEAF to develop two scenarios of international actions that would represent a plausible range of the flexibility mechanisms. CCEAF recommended that the study prepared by the Energy Information Administration (EIA) of the U.S. Department of Energy,[8] form the basis of the Scenarios. The EIA study analyzed eight cases for the U.S. to meet its Kyoto target. Each case was based on different proportions of domestic and international permit trading. CCEAF recommended two cases from the EIA study, defined in terms of the scope and stringency of the Kyoto mechanisms, to model the International Scenarios (Chart 3.3).

**Chart 3.3**
**EIA Cases**
**Percent Change from the Base Case**

| | Kyoto Loose | | | Kyoto Tight | | |
|---|---|---|---|---|---|---|
| | 2005 | 2010 | 2020 | 2005 | 2010 | 2020 |
| **Change in GDP** | 0 | -1 | <-1 | <-1 | -2 | <-1 |
| **Change in inflation** | 0 | 1 | 1 | 2 | 3 | 2 |
| **Natural gas export prices** | 1 | 0 | 13 | 1 | 18 | 38 |
| **Natural gas exports** | -1 | -1 | 3 | 0 | 7 | 9 |
| **Crude oil export prices (light including synthetic; and heavy including bitumen)** | -1 | -4 | -7 | -2 | -11 | -9 |
| **Crude oil exports** | 0 | 0 | 1 | -1 | -1 | 0 |
| **Average electricity export prices** | 2 | 20 | 30 | 23 | 49 | 45 |
| **Coal prices** | | | | | | |
| **- End use** | 11 | 150 | 260 | 170 | 385 | 385 |
| **- Import price** | 2 | 3 | 3 | 2 | 2 | 1 |
| **Carbon Price (US $1996/per metric ton)** | N.A. | 67 | 99 | N.A. | 163 | 141 |
| **$CO_2$ Price (CDN$1996/metric ton)** | N.A. | 25 | 36 | N.A. | 60 | 52 |

***Kyoto Loose***[9] posits a situation in which there is a well established permit trading system with low transaction costs, buy-in by developing countries and plentiful JI and CDM opportunities. Under these circumstances the U.S. can discharge 75 percent of its obligation internationally. The resulting permit prices is C$(1995) 24 per tonne of $CO_2$. Kyoto Loose approximates the Clinton Administration's preferred position.

***Kyoto Tight*** assumes the permit trading system is not as well developed, with higher transaction costs. Participation by developing countries is limited, CDM and JI opportunities are constrained. This results in the U.S. discharging only 33

8 *The Impacts of the Kyoto Protocol On U.S. Energy Markets and Economic Activity* , October 1998.

9 The terms *Kyoto Loose* and *Kyoto Tight,* developed by CCEAF, are intended to reflect the degree of flexibility in the Kyoto Mechanisms. These Scenarios were developed from the EIA cases: *1990 +24 percent* and *1990 +9 percent* respectively. The EIA reference case indicated that U.S. GHG emissions would be 33 percent higher than the 1990 level. The U.S. target is 7 percent below the 1990 level.

percent of its obligations internationally, meeting the remainder through domestic actions. The permit price is C$(1995) 58 per tonne of $CO_2$. CCEAF argues that Kyoto Tight represents the minimum conditions for U.S. ratification.

The primary purpose of using the EIA study is to obtain a credible range of international carbon prices to incorporate into the analysis. An additional benefit of this study is that it provides a comprehensive analysis of the U.S. actions on energy prices, energy imports and economic activity, all of which have important implications for Canada's achievement of the Kyoto target. For consistency in its analysis, the AMG decided to use the major results from the EIA. Some of the more important energy inputs are provided in Chart 3.3. Of particular note is that world oil prices in 2010, decline by 4 percent in Kyoto Loose compared to the reference case, and by 11 percent in Kyoto Tight. The EIA does not expect Canadian crude oil exports to be affected.[10] By contrast, natural gas prices rise by 18 percent, and imports from Canada increase by 7 percent under Kyoto Tight, as natural gas displaces coal in electricity generation in the U.S. In Kyoto Loose, there is little impact on the natural gas prices and imports. The AMG did not use the EIA electricity imports, from Canada, as they did not appear to be consistent with the electricity pricing assumptions. The AMG decided that electricity trade would be about the same as the reference case and that no new plants would be built solely for electricity exports from Canada. The EIA study also provided some information on the macroeconomic impacts, which indicated that there would be a reduction in Gross Domestic Product of 1 to 2 percent.

## 3.4 Understanding the Results

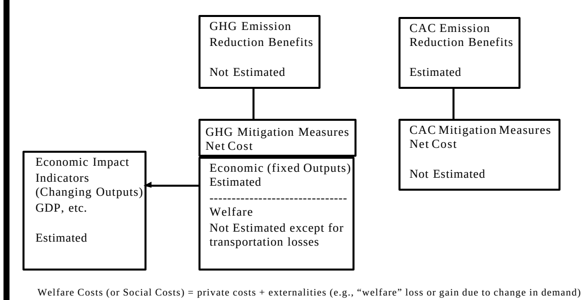
The following chapters of this report present the estimates of the economic, environmental and health impacts. Before presenting a detailed description of these results, it is critical to understand what is implied by each of the results.

In general, the results reported reflect the change in activity from a reference point referred to as the business-as-usual case (BAU). The results are, therefore, to be viewed as incremental to the activity that would have occured in the BAU. As well, the results are typically reported for 2010, as this is the mid-point in the Kyoto commitment period (i.e., 2008-2012).

10 There was some divergence of opinion among the AMG regarding the impact of the Kyoto Scenarios on the level of energy exports, particularly crude oil. There is a view that the imposition of abatement costs on the Upstream sector may render some supply sources uneconomic. Alternatively, the cost of abatement is likely to be less than some of the recent low price shocks, which had no discernable impact on energy exports. This area requires more detailed analysis.

The section attempts to provide the reader with guidance on a set of fundamental issues related to the AMG analysis. The elements are portrayed in Chart 3.4, which provides an overview of the results generated by the microeconomic, macroeconomic and environmental and health impact analyses.

**Chart 3.4**
Elements to Assess Economic, Environment and Social Costs and Benefits




The first element is the direct costs of abatement. These were estimated by the micro-models (energy technology) – MARKAL and CIMS – and are summarised in Chapter 4. These direct costs consist of the increase in expenditures on capital and labour (i.e., the real resource costs) to undertake the new investment to be incurred in response to the measure. In some cases, there may be decreases in expenditures. For example, an investment in a more energy-efficient technology will result in lower expenditures on energy consumption. These increases and decreases are added together to obtain the total abatement cost. Since all expenditures, or avoided expenditures, do not occur in the same year, it is necessary to discount those that occur in the future, since a dollar spent or saved ten years from now does not have the same value as a dollar spent or saved this year.

Ideally, the analysis of the direct costs of abatement should include both financial expenditures and non-monetary impacts (i.e., welfare costs). The latter includes the value of time spent (e.g., to make a trip), other impacts on the environment and changes in the level or quality of service being provided.

While both microeconomic models provide estimates of cost of abatement, there are variations in what these costs actually represent. In MARKAL, all costs are actual costs of resources incurred by the consumers or producers. In CIMS, the costs are those perceived by consumers and producers, taking into account consumer product preferences, attitudes to risk, financial costs, relative to other product attributes, and time preferences.

The exclusion of welfare cost estimates means that macroeconomic results may not represent the net social cost to Canada of realising the Kyoto target. MARKAL estimated some welfare costs associated with the increased motive fuels tax. CIMS did not explicitly estimate any welfare costs. There may be other welfare losses or benefits occurring in the microeconomic modelling, but these impacts are not captured by this analysis.

Both models also provide an estimate of the marginal cost of abatement (i.e., the change in total costs when one more unit of $CO_2$ is reduced). Marginal costs – reported as the cost per tonne of GHG saved – are useful to consider in addition to total costs because they reflect the "strain" on the economy by reducing another unit of GHG from any given level. The reader should be aware that the cost per tonne multiplied by the GHG saved does not yield the total cost.

The costs reported in the micro analysis are partial in nature in two different senses. First, they are the initial costs incurred by industries and consumers to reduce GHG. They can be considered direct costs in that they do not include the "second round effects" on industries covered by the macroeconomic analysis. In this initial impact, the non-energy output (e.g., industrial manufacturing output) remains constant. However, "second round effects" effects are included in the costs for the energy supply industries. Second, the costs estimated by the microeconomic models do not include all the intangible costs (a component of total social cost) such as the value of time, changes in the quality of services provided, or the environmental and health benefits. The environmental and health benefits are examined in Chapter 7.

The second element is the macroeconomic analysis. The micro-modelling results provided a basis for undertaking the macroeconomic analysis, summarised in Chapter 5. The resource costs and fuel-related costs are inputs to the macroeconomic analysis.

Results from the macroeconomic analysis focus on impacts across the economy and, to the extent that they capture second-round effects, such as changes in industrial output, are more complete than the microeconomic analysis. The macroeconomic results provide information on several indicators, the most important of which are gross domestic product (GDP), employment, total factor productivity, inflation, imports and exports and government finance.

GDP, as a measure of the economy's total income or production, cannot be compared with welfare. However, since GDP provides information on changes in final demand for goods and services, it is sometimes interpreted as a measure of general well being. While the macroeconomic impacts account for changes in output through sectors of the economy and the overall economy, they do not reflect changes to consumer utility. In other words, changes in the level of GDP do not account for the relationship between distribution of income and overall social welfare. Moreover, the GDP results do not account for the direct implications for the economy of climate change, nor for the local climate implications that follow from reducing the emissions of other pollutants that are associated with GHG emissions. Therefore, comparisons of changes in GDP to welfare changes (i.e., benefits or losses) are not appropriate.

The economic impacts of implementing packages of measures to reduce GHG emissions can be expressed as changes in GDP. It is important to bear in mind that these impacts are presented as "a reduction of x percent in GDP" and are relative to the GDP underlying the BAU. For example, a reduction in GDP of 3 percent in 2010 means that, over the decade, the economy will grow by about 26 percent instead of 30 percent as projected in the BAU (97 percent of 130 percent). This is equivalent to the loss of about one year's growth. It does not mean that the annual growth rate for GDP declines by 3 percent.

The environmental and health impacts (EHI) associated with the GHG mitigation actions constitute the third element. The fuel mix changes from the micro models are inputs for calculating the environmental and health benefits. Like the micro- and macroeconomic analyses, the EHI impacts are changes from the BAU. The EHI results are presented in both physical (i.e., changes in emissions levels) and quantitative (i.e., financial) terms.

The benefit assessment comprises two parts – the primary benefit and the secondary or co-benefit. The primary benefit relates to the contribution that the GHG mitigation actions make to an overall improvement in the climate and the resulting impacts on the environment, economy and society. The report does not provide a valuation of these benefits. Such benefits are very difficult to estimate as they are uncertain, future, global in nature and contingent on others acting.

The secondary or co-benefits include those associated with the impact of the proposed GHG reduction measures on the more "conventional pollutants" such as $NO_X$, $SO_X$, volatile organic compounds and particulates. These emissions lead to deteriorating air quality and can have negative health and environmental impacts. Therefore, measures to reduce GHG that also reduce these other emissions usually yield positive benefits, but occasionally negative co-benefits may occur. In essence these co-benefits can be viewed as a "bonus" to the primary reason for undertaking these measures to reduce GHG emissions. The EHI analysis provides a valuation of the co-benefits. The co-benefits are more readily measured as they are local in nature and less contingent on actions by others.

The financial impacts resulting from the EHI analysis reflect a change in societal welfare. As such, they can be compared to the costs of GHG emissions abatement, but not to the impact on GDP. However, caution should be taken in comparing the EHI results in Chapter 7 with the microeconomic results in Chapter 4. The EHI analysis does not take into account the potential for realising the same benefits through non-GHG reducing measures. If more analysis were undertaken to fill-in such information gaps, a comparison could be made between the microeconomic costs and the monetized EHI co-benefits.

*Uncertainty*

Climate change analysis is a complex issue with many uncertainties. The principal areas of uncertainty include:

- The reference case assumptions, especially its economic growth, energy prices and the projection of GHG emissions.

- The assumptions used in this analysis, particularly regarding agriculture and soil sinks.
- The timing of the implementation of Kyoto-related policies.
- The nature of the international mechanisms.
- The degree of interprovincial electricity trade.
- The sensitivity of Canadian imports and exports to changes in foreign prices.

# Chapter 4
# Energy-Technology Model Results

This chapter provides the direct results at the national, sectoral and regional levels for the two energy-technology models.[11] These results include the GHG emissions reduction, the associated cost and energy consumption for various path-scenario combinations. Not all of the combinations were explored because only limited additional insights would be provided. The combinations analyzed are shown in Chart 4.1. All five Paths were analyzed in the Canada Acts Alone Scenario. Paths 2 and 4 were fully examined under the two International Scenarios. Both sets of results from the energy-technology models (CIMS and MARKAL) are shown.

Chart 4.1
Paths and Scenarios
Examined in Micro Economic Analysis

| | Canada Acts Alone | Kyoto Tight | Kyoto Loose |
|---|---|---|---|
| **Path 0** | X | | |
| **Path 1** | X | | |
| **Path 2** | X | X | X |
| **Path 3** | X | | |
| **Path 4** | X | X | X |

Detailed results from both sets of analysis with the energy-technology model are available in individual reports. The results with CIMS model may be found in the report, Integration of GHG Emission Reduction Options Using CIMS, prepared by Energy Research Group / M.K. Jaccard and Associates. The results with the MARKAL model are contained in the report, Integrated Analysis of Options for GHG Reduction with MARKAL, prepared by HALOA, Inc.

## Key Learnings

- There is a clear relation between the level of the flexibility available in an emission reduction policy and the total cost of emission reduction efforts. It can generally be shown that moving from individual sector emission targets to a cross-sector emission target will allow the desired objective to be achieved at a lower national cost.

---

11 The results for the Agriculture sector, which were modelled separately by the Agriculture and Agri-Food Issue Table, are also included.

- Greenhouse gas emissions are reduced through improvements in efficiency that reduce fossil fuel use and through fuel switching away from more carbon-intensive fuels. The relative impact on consumption of different energy sources depends on the size of the emission target and the availability of less carbon-intensive fuels and efficient technologies. For example, coal and oil product uses tend to switch to natural gas, thereby reducing the consumption of coal and oil products in all Paths, relative to BAU. Somewhat surprisingly, domestic demand for natural gas also declines. The reason for this is that increasing natural gas demand, from switching to natural gas in some areas, is offset by improvements in efficiency of the use of natural gas. Changes in specific assumptions about availability of technology or trade opportunities could change this result. If capture and storage of $CO_2$ from coal-fired generation and to a lesser extent, enhanced hydro-electricity trade were unavailable then greater fuel switching to gas-fired electricity generation could increase the demand for natural gas.

- In order to achieve cost-effective emission reductions in Canada, different sectors face opportunities or challenges to reduce emissions. The industrial sector, particularly oil and gas producers, and the transportation sector seem to face the greatest challenges. By contrast, there appears to be lower-cost opportunities in electricity generation, related to the availability of $CO_2$ capture and storage, and interprovincial trade.

- Both energy-technology models suggest similar emission reduction patterns across the provinces. In all Paths in which the national objective is attained, emissions in Alberta and British Columbia remain above 1990 levels. All of the other provinces, to varying degrees, reduce their emissions below 1990 levels and in most cases by more than 94 percent of those levels. However, the direct cost pattern is somewhat different. For most provinces, the direct costs decline when an optimized policy approach (i.e Paths 2 and 4) is employed. For Alberta and Saskatchewan, however, the costs increase. This is largely related to the additional costs associated with $CO_2$ capture and storage.

- For Canada, access to the Kyoto mechanisms significantly lowers the direct costs of reducing emissions, and changes the emission burden across sectors and provinces.

- Further work is needed on international scenarios, particularly in understanding Canadian vulnerability to changes in world and North American commodity prices as a result of an international climate change agreement.

Sensitivity analysis on the results suggest that the costs of emission abatement in Canada, derived from the analysis and insights of the Issue Tables, rise gradually to within about 50 Mt of the Kyoto target. Emissions abatement costs then begin to rise at a much faster rate. This result suggests that increases in Canada's emission gap will disproportionately increase the total costs of reducing emissions. It also suggests that access to international flexibility mechanisms, the outcome of international negotiations on agricultural and soils sinks, the availability of low cost emission reduction technologies and assumptions in the reference case will all have impacts on the national, sectoral and regional costs of emission abatement.

### 4.1 Context of the Canada Acts Alone Results

In order to interpret the results it is important to understand the context in which they were derived. There will be differences between the results given by the two models, mainly attributable to the differing philosophies of the models as discussed in Chapter 3. The AMG chose these two models specifically to examine the impact of the different model philosophies.

Other differences will occur as a result of the unique model structure and set of assumptions for each model. The most important differences may arise from the treatment of the following issues:

> ***The Post-2012 Period***. The two energy-technology models treat this time period differently as a result of the different structure of the two models. For the optimizing model, MARKAL, the Kyoto commitment of 565 Mt was held constant, whereas for the behavioural model CIMS, the marginal cost of abatement, for 2010, was held constant. This may cause the GHG emissions in CIMS to be higher than the Kyoto target after 2010.
>
> ***Average vs. marginal cost pricing***. As mentioned in Chapter 3, the price of electricity is determined differently in the CIMS and MARKAL models. In the CIMS model, the price is determined by the average cost of producing electricity. In MARKAL, energy producing sectors set the price to reflect the incremental cost of producing the last unit of output. The result of marginal cost pricing is that energy-producing sectors receive extra profits because additional revenue is greater than the total cost of emission reduction policies.
>
> ***Inter-provincial electricity trade***. MARKAL assumes that the electricity market is freely traded between provinces, whereas inter-provincial trade is restricted in CIMS. This implies that MARKAL allows for new inter-provincial transmission while CIMS does not. As a result, CIMS shows a higher level of emissions in the electricity sector since some hydro-electricity would not be available to displace fossil fuel power generation.
>
> ***Refinery Output***. In the CIMS model, it is assumed that the Canadian refinery industry remains competitive in the North American market; thus, if Canadian demand

for refined product declines, any surplus can be exported. By contrast, in the MARKAL model some portion of this industry will not be competitive, meaning that a decline in demand may cause a reduction in refinery capacity. It may be expected that CIMS would produce a higher level of emissions under this assumption.

For the purposes of the AMG analysis, the following assumptions are common to the CIMS and MARKAL work:

***Fixed non-energy sector output***. This assumption maintains the output of all non-energy sectors of the economy at reference case levels. The AMG deliberately imposed this constraint on the energy-technology models because it felt that a macroeconomic model would better capture the effect of energy changes on all sectors of the economy. The only exception is in the transportation sector where road travel demand is allowed to change. This exception was made because many of the Tables' measures were aimed specifically at reducing travel demand.

***Fossil Fuel Production***. In the Canada Acts Alone cases, fossil fuel production was held to reference case levels. This assumption was made to isolate and understand the direct effects of GHG abatement strategies. This assumption places greater demands on energy producers to reduce emissions.

***Energy Exports***. The production of fossil fuels is maintained at the reference case levels; consequently, exports vary depending on domestic demand. For example, if domestic crude oil demand declines, then exports will rise by the amount of the decline; in other words, the surplus is sold to the U.S. to respect the constant production assumption.

***Energy Export Prices***. These have been maintained at reference case levels. The reason for this assumption is twofold. First, Canada would not be expected to have any effect on world oil prices, and second, without directly modelling the North American natural gas market, supply and demand in the U.S. and the resulting effect on prices are uncertain.

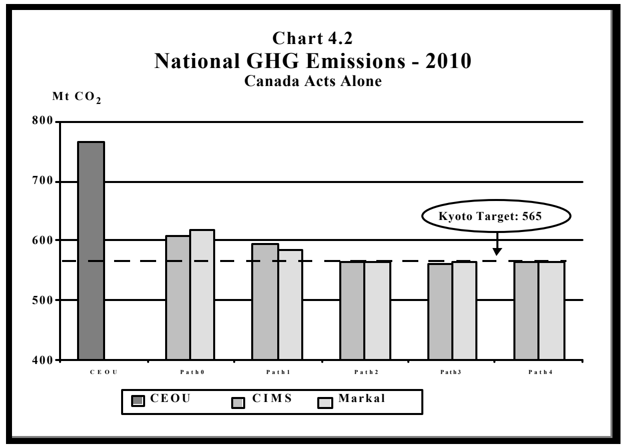
The variations to these assumptions for the microeconomic analysis of the International Scenarios are provided in Section 4.4; for the macroeconomic analysis, in Chapter 5. The sensitivity analysis presented in this chapter will be compared to the MARKAL results based for Path 2 Canada Acts Alone.

## 4.2 Results: Canada Acts Alone

### *National Results*

*GHG Emissions*

In the reference case (BAU),[12] GHG emissions are projected to reach 748 Mt in 2010, provided that the assumption of 16 Mt for Forestry and Agricultural sinks is included in the final text of the Kyoto Protocol (see Chapter 3). The required reduction is 183 Mt to reach the Kyoto target of 565 Mt (Chart 4.2). Each of the Paths was intended to reduce emissions to achieve this target. However, Paths 0 and 1 did not attain this level. Paths 2, 3 and 4 achieved the targeted reduction by design.




Path 0, which is an aggregation of all Issue Table measures, does not achieve the Kyoto Target. While some of the Issue Tables could not provide sufficient measures to meet the emission target, those that were submitted achieve about two-thirds of the necessary reductions. One reason that Path 0 did not achieve the emission target was that the Electricity sector's preferred method of achieving emission reductions, emission pricing, was not included. The emission reductions in Path 0 fall short of the target by 44 and 54 Mt for CIMS and MARKAL respectively.

In Path 1, each sector is expected to meet a *"6 percent below 1990 emissions"* target. The overall reduction target was not achieved in Path 1 because the Upstream and Refining sector had insufficient measures to meet its emission target, even at a cost of $300 per tonne of $CO_2$, and high growth in emissions related to oil and gas production.

*Costs*

Both models provide estimates of the long-term cost of abatement on a unit and total basis. The unit costs reflect the marginal cost[13] of abatement, which can be interpreted as the price of an emissions permit.

12 The terms *reference case* and *BAU* are used interchangeably.

13 Marginal cost is the cost of the last unit of GHG abated. CIMS uses this term synonymously with shadow price.

The 2010 marginal costs of abatement for each *Canada Acts Alone* Path are provided in Chart 4.3. No costs are shown for Path 0 since the measures were imposed. For Path 1, the only relevant marginal cost is for the electricity sector. Of greater interest are the results for the optimized Paths (2 and 4). MARKAL indicates that the economy-wide abatement cost is about \$57 per tonne of $CO_2$, whereas the CIMS estimate is much higher at about \$120 per tonne of $CO_2$.[14] The slightly lower results for Path 3 and 4 occur because the coverage of the emission trading system excludes several high abatement cost sub-sectors. Also of note, in Paths 1 and 3, is the motive fuels tax increase required to achieve the target in Transportation. The additional tax is 16 to 19 cents per litre in MARKAL and about 12 cents per litre in CIMS. To put this in perspective the current federal excise tax on gasoline is 10 cents per litre and the combined federal and provincial level of taxes is, on average, 32 cents per litre.

**Chart 4.3**
**Marginal Costs Of GHG Reduction:**
**Canada Acts Alone**
**(\$ per tonne)**

| | Electricity | Industry & Upstream | Residential & Commercial | Transportati on | Fuel Tax censt/litre |
|---|---|---|---|---|---|
| **MARKAL** | | | | | |
| Path 0 | | | | | |
| Path 1 | 23 | | 5 | 70 | 16 |
| Path 2 | 57 | 57 | 57 | 57 | |
| Path 3 | 32 | 32 | | 84 | 19 |
| Path 4 | 49 | 49 | 49 | 49 | |
| **CIMS** | | | | | |
| Path 0 | | | | | |
| Path 1 | 30 | | 10 | 50 | 12 |
| Path 2 | 120 | 120 | 120 | 120 | |
| Path 3 | 110 | 110 | 20 | 50 | 12 |
| Path 4 | 120 | 120 | 120 | 120 | |

The total investment and net costs for the five Paths are shown in Chart 4.4. In order to interpret these results some explanation is required:

**Chart 4.4**
**Investment and Net Cost by Path**
**Canada Acts Alone**
**($NPV_{10}$ \$Billions)**

| | Path 0 | Path 1 | Path 2 | Path 3 | Path 4 |
|---|---|---|---|---|---|
| **Investment** | | | | | |
| CIMS | 151 | 139 | 106 | 121 | 106 |
| MARKAL | 91 | 77 | 22 | 71 | 30 |
| **Total Net Cost** | | | | | |
| CIMS | 41 | 61 | 45 | 46 | 45 |
| MARKAL | 46 | 52 | 14 | 36 | 20 |
| **GHG Reduction (Mt $CO_2$)** | | | | | |
| CIMS | 141 | 157 | 187 | 192 | 190 |
| MARKAL | 128 | 164 | 181 | 182 | 182 |

Excludes welfare costs.

- They are incremental to the reference case. This is important when comparing apparently large cost differences between models and across Paths.

- The investments include the real

---

14 In Paths 2 and 4, both models attempt to estimate the price of carbon which just causes the target to be reached, i.e., the price required for the last tonne to achieve the target to be abated. In estimating this "marginal cost" price, MARKAL accounts only for direct financial costs. CIMS, by contrast, also takes into consideration less tangible costs which are based on observed consumer behaviour. Although such intangible costs are relevant to determine consumers reaction to policy initiatives, they do, by their nature, contain a large element of subjectivity. The CIMS modelling team has suggested that were these behavioural parameters to be eliminated from their analysis, the strict "financial cost" estimate of the marginal abatement cost might be about \$80 to \$90 per tonne of $CO_2$.

resource costs associated with capital formation and operation and maintenance; they do not include any welfare costs.[15]

- The net cost is determined by comparing the total investments required in the BAU case to the investments for GHG reduction measures in each Path, less the resulting energy cost savings generated by those measures.

- The investments and savings are accumulated over a 20 year period and expressed in present value terms, discounted at 10 percent ($PV_{10}$).

- All investments are net of the undepreciated values after 2022 and are expressed in 1995 Canadian dollars.

The incremental investments range from $106 to $151 billion for CIMS and $22 to $91 billion for MARKAL. The $PV_{10}$ of the net costs associated with these reductions vary from $41 to $61 billion for CIMS and $14 to $52 billion for MARKAL.

In terms of investment requirements, Paths 0 and 1, in which the measures are imposed, are more costly. Path 3, which allows some emissions trading, is slightly less costly. Paths 2 and 4 show the lowest investment cost because the models select the least-cost suite of measures that will meet the emissions target. The incremental investment is significantly smaller in MARKAL.

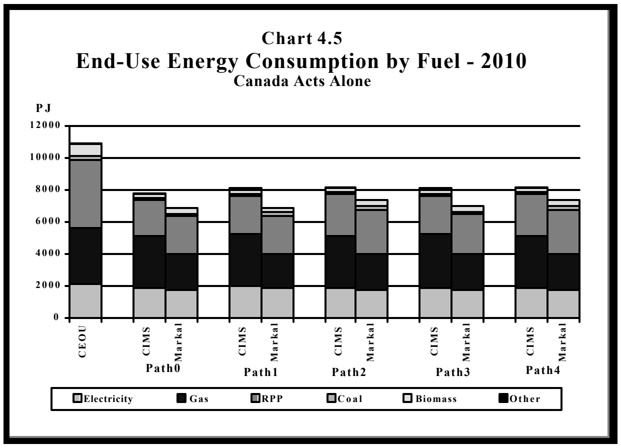
The required investments can give rise to savings in energy costs. The net costs capture the offsetting impact of investments and savings. On a net basis, both models conclude that Path 1 is the most costly because each sector has an imposed target and is forced to use higher cost measures than are available elsewhere in the economy. By contrast, an optimized approach such as Path 2 and 4, in which an aggregate target is used and the most cost-effective measures are selected, appears to offer a significantly lower cost solution. Paths 2 and 4 attain this result by reducing the required emission reduction in high-cost sectors, such as upstream oil and gas, and to a lesser extent, transportation, and increasing it in the low-cost sectors, particularly electricity. An interesting contrast between the models is the similar costs displayed by CIMS for Paths 2, 3 and 4, as compared to the noticeable increase in MARKAL for Path 3. The MARKAL result is expected because imposed measures, which are not selected in Paths 2 and 4, are introduced in Path 3, thereby increasing investments. In CIMS, the measures are selected in these three Paths, which suggests that the behavioural attributes of CIMS cause the cost of the imposed measures, particularly transportation, to be less than the marginal cost of abatement.

---

15 MARKAL did provide an estimate of welfare cost related to transportation, CIMS did not. However, there is some uncertainty regarding the inclusion of welfare costs by Transportation Table.

*End-use Energy Consumption*

In all Paths, total end-use energy consumption is about 30 percent lower than the reference case (as shown in Chart 4.5). MARKAL predicts higher energy savings than CIMS, a result of higher penetration of energy-efficient technologies. The change in the fuel mix is more interesting. Electricity demand declines slightly, relative to the BAU. Natural gas shows a modest decline in CIMS, but a significant decline in MARKAL, up to 40 percent, in Paths where $CO_2$ capture and storage is used, since coal remains viable as a generation fuel source in Alberta and Saskatchewan. Refined petroleum product (RPP) demand decreases substantially, about 30 percent. Both models suggest significant reductions in gasoline and diesel consumption due to reduced demand and efficiency improvements especially in Paths 0, 1 and 3.




Electricity accounts for about 19 percent share of end-use energy in the BAU, rising to about 25 percent in all Paths. In MARKAL, natural gas has a similar share of end-use energy as the reference case (32 percent). However, the CIMS results indicate that natural gas rises to about 40 percent. The share of RPP declines from a 40 percent share in BAU to about 35 percent in the MARKAL results and 30 percent in the CIMS results.

***Sectoral Results - Canada Acts Alone***

This section provides the emissions reduction by sector. The analysis covers seven sectors, namely: electricity, upstream and refining, industry, residential, commercial (including Municipal waste), transportation and agriculture/other. The agriculture/other sector is treated in the same way for all Paths. Only the results for Paths 2, 3 and 4, which attain the Kyoto target, are displayed.

**Chart 4.6**
**SectoralShares of GHG Reductions - 2010**
**Canada Acts Alone**
**(percent of the gap)**

| | Path 2 | | Path 3 | | Path 4 | |
|---|---|---|---|---|---|---|
| | CIMS | MARKAL | CIMS | MARKAL | CIMS | MARKAL |
| Electricity | 43 | 57 | 43 | 40 | 43 | 55 |
| Upstream & Refining | 10 | 12 | 10 | 14 | 10 | 14 |
| Industry | 7 | 5 | 7 | 5 | 7 | 5 |
| Residential | 5 | 5 | 0 | 3 | 5 | 5 |
| Commercial | 6 | 6 | 4 | 4 | 6 | 6 |
| Transportation | 24 | 9 | 31 | 27 | 24 | 10 |
| Agriculture/ Other | 6 | 5 | 6 | 6 | 6 | 6 |

The electricity, upstream and transportation sectors, which represent about 60 percent of the BAU emissions, account for over 75 percent of the emissions reductions for all Paths and in both models. Both models rank electricity as the largest contributor to emission reductions in Paths 2, 3 and 4. In MARKAL, the upstream and refining sector typically ranks second in Paths 2 and 4, whereas CIMS ranks transportation as the second largest contributor. In Path 3, both models rank the contribution in the same order: electricity, transportation and upstream. (Chart 4.6).

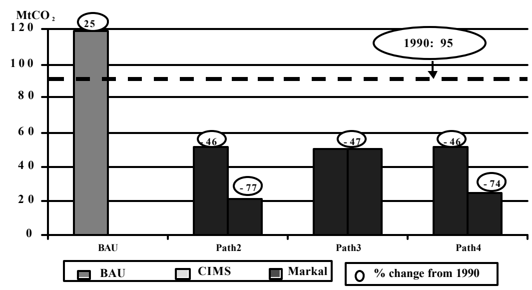
Electricity provides large contributions to emissions reductions because there are lower cost options, relative to other sectors, such as capture and storage of $CO_2$. Transportation provides significant reductions due to fuel savings and the upstream and refining sector is assumed to have high cost generic measures.

*Electricity Sector*

Measures in the electricity sector work in opposite directions. The efficiency measures, in end-use, tend to reduce demand, while fuel switching to electricity tends to increase demand.

In 2010, the BAU projection for GHG emissions is 119 Mt. The emissions reductions projected in Path 3 are similar for both models (68 Mt). For Paths 2 and 4, the CIMS and MARKAL results differ: 67 Mt for both Paths for CIMS and about 95 Mt for MARKAL (Chart 4.7).

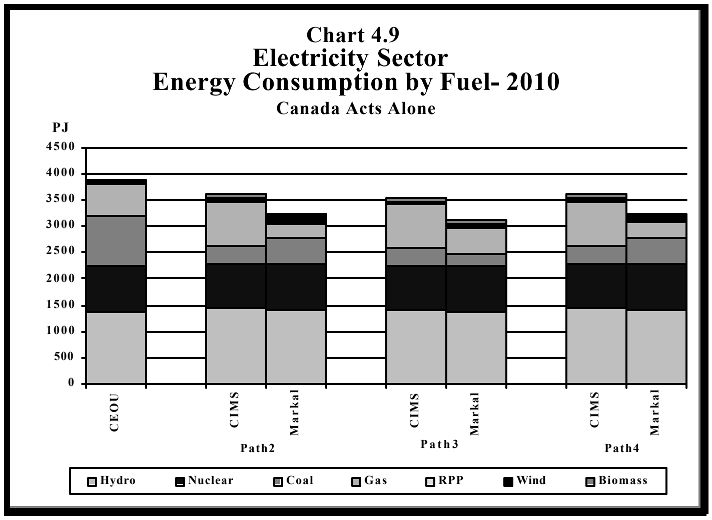
Chart 4.7
**Electricity Sector GHG Emissions - 2010**
Canada Acts Alone




In Paths 2 and 4, $CO_2$ capture and storage, in the deep aquifers of western Canada, is an important abatement strategy in Alberta and Saskatchewan which allows the continued use of coal-fired generation. In these Paths, the capture of $CO_2$ reaches about 27 Mt in CIMS and 43 Mt in MARKAL (Chart 4.8). In both models, capture and storage of the emissions represents about 45 percent of the total reduction in this sector. In MARKAL Path 3, only about 2 Mt is reduced in this manner, a result of the lower marginal cost of abatement for the Large Final Emitters through the permit system, which induces more gas-fired generation in western Canada at the expense of coal.

Chart 4.8
**Capture and Storage of $CO_2$ - 2010**
Canada Acts Alone
(megatonnes)

| | Path 0 | Path 1 | Path 2 | Path 3 | Path 4 |
|---|---|---|---|---|---|
| MARKAL | 0 | 2 | 43 | 2 | 41 |
| CIMS | 0 | 0 | 27 | 24 | 27 |




The fuel mix to generate electricity changes, depending on the reduction strategy chosen. Overall, the amount of fuel to generate electricity is lower in all Paths, relative to the BAU (Chart 4.9). In both CIMS and MARKAL, nuclear energy consumption remains unchanged, while hydro increases by up to 5 percent from the reference case. In all Paths, CIMS tends to predict less coal-fired generation than MARKAL and consequently the amount of capture and storage is lower. Conversely, CIMS expects more natural gas-fired generation. In both models, the consumption of refined petroleum products (RPP) declines in all Paths. Renewable fuels, particularly wind and biomass, do not achieve a very large penetration, typically less than 5 percent, in any Path, including Path 0 where low-emitting electricity generation is subsidized.

In all Paths the electricity sector is expected to achieve substantial reductions in GHG at relatively low cost. Typically, this sector provides 20 to 60 percent of the total reductions required to meet the target.

*Upstream and Refining Sector*

CIMS indicates reductions in the upstream and refining sector to be about 18 Mt for the Paths. MARKAL suggests greater reductions (24 Mt). In 2010, the reference case projection is 146 Mt.

*Industrial Sector*

Detailed results of industry sub-sectors, such as Pulp and Paper and Iron and Steel, can be found in the reports from the microeconomic modellers.

From the reference case level of 115 Mt, all Paths and both models indicate a reduction of about 13 Mt for the industrial sector as a whole.

Total energy consumption is projected to decline from about 4000 PJ in the reference case, to about 3800 PJ for CIMS and somewhat lower, 3500 PJ, for MARKAL in all Paths. The use of RPP shows the largest decline across all Paths for both models. Natural gas remains about the same as the BAU in the CIMS analysis, but is slightly lower in MARKAL. Both sets of energy-technology model results show the use of wood and hog fuel in the industrial sector declining. There is little variation in fuel mix or consumption among the results for the different Paths.

*Residential and Commercial Sectors*

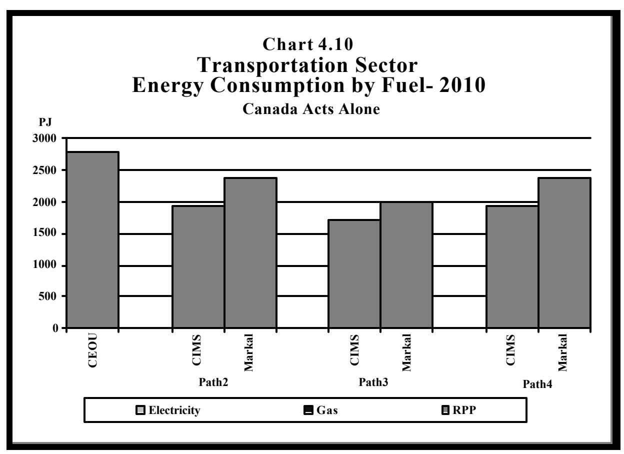
The combined residential and commercial sectors, including municipal waste, generate 106 Mt of emissions in the BAU. The analysis indicates significant reductions for these sectors, in both models for all Paths. Paths 2 and 4 show the highest level of reduction at 27 Mt and 22 Mt for CIMS and MARKAL, respectively. Path 3 shows the lowest level of reduction, at about 14 Mt for both models. The majority of these reductions are obtained through the measures proposed in the Options Packages.

The reference case predicts total energy consumption at about 2,600 PJ, which is dominated by electricity and natural gas. Total consumption drops to about 2,200 PJ in CIMS and about 2,450 PJ in MARKAL. While the fuel shares do not vary substantially, there is a slight trend away from RPP and electricity use in both models. Natural gas increases its share marginally, but overall consumption is generally lower than in the BAU.

*Transportation Sector*

In this sector, both models indicate that emissions decline from the reference case levels of 197 Mt to about 140 Mt in Path 3. This Path incorporates the 44 “most promising” and “promising” measures, as well as the increase in motive fuels tax of 12 cents to 19 cents per litre over current levels. Paths 2 and 4 show smaller reductions, 43 Mt and 24 Mt for CIMS and MARKAL, respectively.

For CIMS, the energy consumption declines sharply form 2,800 PJ in the reference case to about 1,700 PJ in Path 3, and to about 1,900 PJ in Paths 2 and 4. The pattern is similar in MARKAL, but the reductions are lower, with fuel consumption being between 2,000 PJ and 2,400 PJ (Chart 4.10). The full amount of this reduction occurs in RPP use. In the CIMS analysis, natural gas makes a slight penetration, less than 1 percent, into transportation energy consumption.




As many of the measures proposed by the Transportation Issue Table are relatively high cost, few of them are included in the lower-cost Paths (2 and 4). Therefore, the transportation sector has difficulty achieving significant emission reductions in either of these Paths.

*Agriculture/Other Sector*

This sector comprises non-energy- related emissions from agriculture, land use, propellants, hydro-fluorocarbons (HFC) and anaesthetics. The agriculture sector accounts for almost 90 percent of emissions from these sources, which were 66 Mt in the reference case (after an allowance for potential soil sinks of 6 Mt). More detail of the agriculture sector can be found in the report, *Analysis of Strategies for Reducing Greenhouse Gas Emissions from Canadian Agriculture: Technical Report to the Agriculture and Agri-Food Table*.

As a result of the options proposed by the Agriculture and Agri-Food Table, agricultural emissions in 2010 are expected to be 8 Mt less than in the BAU. Three areas comprise most of this reduction: increase in no-till, decrease in summerfallow and grazing management.

The reduction for the other components (propellants, HFC and anaesthetics) is achieved through permit trading as no measures were proposed.

***Provincial Results - Canada Acts Alone***

**Chart 4.11**
**Provincial Emissions -BAU 2010**

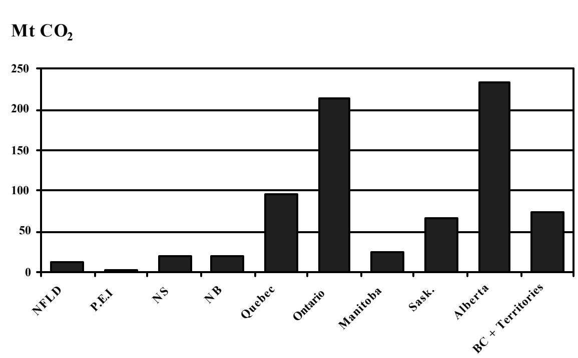



Chart 4.11 provides the provincial distribution of GHG emissions, before adjustments for sinks, in the reference case. Alberta and Ontario each account for about 30 percent of Canada’s emissions. Quebec accounts for about 12 percent, and British Columbia and Saskatchewan for about 10 percent each.

**Chart 4.12**
**Provincial Shares of GHG Reductions - 2010**
**Canada Acts Alone**
**(percent of the gap)**

| | Path 2 | | Path 3 | | Path 4 | |
|---|---|---|---|---|---|---|
| | CIMS | MARKAL | CIMS | MARKAL | CIMS | MARKAL |
| Nfld | 1 | 2 | 1 | 2 | 1 | 2 |
| PEI | 0 | 0 | 0 | 0 | 0 | 0 |
| NS | 5 | 4 | 4 | 3 | 5 | 4 |
| NB | 3 | 3 | 3 | 3 | 3 | 3 |
| Quebec | 10 | 6 | 11 | 9 | 11 | 6 |
| Ontario | 25 | 30 | 26 | 36 | 25 | 30 |
| Manitoba | 3 | 3 | 3 | 4 | 3 | 3 |
| Sask | 10 | 11 | 10 | 6 | 10 | 11 |
| Alberta | 34 | 35 | 34 | 30 | 34 | 35 |
| BC | 8 | 5 | 8 | 8 | 8 | 5 |

Alberta and Ontario provide the highest share of GHG reduction in all Paths. Alberta's share is about 35 percent of the total reductions. The Ontario share varies between 25 and 35 percent (Chart 4.12). In Alberta, high levels of reduction are attributable to the capture and storage of $CO_2$ from electricity production. In Ontario, the reductions are concentrated in the transportation and electricity sectors. There are minor variations between the models regarding which province provides the most emissions reduction. In Path 3, CIMS shows Alberta with a higher level than Ontario, whereas MARKAL shows the reverse. In Paths 2 and 4, both models show Alberta with the highest share of emission reduction. Quebec, British Columbia, Nova Scotia and New Brunswick have about a 4 percent and a 3 percent share, respectively. Manitoba has the lowest share. These results reflect the levels of GHG in each province; those provinces with higher emission levels tend to provide the larger share of emission reductions.

**Chart 4.13**
**Emissions per Capita**
**(tonnes per person)**
**Canada Acts Alone**

| | | Path 2 | | Path 3 | | Path 4 | |
|---|---|---|---|---|---|---|---|
| | BAU | CIMS | MARKAL | CIMS | MARKAL | CIMS | MARKAL |
| Nfld | 22 | 14 | 15 | 14 | 14 | 14 | 14 |
| PEI | 15 | 12 | 12 | 13 | 13 | 12 | 12 |
| NS | 21 | 13 | 18 | 14 | 20 | 13 | 18 |
| NB | 27 | 16 | 15 | 17 | 17 | 16 | 15 |
| Quebec | 12 | 10 | 10 | 9 | 9 | 9 | 10 |
| Ontario | 16 | 13 | 12 | 12 | 11 | 12 | 12 |
| Manitoba | 20 | 15 | 16 | 15 | 15 | 15 | 16 |
| Sask | 57 | 40 | 31 | 40 | 39 | 40 | 31 |
| Alberta | 70 | 52 | 49 | 51 | 52 | 52 | 50 |
| BC | 16 | 13 | 13 | 13 | 12 | 13 | 13 |

In Paths 2 and 4, both models indicate that Alberta and Saskatchewan have the highest emissions per capita, 52 and 40 tonnes in CIMS and 49 tonnes and 31 tonnes in MARKAL. These estimates are much higher than those for other provinces, whose emissions per capita tend to be in the range of 10 to 20 tonnes, because of Alberta and Saskatchewan's relatively small population and relatively high emissions in the upstream oil and gas and electricity sectors. Both Alberta and Saskatchewan show increased per capita emissions in Path 3 for MARKAL, whereas most other provinces experience a decline. This is due to much less capture and storage of $CO_2$ occurring in Path 3 compared to other Paths. Although the CIMS results show less variation across the Paths than those from MARKAL, the increase in Path 3 is not apparent in CIMS as the level of capture and storage of $CO_2$ is retained in this model (Chart 4.13).

The costs identified for each province should not be viewed as a cost, or in some cases revenue, to the provincial jurisdiction. They simply reflect the private and government investments and savings that occurred in each province.

The $PV_{10}$ of the net costs varies widely among provinces (Chart 4.14). In CIMS, the cost changes across the Paths are small as most measures are retained as a result of the marginal cost of abatement in the model being higher than the cost of most measures. This also explains the Path 3 results, which are not consistently higher in all provinces. Ontario, Manitoba and Saskatchewan show smaller costs in Path 3, while British Columbia, Alberta and Quebec show higher costs.

**Chart 4.14**
**Provincial Costs**
**Canada Acts Alone**
**($NPV_{10}$ $1995 billions)**

| | Path 2 | | Path 3 | | Path 4 | |
|---|---|---|---|---|---|---|
| | CIMS | MARKAL | CIMS | MARKAL | CIMS | MARKAL |
| Nfld | 0.8 | -3.7 | 0.8 | -3.3 | 0.8 | -3.4 |
| PEI | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 |
| NS | 1.1 | 0.8 | 1.2 | 0.8 | 1.1 | 1.0 |
| NB | 0.9 | -0.3 | 1.0 | 0.0 | 0.9 | 0.0 |
| Quebec | 8.7 | -0.2 | 11.0 | 10.4 | 8.7 | 1.2 |
| Ontario | 18.0 | 8.9 | 16.1 | 18.7 | 18.0 | 11.8 |
| Manitoba | 1.9 | -0.7 | 1.4 | -0.1 | 1.9 | -0.7 |
| Sask | 3.0 | 1.4 | 2.7 | 1.3 | 3.0 | 1.7 |
| Alberta | 6.3 | 6.3 | 7.6 | 2.4 | 6.4 | 5.2 |
| BC | 3.5 | 1.0 | 4.4 | 5.8 | 3.5 | 2.8 |

Excludes welfare costs.

In MARKAL, Ontario and Alberta show the highest costs across all Paths, except for Path 3. This Path indicates a decline for Alberta because there is less capture and storage of $CO_2$. The higher cost in Path 3 is particularly noticeable in Quebec because of the imposed measures, mostly in transportation. Newfoundland and, to lesser extent, New Brunswick, show "negative cost" in the MARKAL cases, reflecting the export of electricity. Nova Scotia and Prince Edward Island have relatively consistent costs across all Paths and both models.

## 4.3 Context of International Scenarios Results

In the International Scenarios, the following changes in assumptions have been made to the Canada Acts Alone Scenario:

> ***Fixed output***. This assumption is relaxed for oil and gas production and electricity generation. If domestic demand for fossil fuels change then production is allowed to change.
>
> ***Energy Exports***. The percentage increase in energy prices and oil and natural gas export levels were provided by the EIA study (Section 3.3). Total oil and natural gas production then becomes the sum of exports and domestic demand.
>
> ***The Post-2012 Period***. Both models acquire a sufficient amount of permits such that the Kyoto target is maintained.

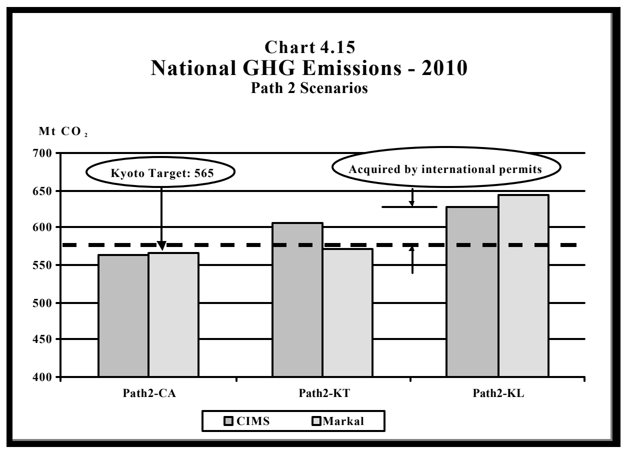
The cases will be distinguished using CA for Canada Acts Alone, KT for Kyoto Tight and KL for Kyoto Loose. In the CA Scenario, all the reductions are achieved domestically. With the introduction of international emission trading, not all of the reductions need to be attained domestically because the lower amount of domestic reductions is offset by the purchase of international permits. However, in all cases the Kyoto target is achieved.

## 4.4 Results: Path 2 Kyoto Tight and Kyoto Loose

### *National Results*

*GHG Emissions*

In Path 2KT, the permit cost ($58 per tonne of $CO_2$) causes domestic emissions to rise as fewer reductions are achieved through measures. The increase in emissions is 30 Mt and 7 Mt for CIMS and MARKAL respectively, relative to CA (Chart 4.15). In CIMS, about 85 percent of the reduction is achieved domestically, compared to over 95 percent in MARKAL. KT in MARKAL is similar to CA because the international price of permits is almost the same as the marginal cost of abatement in CA. For CIMS, more permits are purchased because the permit price is considerably lower than the marginal cost in CA. Nonetheless, measures are still used for GHG abatement, although their penetration is lower than in CA.




*Costs*

In Path 2KL, domestic emissions rise by 50 Mt for CIMS and 80 Mt for MARKAL compared to the Path 2CA results. The CIMS domestic share of reductions in emissions becomes about 70 percent and the MARKAL figure is 55 percent. This is a result of the lower permit cost assumption in Path 2KL of $24 per tonne of $CO_2$, which is significantly less than the marginal costs projected by both models.

Both models indicate that the net costs for the two international Scenarios are lower than CA. The MARKAL net costs indicate that there is a larger surplus in KT than in KL (Chart 4.16). Larger cost variations are seen in CIMS, a result of the much higher marginal cost of abatement compared to MARKAL (\$120 vs \$57 per tonne of $CO_2$) in the CA Scenario. The total cost of the permits in both models is about the same for both international Scenarios. This apparently anomalous result is due to the assumption that permits are being purchased up to 2020 and the figures indicated are $PV_{10}$ of these purchases, compared to the single year (2010) of emission reductions.

**Chart 4.16**
**Investments and Net Costs**
**Path 2 Scenarios**
**($NPV_{10}$ \$billion)**

| | Path 2 CA | Path 2 KT | Path 2 KL |
|---|---|---|---|
| **Investments** | | | |
| CIMS | 105 | 63 | 46 |
| MARKAL | 22 | 24 | 17 |
| **Permit Purchases** | | | |
| CIMS | | 7 | 5 |
| MARKAL | | 6 | 9 |
| **Net Costs** | | | |
| CIMS | 44 | 12 | -7 |
| MARKAL | 14 | -27 | -18 |

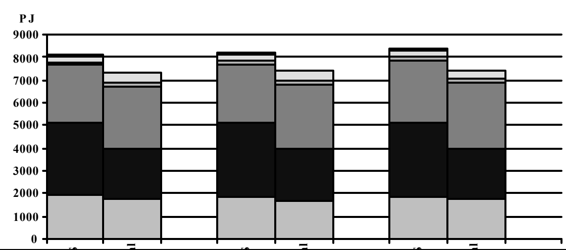
Excludes welfare costs.

The MARKAL net costs indicate that there would be surplus in both KL and KT, even after the purchase of permits. This surplus is created by not implementing the high cost measures, by higher priced electricity exports and by fuel savings in the transportation sector.

*Energy Consumption*

In 2010, Total end-use energy consumption is projected to be slightly higher than the CA results in both KT and KL (Chart 4.17). This is due to the exclusion of higher cost measures, particularly in transportation.

**Chart 4.17**
**End-Use Sectors Energy Consumption - 2010**
**Path 2 Scenarios**




***Sectoral Results***

In Path 2KT, the CIMS results track the CA Scenario only in the residential/commercial sector because there are low cost measures available in this sector (Chart 4.18). Both the electricity and transportation sectors have a smaller share of emission reductions compared to CA, because the marginal cost of reductions in these sectors is higher than the international

**Chart 4.18**
**Sectoral Shares of GHG Reductions - 2010**
**Path 2 Scenarios**
**(percent of the gap)**

| | Path 2 CA | | Path 2 KT | | Path 2KL | |
|---|---|---|---|---|---|---|
| | CIMS | MARKAL | CIMS | MARKAL | CIMS | MARKAL |
| Electricity | 43 | 57 | 32 | 55 | 27 | 23 |
| Upstream & Refining | 10 | 12 | 15 | 13 | 4 | 11 |
| Industry | 7 | 5 | 4 | 4 | 3 | 3 |
| Residential | 5 | 5 | 4 | 4 | 3 | 3 |
| Commercial | 6 | 6 | 5 | 6 | 5 | 5 |
| Transportation | 24 | 9 | 18 | 9 | 15 | 7 |
| Agriculture/ Other | 6 | 5 | 6 | 5 | 6 | 5 |
| International Permits | 0 | 0 | 16 | 4 | 27 | 43 |

permit price. Permits provide about 16 percent of the reductions.

The MARKAL analysis for KT is very similar to the CA results. This is expected since the marginal cost of abatement is similar in both cases.

For CIMS, in Path 2KL the same trends as the KT case are evident, but with smaller shares of reduction in the electricity and transportation sectors. In CIMS, the GHG reduction resulting from permit trading is 27 percent of the total reduction. In this case, the MARKAL results are much different from CA, but resemble the trend exhibited in the CIMS results. The MARKAL results show even lower shares of reduction in the electricity, transportation and upstream than either CA or Path 2KT in CIMS. The MARKAL assessment of 2KL indicates that permit trading accounts for nearly half of the abatement. This result is expected owing to the low cost of international permits relative to the domestic only cost of abatement.

### *Regional Results*

In KT, CIMS projects that Alberta increases its share of emissions reduction relative to the other provinces from 34 to 41 percent relative to CA (Chart 4.19 does not include the contribution of Kyoto mechanisms). Ontario and the Atlantic provinces show the largest decrease in their provincial share of emissions reduction. However, the overall ranking of the provinces does not change. In MARKAL, the provincial shares are very similar to CA.

**Chart 4.19**
**Regional Shares of Reductions - 2010**
**Path 2 Scenarios**
**(percent of the gap)**

| | Path 2 CA | | Path 2 KT | | Path 2KL | |
|---|---|---|---|---|---|---|
| | CIMS | MARKAL | CIMS | MARKAL | CIMS | MARKAL |
| Atlantic | 9 | 9 | 5 | 8 | 4 | 4 |
| Quebec | 10 | 6 | 8 | 6 | 6 | 4 |
| Ontario | 25 | 30 | 18 | 30 | 15 | 28 |
| Manitoba | 3 | 3 | 3 | 3 | 2 | 3 |
| Sask | 10 | 11 | 10 | 12 | 9 | 4 |
| Alberta | 34 | 35 | 34 | 37 | 30 | 17 |
| BC | 8 | 5 | 6 | 4 | 6 | 4 |
| International Permits | 0 | 0 | 16 | 0 | 28 | 36 |

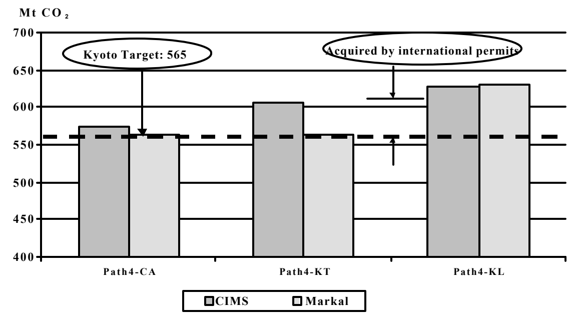
The KL results for CIMS are virtually identical to KT. A significant difference occurs, however, in the MARKAL results for KL. Alberta reduces its share relative to CA, from 35 to 27 percent, and Ontario increases its share from 30 to 43 percent. This changes the relative ranking of Ontario and Alberta, but the other provinces remain about the same. Ontario now shows the highest level of reductions because the electricity and upstream sectors in Alberta are achieving their reductions through the acquisition of permits, whereas some measures are still being used in Ontario.

## 4.5 Results: Path 4 Kyoto Tight and Kyoto Loose

### *National Results*

*GHG Emissions*

Chart 4.20
**National GHG Emissions - 2010**
Path 4 Scenarios




In Path 4KT, the increase in emissions is 40 Mt and zero for CIMS and MARKAL respectively, relative to CA (Chart 4.20). This is due to the permit cost ($58 per tonne of $CO_2$). KT in MARKAL is similar to CA because the international price of permits is almost the same as the marginal cost of abatement in CA. For CIMS, more permits are purchased because the marginal cost is lower than CA. Nonetheless, measures are still used for GHG abatement, although the penetration of the measures is lower than in CA.

*Costs*

Chart 4.21
**Investments and Net Costs**
Path 4 Scenarios
(NPV$_{10}$ $billion)

| | Path 4 CA | Path 4 KT | Path 4 KL |
|---|---|---|---|
| **Investments** | | | |
| CIMS | 106 | 63 | 46 |
| MARKAL | 29 | 30 | 23 |
| **Permit Purchases** | | | |
| CIMS | | 7 | 5 |
| MARKAL | | 3 | 8 |
| **Net Costs** | | | |
| CIMS | 45 | 13 | -4 |
| MARKAL | 20 | -8 | 2 |

Excludes welfare costs.

In Path 4KL, the emissions rise much more, about 60 Mt for both CIMS and MARKAL. Compared to the CA Scenario, this is a result of the lower permit cost assumption of $24 per tonne of $CO_2$, which is significantly lower than the marginal cost of abatement estimated by each model.

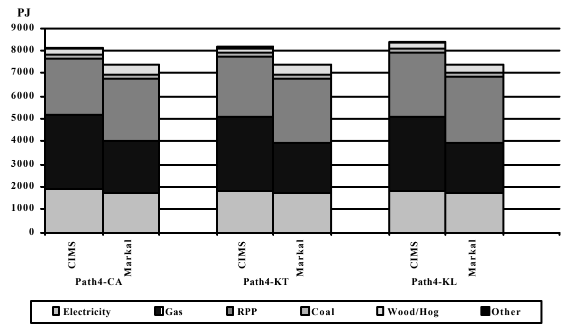
Both models indicate that the investments and net costs for the two international Scenarios are smaller than CA (Chart 4.21). Larger cost variations are seen in CIMS because of its higher marginal cost of abatement compared to MARKAL ($120 vs $57 per tonne of $CO_2$) when Canada acts alone. In MARKAL the total cost of permits is lower than CIMS in KT, but higher in KL. This may be attributed to the selling of a small amount of permits in the MARKAL KT case.

The MARKAL net costs indicate that there is a surplus in KT, but not in KL, CIMS indicates almost identical results with the international Scenarios of Path 2, with a small cost in KT and a small surplus in KL

*Energy Consumption*

In 2010, total end-use energy consumption is projected to be slightly higher than the CA results in both KT and KL (Chart 4.22). This is due to the exclusion of higher cost measures, particularly in the transportation sector.

**Chart 4.22**
**End-Use Sectors Energy Consumption - 2010**
**Path 4 Scenarios**




***Sectoral Results***

The CIMS and MARKAL results in Path 4 are almost identical to those in Path 2 (Chart 4.23).

The significant difference from Path 2KL occurs in the MARKAL results. Purchases of permits in Path 4KL decline to 36 percent of the GHG reductions compared to 43 percent in Path 2KL. This results in the electricity, upstream and transportation sectors increasing their contributions.

**Chart 4.23**
**Sectoral Shares of GHG Reductions - 2010**
**Path 4 Scenarios**
**(percent of the gap)**

| | Path 4 CA | | Path 4 KT | | Path 4KL | |
|---|---|---|---|---|---|---|
| | CIMS | MARKAL | CIMS | MARKAL | CIMS | MARKAL |
| Electricity | 43 | 55 | 32 | 56 | 26 | 24 |
| Upstream & Refining | 10 | 14 | 15 | 15 | 14 | 15 |
| Industry | 7 | 5 | 4 | 4 | 3 | 3 |
| Residential | 5 | 5 | 4 | 4 | 3 | 4 |
| Commercial | 6 | 6 | 5 | 6 | 5 | 5 |
| Transportation | 24 | 10 | 18 | 9 | 15 | 8 |
| Agriculture/ Other | 6 | 6 | 6 | 6 | 6 | 6 |
| International Permits | 0 | 0 | 16 | 0 | 28 | 36 |

***Regional Results***

In Path 4, the regional results are the same as those for the respective models in Path 2 (Chart 4.24).

**Chart 4.24**
**Regional Shares of Reductions - 2010**
**Path 4 Scenarios**
**(percent of the gap)**

| | Path 4 CA | | Path 4 KT | | Path 4 KL | |
|---|---|---|---|---|---|---|
| | CIMS | MARKAL | CIMS | MARKAL | CIMS | MARKAL |
| Atlantic | 9 | 9 | 5 | 8 | 4 | 4 |
| Quebec | 11 | 6 | 8 | 5 | 6 | 3 |
| Ontario | 25 | 30 | 18 | 30 | 15 | 27 |
| Manitoba | 3 | 3 | 3 | 3 | 2 | 3 |
| Sask | 10 | 11 | 10 | 13 | 9 | 6 |
| Alberta | 34 | 35 | 34 | 37 | 30 | 17 |
| BC | 8 | 5 | 6 | 5 | 6 | 4 |
| International Permits | 0 | 0 | 16 | 0 | 28 | 36 |

### 4.6 Sensitivities

Both to understand more fully the results and to address the concerns raised by the Issue Tables and other stakeholders regarding the analysis, the AMG undertook "sensitivity analyses" to examine the potential scope and impact of using different assumptions in the roll-up analysis. The results of these sensitivities highlight the implications of assumptions which have a major impact on the results. They also identify some of the sources of difference between the MARKAL and CIMS results.

The sensitivities were undertaken by HALOA, Inc. with the MARKAL model and the results are compared to the Path 2CA. These four sets of results detailed below give an indication of the sensitivity of the overall analysis to changes in specific assumptions.

*Sensitivity One: Carbon Sinks*

The assumption that 16 Mt could be sequestered in agriculture soil and forestry sinks reflects an optimistic outcome for Canada in the international negotiations to finalize the Kyoto Protocol. This sensitivity was undertaken in two parts using:

- The amount that can be sequestered is zero; therefore 16 Mt of emissions reductions would have to be found elsewhere, the *+16 Mt* sensitivity; and

- Agricultural soil and forests become a net source of emission of 21 Mt, the worst case estimate of the outcome of the negotiations as suggested by the Sinks and Agriculture and Agri-Food Tables. In this case 37 Mt of emissions reductions would have to found elsewhere, the *+37 Mt* sensitivity.

The results indicate that the marginal cost of abatement rises from $57 per tonne of $CO_2$ in Path 2CA to $71 and $99 per tonne for *+16 Mt* and *+37 Mt* respectively. Total net costs rise by almost $4 billion for *+16 Mt* and $10 billion for *+37 Mt*, 28 and 70 percent respectively.

In both components of the sinks sensitivity analysis, three sectors - electricity, transportation and residential - provide most of the additional GHG reductions. In the *+16 Mt* case these sectors provide over 90 percent and in *+37 Mt* they provide almost 85 percent of the additional reductions.

In electricity, although more power is consumed, the reduction is achieved through more use of high efficiency coal plants, with between 5 and 13 additional megatonnes of $CO_2$ being captured and injected into aquifers. As well, additional hydro and wind power is brought on-stream, which increases inter-provincial trade. Electricity sector emissions are reduced to14 Mt and 9 Mt respectively, with most of the impact in British Columbia, Alberta and Saskatchewan, although all provinces are affected to some degree.

Transportation achieves some of its reduction by switching to alcohol based fuels, but the largest portion is due to fewer vehicle kilometres travelled (VKT) and is fairly uniform across the country. Total reduction from this sector is 5 and 11 Mt for the two parts of this sensitivity analysis.

In the residential sector in 2010, more efficient heating systems are adopted and there is a significant switch to wood, 30 PJ in the *+16 Mt* and 140 PJ in the *+37 Mt.* Wood use, using advanced combustion technology that eliminates the associated $CH_4$, represents about 15 percent of the residential fuel in *+16 Mt* and it approaches 25 percent in *+37 Mt.*

Revising the sink assumptions produces very high costs and leads to some unusual results such as more coal-fired generation.

*Sensitivity Two: Natural Gas Prices*

A 50 percent increase in natural gas prices from the original reference case level was analyzed as a sensitivity case, with the MARKAL model, for Path 2CA. $CO_2$ capture and storage was maintained at the level in Path 2CA (43 Mt). The 50 percent increase in natural gas prices results in a 17 percent reduction in natural gas use in Canada relative to Path 2CA case. The decline in natural gas use leads to greater use of fuel oil in industry and the residential sector and causes these sectors to undertake fewer emission reductions. To meet the Kyoto target, greater emission reductions occur in the electricity and transportation sectors. Emissions are reduced in the electricity sector despite a slight increase in carbon intensive electricity from coal and a substantial reduction in electricity produced by natural gas. Additional emission reductions in the electricity sector are achieved by nearly equivalent increases in the amount of electricity produced from hydro power and wind. Wind power generation increases by over 60 percent from the original Path 2CA. Higher natural prices and other adjustments in electricity production cause increases in electricity prices across the country.

*Sensitivity Three: Capture and Storage of $CO_2$*

In Path 2, there was no technological limit of the quantity of $CO_2$ that could be injected into deep aquifers in western Canada. Since this is a major source of emission reductions the robustness of the assumption, using MARKAL, was tested in three ways:

- The total volume injected was restricted to half the projected amount in Path 2 (cut from 43 Mt to 21 Mt) until 2012, thereafter there was no limit imposed. In this case, 21 Mt of GHG reductions must be found from other sources until 2012 - the *21 Mt* sensitivity.

- The limit is maintained after 2012, such that total injection is limited to 21 Mt. In this case, 21 Mt of GHG reductions must be found from other sources for the entire projection - the *21 Mt LTD* Sensitivity.

- There is no potential to capture and contain $CO_2$. In this case, 43 Mt of GHG reductions must be found from other sources for the entire projection - the *Zero* sensitivity.

The costs for all three sensitivities are presented, but only the *21 Mt* case is discussed for GHG reductions.

In these sensitivities, the marginal cost of abatement rises form $57 per tonne of $CO_2$ in Path 2 to about $63 per tonne of $CO_2$ in *21 Mt* and *21 Mt LTD*. The *Zero* sensitivity indicates a cost of $68 per tonne of $CO_2$ in 2010. It should be noted that the marginal cost rises significantly post 2010 in all sensitivities, particularly the *Zero*, which reaches over $170 per tonne of $CO_2$ by 2020. The $PV_{10}$ of the net costs rise marginally in *21 Mt*, $160 million (1 percent compared to Path 2). In *21 Mt LTD* the net cost is higher, almost $600 million (4 percent) and the *Zero* is $1.5 billion higher than Path 2 (10 percent).

In the *21 Mt* sensitivity, the electricity sector increases its emissions by almost 5 Mt, offset by 4 Mt in the Transportation sector through fuel switching to alcohol based fuels. Other sectors provide the balance, generally through fuel switching to hydro, natural gas and wind.

Since the electricity sector has increased by 5 Mt relative to Path 2, 16 Mt of reductions (21 less 5 Mt) has been achieved within this sector through switching to less GHG intensive fuels. Compared to Path 2, the principal differences are:

- An increase in hydro in British Columbia and Manitoba of about 4 percent.

- An increase in wind (45 percent) and natural gas-fired generation (65 percent) in Alberta and Saskatchewan.

- Less coal-fired generation (50 percent) in Alberta and Saskatchewan.

- Increased provincial trade between British Columbia and Alberta and between Manitoba and Saskatchewan.

- Natural gas exports decline slightly and crude oil exports increase slightly. Provinces to the east of Manitoba are unaffected by this sensitivity.

*Sensitivity Four: Inter-provincial Electricity Trade*

In the MARKAL model electricity is freely traded among provinces, whereas CIMS adopted the view that deregulation would not proceed quickly and the inter-provincial flows would remain at the existing levels plus any announced inter-connections. In order to test the impact of these differing views, electricity trade in the MARKAL model was constrained to match that of CIMS.

Under this constraint, the marginal cost of abatement rises very slightly, less than $1 per tonne of $CO_2$. However, the $PV_{10}$ of the net costs increases by over $1 billion (7 percent).

Electricity emissions increase by just over 3 Mt, as hydro production declines, which is offset by small decreases in all other sectors, principally through fuel switching. An additional 2 Mt is injected into deep aquifers. In 2010, interprovincial trade is reduced by 18 TWh relative to the unconstrained case. This represents about 40 percent of the "imports" to Ontario, Alberta and Saskatchewan.

- The main changes, relative to Path 2, to electricity generation are:
- Total production is larger by 11 TWh (2 percent).
- Less hydro is produced, in Quebec (6 TWh) and Manitoba (4 TWh).
- More hydro is produced in British Columbia (1.5 TWh).
- Gas-fired generation increases in Ontario by 21 TWh, 14 percent of total provincial consumption. This offsets all of the decline in imports.
- Exports between Quebec and Ontario decline by 13 TWh.
- Exports between Manitoba and Ontario/Saskatchewan decline by about 5 TWh.

# Chapter 5
# Macroeconomic Results

This chapter provides the impact of the GHG measures on the economy as a whole as estimated by the Informetrica Model (TIM). The results from the energy-technology models are the source of sectoral assumptions about the changes in real investment required to put new technologies into place, which in turn determine reductions and/or changes in fuels used in the economy. The macroeconomic analysis also estimates permit payments, for industries covered by permits. For "uncovered" industries the investment flows determine the value of subsidies. The full set of results from Informetrica may be found in the report *Macroeconomic Impacts of GHG Reduction Options: National and Provincial Effects.*

**Key Learnings**

- At the national level, attainment of the target is expected to lead to sustained, long-term negative economic impacts. In the long run, the reduction in gross domestic product (GDP), relative to the business-as-usual case, ranges from 0 to 3 percent depending on the path-scenario combination and the microeconomic input (CIMS or MARKAL).

- The overall GDP impacts vary over time. Initially, economic activity increases modestly in response to increased investment in emissions reducing technologies. Thereafter, higher production costs, deterioration in competitiveness and lower incomes combine to reduce GDP below business-as-usual levels. The "adjustment period" is expected to be lengthy, perhaps as long as 15 years.

- Based on preliminary modelling of some characteristics of emissions permit trading, this instrument can be viewed as cost-effective for the industrial and electricity sectors. However, the analysis to date underscores the importance of the design of such an instrument, in particular the permit allocation mechanism. Each allocation method carries with it different distributive effects on the economy.

- Over the long-term, total employment is reduced moderately, but unevenly across sectors. Transportation tends to show large gains, whereas the energy industries indicate losses.

- The findings suggest the potential for some variability in GDP impacts across industries between the CIMS and MARKAL inputs.

- The provincial GDP impacts are generally within 1.5 percentage points of the national average impact. The relative ranking of each province typically varies by Scenario. In the Canada Acts Alone scenario, Newfoundland, Prince Edward Island, Quebec and British Columbia are less affected, relative to the national average, whereas Ontario and Saskatchewan are more negatively affected. The impact on Alberta is close to the national average. The results for Nova Scotia, New Brunswick and Manitoba vary between the studies.

  In the International Scenarios, Newfoundland, Prince Edward Island and British Columbia remain in the "less affected" category and are joined by Manitoba. Saskatchewan remains in the "more affected" category, which now includes Alberta and New Brunswick. By contrast, Ontario's GDP impact is smaller than under Canada Acts Alone, becoming close to the national average. Quebec's position is largely unchanged across the Scenarios, although one study indicates that its GDP would be consistently higher than in the business-as-usual case. For Nova Scotia, one study indicates impacts that are greater than the national average, while the other suggests the opposite.

- The analysis supports the contention that competitiveness – as measured by changes in productivity – will be adversely affected by the achievement of the Kyoto target. The impact is somewhat attenuated if Canada's trading partners are also committed to attaining their targets and Canada has access to flexibility mechanisms. Under this Scenario, Canada's trading partners will also face reductions in economic activity, with negative consequences for Canadian export performance. At the national level, the net impact of these two forces is to reduce the loss by about 0.5 percent of GDP.

## 5.1 Introduction

An important assumption of the analysis undertaken with the energy-technology models is that output is held constant. In the macroeconomic analysis, this constraint is relaxed so that the induced effects are incorporated.

Many measures proposed by the Issue Tables include changes to current spending,[16] which imply changes to productivity. For "uncovered" industries, current spending varies with

16 These expenditures include operating and maintenance improvements that lead to energy efficiency and productivity gains. They may also imply reductions in productivity as public and private resources are used to prompt action.

the changes to taxes and subsidies for agriculture, forestry, transportation, buildings, and municipalities. For those instances the Issue Table estimates were used directly.

The economic assumptions underlying the International Scenarios of Path 2 are provided in a study by the Energy Information Administration (EIA).[17] The EIA results provide estimates of the impacts on GDP, energy exports and imports and other parameters of meeting the U.S. Kyoto commitment. The changes in the U.S. economy directly affect Canadian exports, and through imports, Canadian price formation and interest rates (see Section 3.3).

The TIM results show the effects, both regionally and sectorally, on parameters such as Gross Domestic Product (GDP), Inflation, Personal Disposable Income (PDI) and some measures on Canadian competitiveness. In general, the results are shown in percentage variations from the reference case. In the case of GDP, this means that the size of the economy is x percent smaller or larger, in a given year, than the reference case (see Chapter 3 Understanding Results).

As with the energy-technology models, not all Paths and Scenarios were modelled (Chart 5.1). Complete macroeconomic impacts for both MARKAL and CIMS were not undertaken. However, the cases examined provide a reasonable range of results.

**Chart 5.1**
**Paths and Scenarios**
**INFORMETRICA Analysis**

| | Canada Acts Alone | Kyoto Tight | Kyoto Loose |
|---|---|---|---|
| Path 0 | | | |
| Path 1 | | | |
| Path 2 | X | X | X |
| Path 3 | X | | |
| Path 4 | X | | |

## 5.2 Context of Results

Some additional assumptions are required to undertake the macroeconomic analysis:

*Permits* - The TPWG provided several options for permit allocation. The AMG chose a gratis allocation to households as the most practical for modelling purposes.[18] Purchasers of permits acquire them from households at a uniform price. While this assumption may not be the actual allocation process, it provides a view of the economic impact.

---

17 Energy Information Administration, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity,* October 1998.

18 Modelling the allocation mechanism of any permit system is complex. In the Informetrica analysis, it was not possible to transfer fully the proceeds of the permit sale back to households. This incomplete transfer results in a small overestimation of the negative impact on GDP and disposable income after 2007.

*Subsidies* The government covers the full cost of the investments associated with the implementation of generic measures, through subsidies, precisely allocated to those industries defined by TPWG (see chapter 2).

*Fiscal and Monetary policy* - is assumed not to change. Taxes are assumed to remain consistent with the BAU, except for the additional motive fuels tax.

## 5.3 National Results

*Direct Investments*

The investments required to implement the measures affect other spending, which may have positive or negative effects. The extent to which current spending, transfers and productivity effects are incorporated into the Paths depends on the extent of the inclusion of the Issue Tables measures.

Information campaigns for the enforcement of speed limits for example, require additional spending for labour and increase associated purchases of goods and services. These resources are usually purchased by governments. It should be noted that when government spends for goods and services, supply to meet the spending is often produced by business (e.g., advertising campaigns).

As a direct effect on resource requirements in the economy, introduction of major new capital implies a restructuring of demand, leading to reductions in operations for some industries and increases for others. Prominent in this regard is urban transit. In Paths where expansion of the transit system occurs, it needs to be recognized that this implies an increase in transit riders, at the expense of spending for parking, repairs and other non-fuel expenses related to the operation of a vehicle.

In the CIMS-based results, current government spending is about equal across each variant of Path 2 (Chart 5.2). Path 3 shows a large negative number, due to government revenue from the incremental motive fuels tax. Path 4 shows virtually no government expenditures because the permit system substitutes for government expenditures for education, enforcement and other stimuli to reduce GHG. Household non-durable spending is consistent across all the CA Paths. It drops to almost zero in Path 2KT and becomes income in Path 2 KL. This is because of the income to the households from the permits. Business operating expenses are consistent across all Paths.

**Chart 5.2a**
**Direct Impact on Income Sectors 2000 to 2020**
**CIMS**
**$(1997) billions**

| | Path 2CA | Path 2KL | Path 2KT | Path 3CA | Path 4CA |
|---|---|---|---|---|---|
| **Current Spending** | | | | | |
| Govt spending less taxes | 18.7 | 16.2 | 16.2 | -119.2 | 1.1 |
| Household spending | 37.6 | -22.6 | 4.3 | 35.7 | 37.6 |
| Business op expenses | -17.7 | -20.3 | -17.7 | -19.1 | -21.0 |
| **Investment Spending** | | | | | |
| Government | 21.7 | 63.3 | 69.9 | 34.5 | 22.0 |
| Household | 205.2 | 61.1 | 64.8 | 208.7 | 205.3 |
| Business | 166.8 | 106.7 | 125.3 | 163.8 | 166.6 |
| **Total** | **393.7** | **231.2** | **260.0** | **411.0** | **393.9** |

**Chart 5.2b**
**Direct Impact on Income Sectors 2000 to 2020**
**MARKAL**
**$(1997) billions**

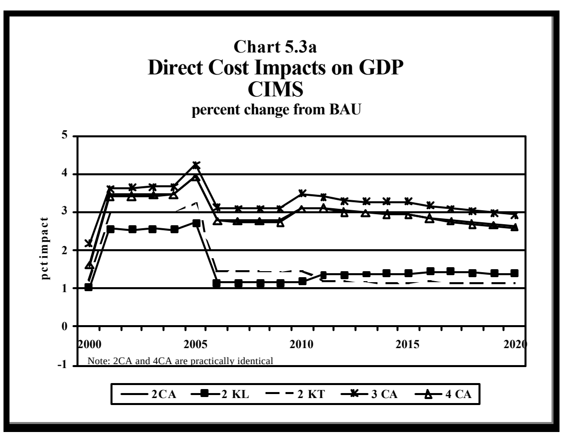
| | Path 2CA | Path 2KL | Path 2KT | Path 3CA | Path 4CA |
|---|---|---|---|---|---|
| **Current Spending** | | | | | |
| Govt spending less taxes | -67.7 | 16.0 | 18.5 | -210.7 | 7.5 |
| Household spending | -33.4 | -117.8 | -19.6 | 23.8 | -33.4 |
| Business op expenses | 6.7 | 7.6 | 7.6 | -7.9 | 6.9 |
| **Investment Spending** | | | | | |
| Government | 4.3 | 4.3 | 4.2 | 26.7 | 4.0 |
| Household | 71.9 | -0.1 | 1.1 | 159.3 | 72.1 |
| Business | 28.3 | 16.8 | 16.8 | 60.3 | 26.1 |
| **Total** | **104.6** | **21.0** | **22.0** | **246.3** | **102.2** |

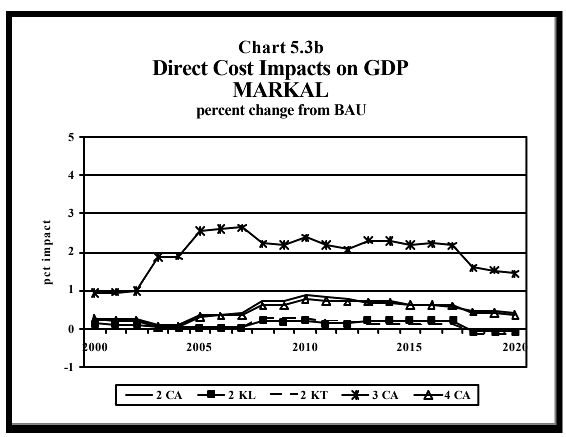
Government investment spending is highest in Path 2KL and KT. Paths 2 and 4CA are the lowest and about equal, while Path 3CA is somewhat higher because of the imposed measures in that Path. Household investment is fairly consistent across the CA cases and much lower in the international Scenarios. Business investments are consistent across the CA cases, but lower in the international Scenarios.

The MARKAL-based results, for current government spending, show a similar trend to CIMS, except in Path 2CA. The only similarity between the models in current household spending is in Path 3CA and, to a lesser extent, in Path 2KL. CIMS indicates generally negative figures, for the business operating expenses, whereas the MARKAL based results are generally positive in sign.

Total investment spending shows similar trends at the macro-level between the models, but as would be expected the MARKAL-based results are generally much lower.

*Investment*



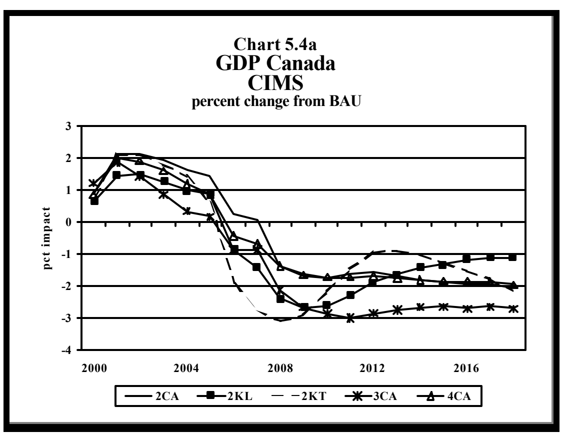
Direct investments have been aggregated for all sectors. Additional spending for new capital, operations of government and business is proportionately doubled (1 to 3 percent) in the CIMS-based CA cases compared to that of the international Scenarios, although this difference narrows after 2005 (Chart 5.3).

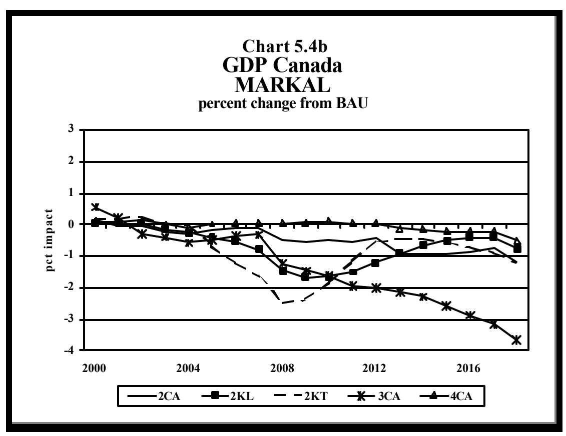
All Paths show a substantial positive impact on GDP (plus 2 to 4 percent) up to 2005. This is due to the investments required for GHG abatement actions. As expected, Path 3CA shows the highest impact and Path 2KL and KT the lowest. After 2005, there is a decline, but these investments continue to be positive. The gap between Path 3CA and the international Scenarios turns to widen.

By contrast, the MARKAL-based results show virtually no change for Paths 2KL and KT and a less than 1 percent increase for Paths 2 and 4CA. Path 3CA shows a similar trend to the CIMS-based results, but about 1 percentage point lower.

*Gross Domestic Product*

It is expected that there would be an increase in Canadian demand and production early in the implementation of policies to meet the Kyoto target. This is due to the demand for production from actions being larger than the reduction from demand for fuels, or from the negative effects that may follow from increased unit costs of production (Chart 5.4). There would be lasting negative effects as long as the real resource costs of an action exceed the resource saving of fuel reduction.




In the near term, there appears to be little distinction between the Paths in the CIMS-based results, and the economy is expected to be 1 to 2 percent larger. For this period, the view that access to international permits leads to less economic disturbance is not clear as investment levels are similar. However, over the longer term GDP is expected to be 1 to 3 percent less than the reference case with the KL and KT Scenarios tending towards the more positive end of the range, indicating that international actions are more beneficial than domestic actions alone.

In the MARKAL-based results the GDP increase in the early years is barely visible, largely because the investments are substantially lower than CIMS. However, the long-term effects are similar, but somewhat muted compared to CIMS, except in Path 3CA where GDP loss is greater.

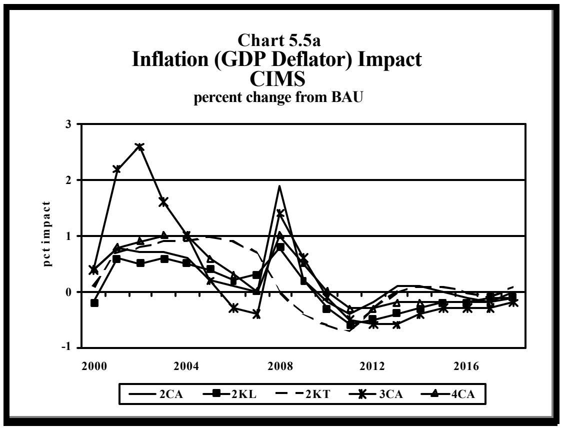
*Inflation*

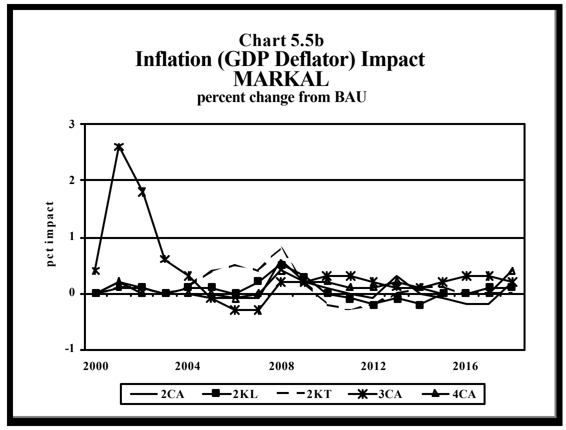
Chart 5.5 shows the change in inflation, compared to the BAU, for each of the Paths analyzed.

As a result of the motive fuels tax, both models indicate a spike in inflation (2 to 3 percent higher than BAU) in 2003 for Path 3CA. The spikes in both models and all Paths in 2008, are due to the introduction of permit trading, although the MARKAL increase is less because of lower permit prices in Paths 2 and 4CA. These inflationary spikes are likely a result of the allocation method used in the modelling. The permits have been allocated *gratis* to households which, in turn, sell them to GHG emitters. Alternative allocation methods may yield different results. It is important to identify these kinds of "spike" risks when designing an allocation system.

The main finding is that, regardless of option, or of whether Canada acts alone or in concert, there is some appreciable risk that price increases will be accelerated. Parallels to the OPEC "shock" years are inexact because, in that instance, the supply price of fuels was raised, whereas in these instances, it is either unchanged or, in the Scenarios, is reduced (at least for oil). During the period after the OPEC shock (1974) it has been suggested that the lasting damage may have been induced by the monetary policy, in which interest rates rocketed upwards. In this analysis, a real interest rate rule has been maintained, so that nominal interest rates rise modestly during the next decade, and sharply when the spikes occur.

Early monetary policy action is expected to be modest. If the large action is concentrated in years after 2010, supply-constrained sector inflation is a high risk, but not included in these results.




*Personal Disposable Income*

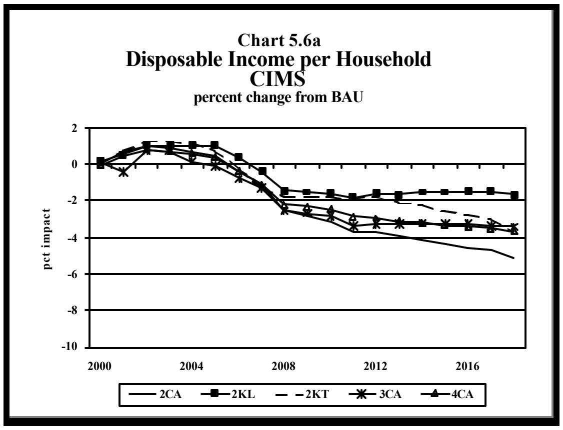
The CIMS-based results suggest that there is little that distinguishes the Paths in their effect on average income of households through most of this decade (Chart 5.6). The BAU indicated substantial growth of disposable income between now and the end of the decade. In the longer term, the international Scenarios appear to have the least negative effect, but are still negative.

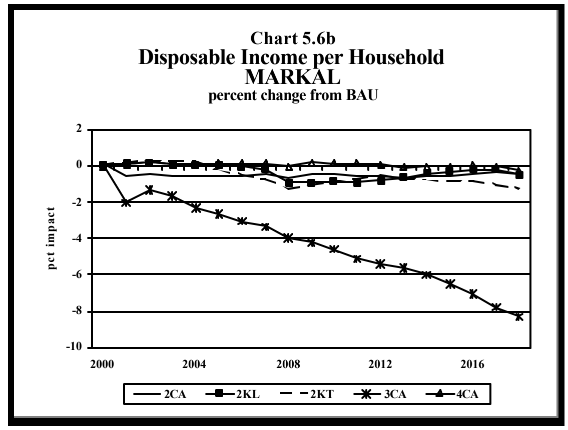
There is not much difference between one domestic scenario over another, although it should be noted that additional motive fuel tax, as in Path 3CA, would have transitory negative effects on real income.

The CIMS analysis indicates that, for Paths 2CA and 4CA, that total spending, fuel reduction, and permit payment levels are about the same. They are distinguished only by a smaller fiscal thrust in Path 4CA, and the relative price effects of a broad-based trading system, as compared to other trading schemes. In the TIM results, disposable real income per household is about the same. The difference is in the number of households resulting from the two Scenarios. Maintaining the household formation at the reference case levels may have missed some insights into the effects of disposable income.

The effects on income distribution may vary more sharply among the options, but there are no distinctive signals in the CIMS-based analysis.

Similar trends are evident in the MARKAL-based results, except for Path 3CA which indicates a continuous and relatively large erosion of Personal Disposable Income, compared to other Paths.




*Employment*

In Path 2CA, employment increases modestly overall (about 1 percent over the period 2000 to 2012) in the CIMS analysis. Over the longer term employment is reduced in all Paths. However, there are some major sectoral differences. The increase is dominated by transportation services (20 percent) followed by construction (6 percent). This is due to the heavy investments and operating costs that are expected for urban transit systems. Consumer goods and services also show an increase, 0.7 percent. The resource-based industries show a decline of 1.5 percent. Path 4CA shows similar trends. These results are not reflected in the MARKAL analysis, although showing similar overall trends, but with no sector experiencing substantial gains nor losses.

In Path 2KL, both models indicate that total decline in employment is small (0.4 percent) with no sector showing strong gains, since the urban transit systems are not built. The resource based industries show a similar decline to Path 2CA.

In Path 2KT, total employment in the CIMS-based results increases very slightly (0.1 percent) with strong gains in transportation services (10 percent) and construction (3.5 percent). As with the other two cases, resource industries show a decline (1.7 percent). MARKAL shows a modest decline in employment early in the projection and modest increase in the latter part, with no sector showing large gains nor losses.

In the CIMS-based Path 3CA, employment decreases very slightly (0.1 percent) over the period 2000 to 2012. There are, however, some major sectoral differences. Electrical and electronic component (-8 percent) and metallic mineral and products (-6 percent) show the most significant declines. The most significant increases are in Transportation services (20 percent) and construction (5 percent). MARKAL shows a similar overall decline, but only the recreation sub-sector shows appreciable decline (6 percent). Transportation shows similar gains to CIMS. In the longer-term both the CIMS and MARKAL-based analyses show employment declining by about 2 percent.

*Balances*

Relative to the BAU, incomes are reduced, but current spending is either higher or little changed (Chart 5.7). This follows from a reduction in the average saving of households in all of the Paths. That is, consumers standards of living are "protected" by reduced saving. Government spending remains at reference case levels, except for directly related expenditures - such as planning, enforcement, and education programs - that increase modestly. However, these are not present in Path 4CA. This outcome may be compared to the period 1990 to 1999, in which the average personal saving rate fell from about 10 percent to almost zero, while incomes were falling or stagnating.

**Chart 5.7a**
**Balances - Savings Impact**
**CIMS**
**average pct of change as pct of GDP**

| | 2 CA | | 2 KL | | 2 KT | | 3 CA | | 4 CA | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 00-12 | 13-18 | 00-12 | 13-18 | 00-12 | 13-18 | 00-12 | 13-18 | 00-12 | 13-18 |
| Personal | -1.1 | -2.3 | 0.1 | -0.5 | -0.1 | -1.1 | -1.5 | -2.6 | -1.1 | -2.1 |
| Business | 0.8 | 2.2 | 0 | 0.7 | 0.3 | 2.0 | 0.9 | 2.0 | 0.7 | 1.6 |
| Gov't | 0 | -0.5 | -0.4 | -0.8 | -0.3 | -0.7 | 0 | -0.6 | 0.2 | -0.2 |
| Foreign | 1.3 | 1.0 | 1.1 | 0.7 | 1.1 | -0.2 | 1.6 | 1.3 | 1.3 | 1.0 |

**Chart 5.7b**
**Balances - Savings Impact**
**MARKAL**
**average pct of change as pct of GDP**

| | 2 CA | | 2 KL | | 2 KT | | 3 CA | | 4 CA | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 00-12 | 13-18 | 00-12 | 13-18 | 00-12 | 13-18 | 00-12 | 13-18 | 00-12 | 13-18 |
| Personal | -0.1 | -0.1 | 0.1 | 0.1 | 0.2 | -0.1 | -2.2 | -3.2 | 0 | -0.2 |
| Business | -0.1 | -0.4 | -0.1 | 0.1 | 0.1 | 0.9 | 1.2 | 3.3 | -0.1 | -0.3 |
| Gov't | 0.2 | 0.3 | -0.4 | -0.3 | -0.4 | -0.2 | 0.5 | -0.3 | 0.1 | .03 |
| Foreign | 0.1 | 0.3 | 0.3 | 0.4 | 0.2 | -0.5 | 0.8 | 0.6 | 0.1 | 0.3 |

The magnitude of the Current Account deficit is increased throughout and in all Paths due to additional recourse to foreign borrowing. Foreign borrowing, to finance Canadian investment, is a feature of the entire last century. A sustained increase, equivalent to 1 percent of GDP, would be notable in currency markets and among international economic policy observers.

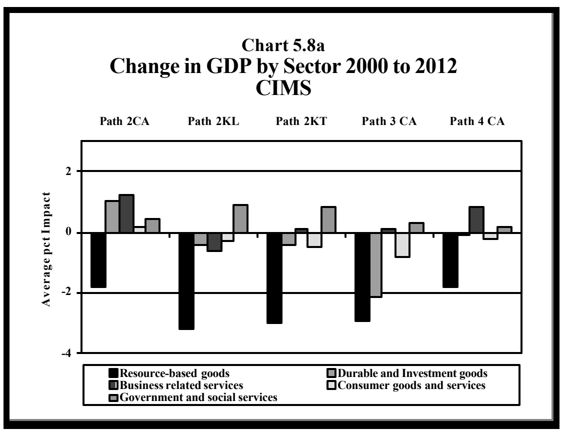
The effects on government balances are the least significant among all the saving systems. For the most part, the subsidies provided by governments to stimulate emissions reduction do not have significant impact on the balances. The incremental motive fuel tax revenues of Path 3CA, because they are not recycled, protect government balances, and could compensate for the damage to revenues caused by negative effects on private incomes.

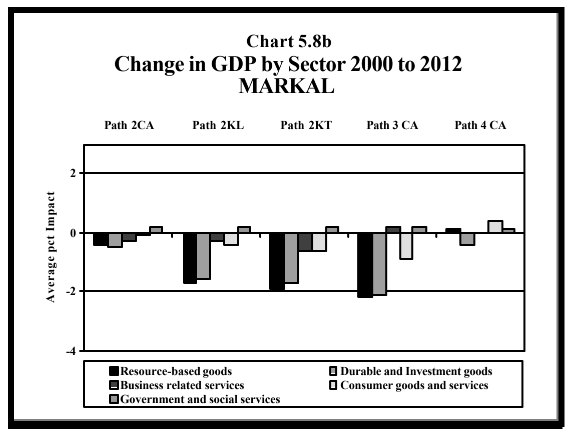
## 5.4 Sectoral Results

The sectors for the macroeconomic analysis are somewhat different from the energy-technology model sectors, a reflection of the differing model structures. However, the groupings have been arranged to resemble the energy-technology models as closely as possible. The sector results are shown as average changes over two time periods:
2000 to 2012 (the end of the first commitment period) and 2013 to 2018.

*2000 to 2012*

There are only minor sector distinctions between Paths 2CA and 4CA (Chart 5.8). The CIMS view is that the capital costs, fuel saving and permits trading are the same for these two cases. They are distinguished by slight variations in: current government spending and transfers; the relative price differences owing to the price increases for oil, gas and electricity in Path 4CA; and the allocation effect of permit payments to a larger number of sectors in Path 4CA than in Path 2CA.




Resource industries show the most severe negative effects in all Paths. Within this sector, mining, chemicals and the agriculture/food industries are the most affected. Energy producers' output is moderately affected in the CA cases, but significantly reduced in the international Scenarios. Forest products are little affected.

Other sectors are little affected and some, notably durables in the early years, indicate an increased GDP. Either directly, or through induced income effects, these sectors benefit from increased domestic demand caused by actions to meet Kyoto targets.

Path 3CA, in the CIMS analysis, represents the most damaging case. In 2010, there are some severe effects on iron ore mining (-30 percent), rubber and plastic products (-15 percent), leather goods and clothing (-15 percent), iron and steel (-20 percent), non-ferrous smelting (-

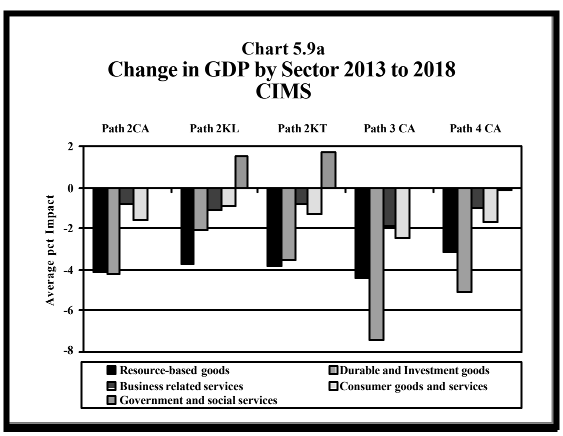
12 percent), automotive assembly (-13 percent), non-electrical machinery (-15 percent), truck assembly (-30 percent), and electronic products (-17 percent). Positive effects for the construction of roads and urban transit are related to the implementation of the urban transit measures.

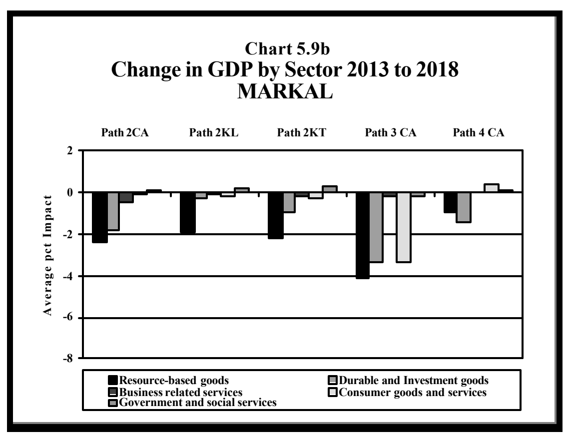
The coal industry is the one industry that will face significant deterioration. The size of the industry is reduced by from 40 to 50 percent in Path 3CA. This occurs early in the projection, given the CIMS view that reductions in this fuel would be sharply curtailed immediately. Apart from direct effects on thermal coal, related to electric power, metallurgical coal would be unfavorably affected in the CA cases as Canadian unit costs of production would rise relative to those of competing international suppliers.

The MARKAL based results show a similar trend across all Paths except Path 2CA, but the effect is more muted. In Path 2CA, durables, business services and consumer goods and services are all mildly negative in this period, compared to CIMS being positive. This is due to the differences in the investment levels between the models.

*2013 to 2018*

In the longer term, effects are generally more severe and widespread across in the industrial sector (Chart 5.9). Most of the reductions in GDP have been realized by 2012. However, further erosion to output is expected after 2013. Over the long-term, the resource industry




faces further declines in GDP, in the range of 4 percent. Durables face a similar decline in GDP. These trends are evident in both CIMS and MARKAL

## 5.5 Provincial Results

The provincial results are presented using the averages for 2013 to 2018. Early in this decade, the pattern of effects includes positive impacts, followed by varying degrees of decay to below BAU estimates by the end of the decade. The provincial impacts are a reflection the sectoral impacts.

For the period 2013 to 2018, the results indicate lasting, long-term effects in both models for the most provinces (Charts 5.10 and 5.11). The more moderate negative effects of International Scenarios are reflected across the regions, compared to impacts based on domestic action only, Central Canada shows the largest improvement between domestic and international actions. Ontario is somewhat more vulnerable than Quebec, owing to the positive effects of Quebec's hydro electricity generation. The impact on Ontario is due to its trade-sensitive manufacturing industries. Saskatchewan and Alberta are most affected in the long term because of the dominance of resource-based industries in those provinces. Among Atlantic provinces, Nova Scotia and New Brunswick appear most vulnerable. Newfoundland and P.E.I. are less affected due to the high level of influence of government spending, which remains unchanged by assumption. Effects on British Columbia and the Territories are generally smaller than the Canadian average because of the relatively small impacts on the forestry products industry, which maintain exports at the BAU levels, on the assumption that exports to North Asia are relatively unaffected..

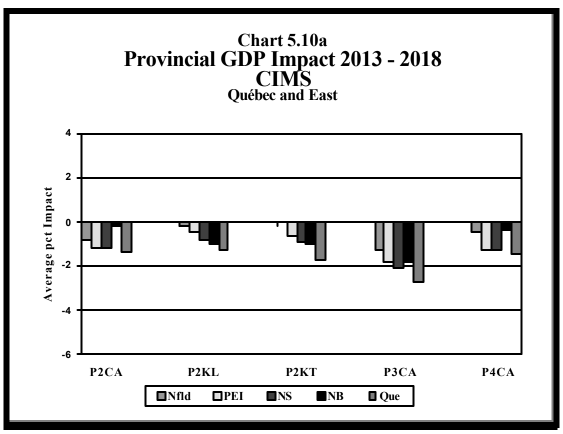


**Chart 5.10a**
**Provincial GDP Impact 2013 - 2018**
**CIMS**
**Québec and East**

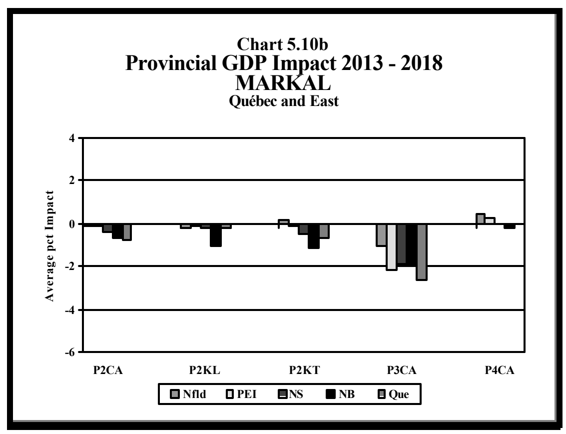


**Chart 5.10b**
**Provincial GDP Impact 2013 - 2018**
**MARKAL**
**Québec and East**

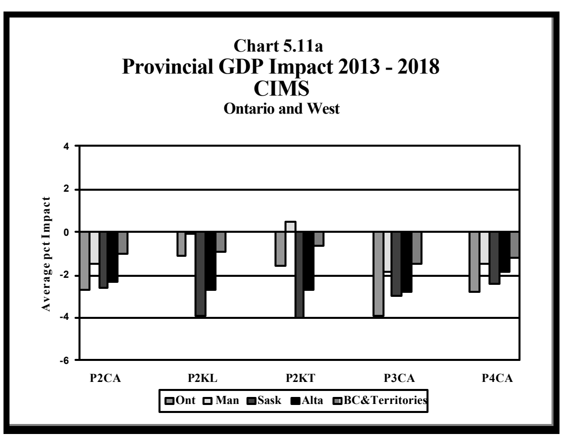


**Chart 5.11a**
**Provincial GDP Impact 2013 - 2018**
**CIMS**
**Ontario and West**

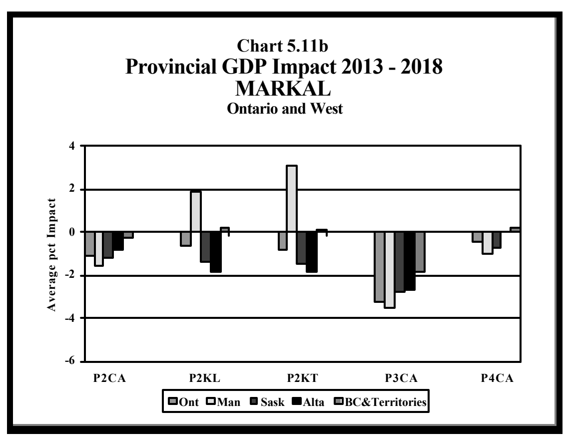


**Chart 5.11b**
**Provincial GDP Impact 2013 - 2018**
**MARKAL**
**Ontario and West**

The most notable different between CIMS and MARKAL occur in Newfoundland and Manitoba which show modest "gains" (i.e., the provincial GDP is higher than the reference case) in some Paths, particularly 2KT and 2KL in MARKAL, while CIMS shows a negative effect. This is mainly due to electricity exports.

In the Canada Acts Alone Scenario, Ontario accounts for more than one-half of all lasting negative effects on the Canadian economy. In the International Scenarios, this province accounts for about one-third of the impacts. Alberta, Quebec, and British Columbia follow next in importance, in terms of their effect on the Canadian economy.

These regional and provincial distinctions would likely be more pronounced if the analysis were to account for inter-provincial migration. As a general rule, it would be expected that the labour force and population would respond to relative impacts on jobs, but this channel of influence is not operational in these results.

## 5.6 Competitiveness

Competitiveness is a multi-dimensional issue, involving factors such as productivity, export performance, fiscal climate and technology. The AMG approach to competitiveness is based on two reports.[19] In these reports various measurements of competitiveness were defined (Chart 5.12).

**Chart 5.12**
**Measures of Competitiveness**

| Plourde | Hirshhorn |
|---|---|
| Change in real GDP per capita | Extent of competition from foreign firms |
| Change in total factor productivity | Significance of price competition |
| Change in imports and exports | Expected impact of GHG policies on foreign competitors |
| Change in real unit costs | |
| Change in net investment flows | |

It is more difficult to quantify the measurements used by Hirshhorn, these will be discussed qualitatively. Where results are available for Plourde's measurements, impacts on competitiveness will be quantified.

The extent of competition from foreign firms depends on the scenario under consideration. In CA, Canada will be at a definite disadvantage, since it will be undertaking abatement measures alone. Therefore, costs arising from GHG reductions will be higher in Canada. In KL and KT, it is assumed that other countries will also reduce GHG emissions. In this instance, the relative

[19] André Plourde; *Competitiveness and the National Implementation Strategy: Elements of a Framework of Analysis*, commissioned by the AMG; and Ronald Hirshorn: *Characteristics of the Canadian Economy and the Implications for Climate Change*, commissioned by Industry Canada.

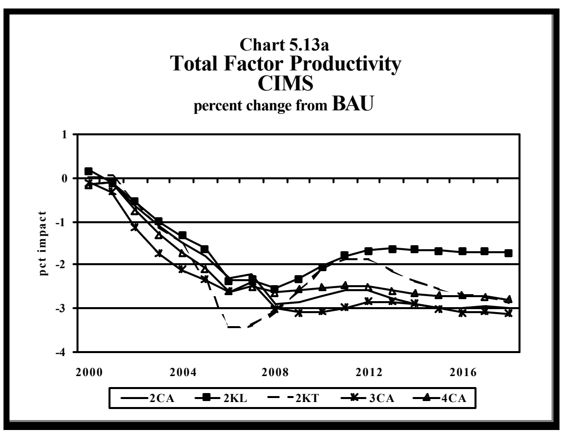
costs of GHG abatement will be important. As there are no directly comparable data, this aspect is difficult to determine. However, there is an indication from the EIA study, used to develop the international Scenarios, that the impact on the U.S. economy would be similar to that projected for Canada. Should the U.S. implement GHG reduction policies, its economy would be smaller, hence opportunities for exports may be curtailed somewhat.

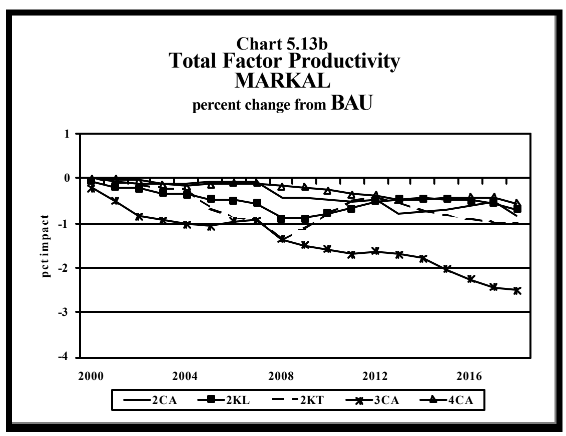
In this analysis, the effect of price competition is reflected in the analysis at the domestic level. At this time it is difficult to infer the international consequences for prices since the GHG policies of other countries such as the United States, are not well articulated at this time.

The change in real GDP per capita will decline in all Paths, especially after 2005.

The level of Total Factor Productivity (TFP)[20] is reduced, in the CIMS-based results, in all cases over the early years, when substantial incremental capital is being added while fuel cost reductions are being introduced (Chart 5.13). The incremental capital is directed at GHG reductions and does not change output. In the longer term, fuel savings "catch up" with the increase in capital to stabilize the level of reduction from the direct effects. It is not expected that in the indirect and induced effects of TIM would alter this.

An important indication, among the domestic policy sets, is that there appears to be no sharp distinction in competitiveness between the CA cases. The selection of one or another of these Paths would probably be based on grounds other than the impact on productivity potential. Acting in concert with other countries (KL and KT) appears to be less damaging.

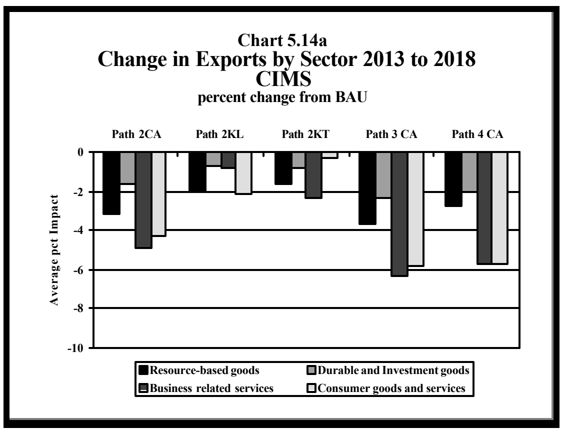


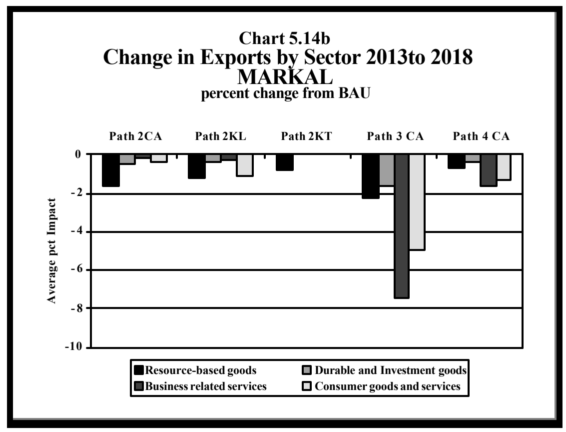




20 TFP is defined as Total Output divided by an index representing Labour and Capital.

The MARKAL-based results show a more gradual decline over the projection for all Paths except Path 3CA. This Path is similar to the CIMS outcome.

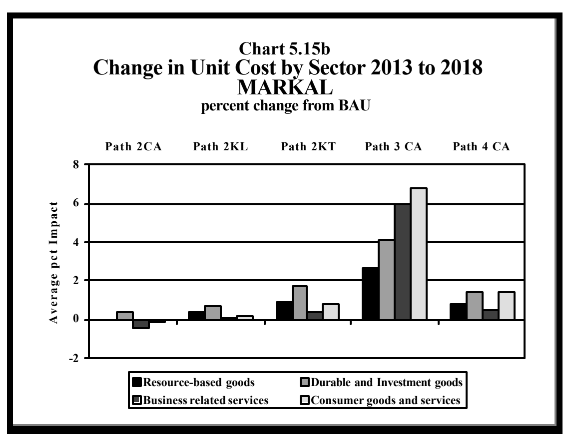
In the CIMS-based analysis, in all cases exports decline (Chart 5.14). As expected, Path 3CA shows the steepest decline for all sectors while Path 2KL has the least impact. Business-related services and Consumer goods and services are generally the most affected sectors. The impact on Resource-based industries and Durable and investment goods is more modest. These declines are attributable to the shrinking of the export market, although the international Scenarios show smaller impacts.



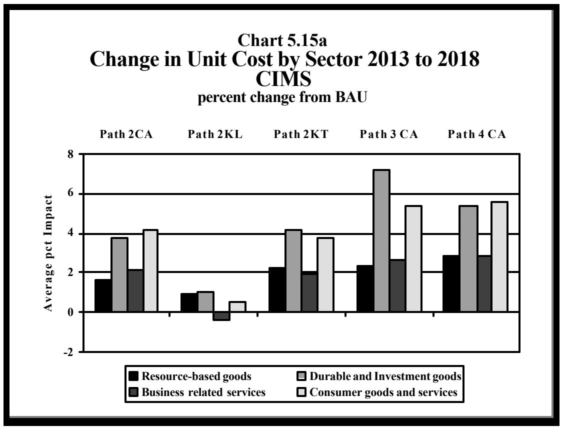




The MARKAL analysis shows similar trends, although there is almost no impact on exports in Path 2 KT.

The change in unit costs mirror the change in exports (Chart 5.15). Path 3CA shows the most severe increases, approaching 8 percent in some sectors and Path 2KL the least impact, with all sectors in the range of 1.0 to 2.5 percent. Consumer goods and services and Durable and investment goods have the highest increases across all Paths. Resource-based industries have the lowest increase.



While there are some differences in the affected industries in MARKAL, particularly in Path 3CA, where consumer goods and business-related services are more affected than in CIMS, the trend is similar. However, in Path 2CA there are no discernable effects in MARKAL.




Canadian competitiveness will be affected the most in the CA cases as there would be no cost "penalties" to Canada's trading partners due to GHG reduction measures. In the international Scenarios the picture is less clear because there are little data to establish the relative effects of TFP and unit costs among the trading partners. To expect no effect would be unrealistic. It would appear that the areas most vulnerable, based on change in exports and unit costs, are business-related services, particularly finance and insurance and consumer goods and services, particularly the leisure industries.

Another important issue that the macroeconomic analysis has not been able to capture is the potential for leakage of investment to countries that have lower, or no costs, to industry under the Kyoto Protocol. This leakage involves the diversion of investment that would otherwise occur in Canada, but is diverted by the costs that Canadian industry faces to meet Canada's Kyoto commitment. The effect is likely to be specific to a certain set of industries that are most vulnerable to international price competition. The diversion of investment from Canada leads to the potential migration of certain sub-sectors of the Canadian economy to other countries. While difficult to quantify, it is a risk to the Canadian economy. Analysis of this issue is an area for future work and should be done on an industry specific basis.

# Chapter 6
# A Complementary View: Analysis using CaSGEM

This chapter explores a complementary view to the Informetrica analysis using a computable general equilibrium model. The nature of this model is such that some input assumptions are different from those used by the energy-technology and econometric models. The full results for CaSGEM can be found in the report, *A Computable General Equilibrium Analysis of Greenhouse Gas Reduction Paths and Scenarios*, prepared by the Economic Studies and Policy Analysis Division of the Department of Finance.

**Key Learnings**

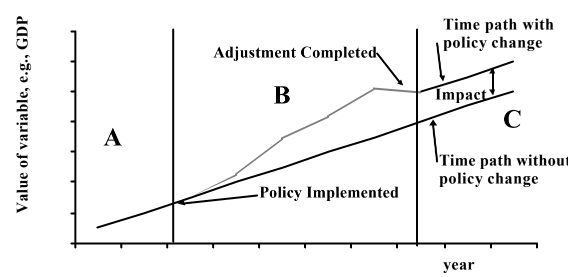
- There are long-run economic costs to implementing the Kyoto Protocol.
- When implemented in a cost-effective way (e.g., Path 4), these costs are neither inconsequential nor enormous.
- Cost-effective implementation implies very uneven effects across sectors and regions.
- Using sector-specific emissions targets would add to the overall cost of implementing Kyoto without reducing the variation in economic impact across sectors.
- "Technical" assumptions have a large bearing on the overall impact and its distribution across sectors and provinces.

## 6.1 Background

Computable general equilibrium (CGE) modelling combines the micro and macro perspectives in a single model. That is, the CGE approach simultaneously models input choices (including energy) and changes in sectoral and aggregate economic activity. Consequently, it is not possible to use all of the output of energy-technology models like CIMS and MARKAL as input into a CGE model. Thus the CGE analysis should be seen as a complement to the Issue Tables-CIMS/MARKAL-TIM results.

The model used to undertake the CGE analysis was the Canadian Sectoral General Equilibrium Model (CaSGEM), a model that was developed and is maintained by Finance Canada. CaSGEM simulates the Canadian economy using representative consumers and producers. It describes the complete economy as an aggregate of 51 sectors producing 59 goods and services, most of which are traded internationally.

**Chart 6.1**
**What CaSGEM Predicts**




CaSGEM is a static model which means that there is only one time period in the model. Thus CaSGEM's simulations of a GHG-reduction policy should be interpreted as showing the long-run impact of a policy change after the economy has completed the (possibly lengthy) adjustment to the new policy. The model assumes perfect competition. In Chart 6.1, Region A shows the economy before a policy change has been introduced, and Region C shows the economy after the adjustment to the new policy has been completed. Unlike TIM, CaSGEM does not describe the transition of the economy from the introduction of the policy to the time at which the economy has fully adjusted to the new policy (Region B in Chart 6.1). Note that the long-run growth rate of GDP (and associated variables) is assumed to be unchanged by the policy, but the change in the *level* of GDP is permanent.

**Chart 6.2**
**Paths and Scenarios**
**For CaSGEM Analysis**

| | Canada Acts Alone | Kyoto Tight | Kyoto Loose |
|---|---|---|---|
| Path 0 | | | |
| Path 1 | | | |
| Path 2 | | | |
| Path 3 | X | | |
| Path 4 | X | | X |

As shown in Chart 6.2, CaSGEM was used to simulate three path-scenario combinations:

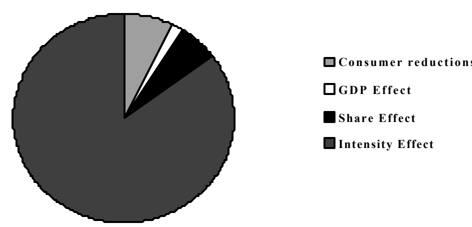
- Path 4 Canada Acts Alone
- Path 4 Kyoto Loose
- Path 3 Canada Acts Alone

It is assumed that all tax rates will be unchanged except for the fuel tax changes specified in Path 3. In a dynamic model like TIM, this could alter the government's budget balance in each year of the simulation, which translates into a change in the government debt at the end of the simulation period. As CaSGEM is a static model, the government cannot accumulate debt and reduce it later because there is no "later." To implement AMG's request to leave tax rates unchanged, *per capita* (i.e., lump sum) transfers to consumers were adjusted to ensure that the government budget remained balanced.

## 6.2 Results: Path 4 Canada Acts Alone

The centrepiece of Path 4 is a tradeable permit system that covers most of the economy.[21] The simulation of Path 4 under the Scenario *Canada Acts Alone* (CA), leads to a 0.8 percent decline in Canada's Gross Domestic Product (GDP), relative to what it would otherwise be. This may appear to be small, but the change would be permanent, so it is not inconsequential. Moreover, the precise figure depends on a number of "technical" assumptions, as discussed below.

**Chart 6.3**
**Channels for Emission Reductions**




These GHG emissions reductions are accomplished through four different channels, as shown in Chart 6.3.

The most important of these channels, the intensity effect, suggests that at least some sectors can fairly readily replace GHG-intensive inputs with less emitting ones. In this particular simulation, much of this reduction in intensity is occurring in electricity production. Chart 6.4 shows the reduction in emissions from coal and natural gas predicted by the model for that sector and the reduction in fuel use. The distinction between emissions and fuel use for coal is caused by the introduction of a new technology to capture and store

**Chart 6.4**
**Emissions and Use of Fossil Fuel in Electricity Production Path 4CA**
percent change vs BAU

| Fuel | Reduction in Emissions | Reduction in Use |
|---|---|---|
| Coal | -87 | -55 |
| Natrual Gas | -18 | -18 |

21 Details on the assumed coverage of the tradeable permits system can be found in the CaSGEM report. Measures that reduce non-fuel-related emissions in upstream oil and gas and agriculture were also imposed in all path-scenario combinations.

emissions from coal-fired generating stations in Alberta and Saskatchewan. This technology implies that coal can continue to be burned without emitting $CO_2$ into the atmosphere.[22]

While the use of coal and natural gas in electricity production is reduced sharply – accounting for almost a third of Canada's $CO_2$ reduction – the decrease in electricity production is a much more modest 2 percent. The reduction in emissions intensity for that sector is more than 70 percent.

Chart 6.5 shows the impact of Path 4CA on fossil fuels, which are responsible for about 81 percent of Canada's current GHG emissions. The table shows both how much more expensive they become – because of the permits that are needed for their combustion – and the degree to which their use is curtailed.

**Chart 6.5**
**Impact on Source of Energy Path 4CA**
**percent change vs BAU**

| Source | Price to Purchaser | Domestic Use |
|---|---|---|
| Coal | 212 | -52 |
| Gasoline | 15 | -7 |
| Diesel | 18 | -10 |
| Fuel Oil | 26 | -18 |
| Natural Gas | 35 | -32 |
| Electricity | 7 | -1 |

The substitution effect accounts for considerably less of the reductions than does the reduction in the emissions intensity. However, the impact of the GHG-reduction policy falls very unevenly across sectors. The sectors with the largest declines in activity (as measured with value added, or GDP) are shown in Chart 6.6.

**Chart 6.6**
**Largest Sectoral Reductions Path 4CA**

| Sector | Percent change in GDP vs BAU |
|---|---|
| Gas Pipelines | -22 |
| Steel | -12 |
| Cement | -12 |
| Industrial Chemicals | -11 |
| Petroleum and Coal Products | -8 |
| Pulp and Paper | -7 |
| Non-ferrous Smelting | -7 |
| Secondary Metal | -5 |
| Air Transport | -5 |
| Coal Mining * | -4 |

* Includes coal mimed by electricity producers for use in Canadian power plants

Some of the very uneven sectoral impact is due to the assumption that Canada Acts Alone. This puts Canadian producers of industrial chemicals, steel and cement at a disadvantage with respect to their foreign competitors. The picture changes – but not completely – when other countries also meet their Kyoto target.

22 In all of the results reported here, if capture and storage of $CO_2$ is economical, the amount of emissions that are stored is taken from the corresponding run of the CIMS model.

Since the industrial make-up of each province's economy is different, it might be expected that the variations in sectoral impacts to be parallelled by wide variations among provincial economies. Chart 6.7 shows that differences do occur among provinces, especially when the electric power sector is included in the calculations.

**Chart 6.7**
**Provincial GDP Path 4CA**
**percent change vs BAU**

| Province | Including Electricity Sector | Excluding Electricity Sector |
|---|---|---|
| Newfoundland | -0.4 | -0.7 |
| PEI | -0.7 | -0.4 |
| Nova Scotia | -2.8 | -0.6 |
| New Brunswick | -2.3 | -0.8 |
| Quebec | 1.2 | -0.8 |
| Ontario | -1.8 | -0.7 |
| Manitoba | -0.8 | -0.7 |
| Saskatchewan | -1.7 | -1.1 |
| Alberta | -1.1 | -1.6 |
| BC and Territories | 0 | -0.8 |
| Canada | -0.8 | -0.9 |

Electric power generation (and hence, its GDP) increases in provinces where electricity is produced with low-GHG technologies such as hydro-electricity, at the expense of provinces that burn fossil fuels to generate electricity.
Surprisingly, the impacts on the electric power production and coal consumption appear muted in Alberta, even though most of the electricity generation is coal-fired. The reason is that capture and storage of $CO_2$ is assumed to be available and more economical in Alberta and Saskatchewan than switching to other fuel sources. This technology is assumed to be economical provided that it costs more than \$38 for alternative methods of abating $CO_2$. Since the cost of a permit to emit one tonne of $CO_2$ in Path 4CA is found to be above \$44 in this simulation, electricity producers in Alberta and Saskatchewan find it cheaper to capture and store their emissions rather than buy a permit allowing them to burn coal without capture and storage.

Note that in this simulation, it is assumed that additions to hydro-electric capacity can be installed in some provinces, and that inter-provincial trade in electricity can increase substantially. These assumptions, along with the assumption of capture and storage, play an important part in the results. Without those assumptions, the total impact of the policy package on the economy would be larger, and the regional distribution of the results would change.

## 6.3 Results: Path 4 Kyoto Loose

In this international Scenario, other countries also implement the Kyoto agreement and trade permits internationally. As discussed in Chapter 3, the permit price in *Kyoto Loose* is assumed to be \$24 per tonne of $CO_2$.
CaSGEM is a model of the Canadian economy only. To address international scenarios, it requires detailed input on prices and economic activity in foreign countries. The requisite input

to CaSGEM was taken from a multi-country CGE model, G-cubed. The CaSGEM report includes an introduction to G-cubed.[23]

This international Scenario has two main advantages for Canada:

- Since other countries are complying with Kyoto, Canadian exporters will be placed at less of a competitive disadvantage: many of their foreign competitors will also be spending money on GHG reduction or on permits.
- The portion of the gap that must be met by domestic actions is reduced, and Canada can now satisfy its commitment at a lower permit price ($44 vs. $24 per tonne of $CO_2$).

There are also two principal disadvantages to Canadians under this international Scenario:

- Since Canada's trading partners will also be reducing GHG emissions, their economies will contract. This will provide smaller markets for Canadian exporters.
- Furthermore, Canada is a net exporter of crude oil and natural gas. The international demand for these two fuels may decline as other countries reduce their GHG emissions. This in turn may drive down the price that Canadian exporters receive for their oil and gas.[24]

The net effect of all these forces, under Path 4KL, is to reduce Canada's GDP by 0.3 percent from its business-as-usual case. This represents a smaller impact than Path 4CA. Furthermore, Canadians buy enough permits from abroad to account for just under one-third of the difference between BAU emissions and the Kyoto target.

The impacts of Path 4KL on the various sectors differ from those in Path 4CA. The overall impact on cement, electricity, industrial chemicals, pulp and paper, and steel is more muted under the Kyoto Loose Scenario as compared to when Canada Acts Alone. Furthermore, capture and storage is no longer a worthwhile proposition in Alberta and Saskatchewan as it is now cheaper to buy permits than to capture and store $CO_2$.

---

23 G-cubed was developed at the Brookings Institution. The version that is used at Finance Canada includes a fully specified block for Canada that was developed by Philip Bagnoli. A full description of the G-cubed model can be found in W. J. McKibbin and P. J. Wilcoxen, "The Theoretical and Empirical Structure of the G-Cubed Model", *Journal of Policy Modelling*, 1999.

24 This is at variance with the expectations of the EIA analysis (see Chapter 3)

## 6.4 Results: Path 3 Canada Acts Alone

Path 3 is also simulated under the assumption that Canada alone fulfils its commitment under the Kyoto Protocol. The difference between this Path and Path 4 is that the permit-trading regime is restricted to a smaller number of industries and is assumed to complement a number of sector-specific measures which are aimed at helping each sector meet its own Kyoto target.

In this Path, only the electric power and industry sectors participate in a permit-trading scheme. Other sectors adopt measures proposed by the various Issue Tables. These measures were first simulated using the CIMS model; the results were then input into CaSGEM using CIMS' calculations of each measure's incremental capital expenditure and energy reductions.

The treatment of the transportation sector differs somewhat. As specified in Path 3, it faces a tax on diesel fuel and gasoline to discourage their consumption.[25] In addition, a number of fuel-saving measures are implemented that are paid for by the emitters or, as is the case for much of the investment in new transportation infrastructure, by government.

In the simulation of Path 3CA, the Canadian economy contracts by 0.9 percent with respect to its BAU case. The economic contraction is only marginally greater than in Path 4. There are two different causes, working in opposite directions, for the differences between the two Paths.

The first difference is the way that compliance is distributed across sectors. In Path 4, compliance with the Kyoto target is distributed across sectors in a cost-effective way because almost all sectors of the economy face a uniform price on emissions.[26] This leads those sectors with the least costly abatement options to do most of the abatement. In Path 3, the policy measures are not chosen with overall cost-effectiveness in mind.

The second difference is that the simulation of Path 3 incorporates measures from the Tables. They proposed a number of low-cost GHG-reducing actions that were not forecast by

---

25 According to the CIMS model, total gasoline use falls by about 40 percent while that of diesel fuel in transportation falls by 25 percent relative to BAU.

26 Uniform pricing of emissions should mimimize the aggregate cost of the additional resources (e.g., capital equipment) that are needed to reduce emissions. This is the conception of "cost" that was used in the energy-technology models to describe the impact of compliance on sectors other than energy producers and transportation. In a model like CaSGEM, minimizing the aggregate resource cost should also mimimize the impact on aggregate GDP.

CaSGEM under Path 4.[27] Furthermore, the policies that are applied on a sector-by-sector basis are assumed to be perfectly targeted– in other words, the measure is as effective and no more costly than planned. Among other things, this means that government subsidizes only additional expenditures that result directly from the new policy.

Again, the net effect of these two opposing influences is that Path 3CA is only marginally more costly than Path 4CA. As shown in the CaSGEM report, when the inexpensive sources of abatement that are assumed in Path 3, but not in Path 4, are removed, Path 3 is noticeably more costly than Path 4. The upshot is that Path 3 is comparable in cost to Path 4 only if a policymaker can induce people to reduce emissions in ways that they would not otherwise do under a price instrument such as permits. Moreover, despite the use of sector-specific emission targets, the variation in the economic impact of the policy package across individual sectors is about the same in Path 3CA as in Path 4CA.

Besides the greater impact on GDP, the major differences between the results of Paths 3 and 4 are:

- Diesel fuel and gasoline use declines significantly more from BAU under Path 3.
- Because of these declines, consumers and the transportation sector (excluding air travel) reduce emissions significantly more (and in the case of transportation's sectoral GDP, the contraction is greater) than under Path 4.
- The electricity sector's emissions fall less under Path 3 than under Path 4 (a reduction of 46 percent in Path 3 compared to 49 percent in Path 4).

As in Path 4, the price of permits is above the $38 per tonne of $CO_2$ that makes capture and storage economical. $CO_2$ emissions reduction from coal burning plants in Alberta and Saskatchewan is, therefore, a significant contributor to overall GHG reductions.

---

27 There may be a number of reasons why CaSGEM and the Tables have different views on the resource cost of reducing emissions. CaSGEM is based on historical responses to price changes and may be unable to predict the ease with which new technologies are adopted in a world where GHG-emissions are more costly. Or, the Tables may underestimate the costs (i.e., the risk inherent in new technologies, the preference of private vehicle travel over public transportation) borne by consumers and producers who adopt new technologies or practices.

## 6.5 Comparison to Results of other Models

The introduction to this chapter noted that the quantitative results differ across the models. This section explores this further by comparing some key results from CaSGEM to those produced by the other models. To focus the comparison, all of the results are taken from simulations of Path 4 under Canada Acts Alone. However, certain assumptions, particularly for oil and natural gas exports, are different from those used in the TIM, CIMS and MARKAL models. In CaSGEM these exports are expected to decline, whereas in the TIM analysis they are expected to remain flat for crude oil and increase for natural gas.

**Chart 6.8**
**Comparison of Energy Prices and Use Path 4CA**
percent change vs BAU

| | CIMS | MARKAL | CaSGEM |
|---|---|---|---|
| | | Price to Purchaser | |
| Coal | 800 | 300 | 212 |
| Gasoline | 35 | 15 | 15 |
| Diesel | 40 | 15 | 18 |
| Fuel Oil | | | 27 |
| Natural Gas | 70 | 45 | 35 |
| Electricity | | | 7 |
| | | Domestic Use | |
| Coal | -55 | -45 | -52 |
| Gasoline | -30 | -15 | -7 |
| Diesel | with gasoline | with gasoline | -10 |
| Fuel Oil | | | -18 |
| Natural Gas | -6 | -19 | -32 |
| Electricity | -4 | -17 | -1 |

One way to summarize the energy-technology aspects of Path 4CA is to consider the simulated impact on energy prices and use. Chart 6.8 compares the results obtained from MARKAL, CIMS, and CaSGEM. The changes in price and energy use are broadly comparable across the models. The predicted changes in natural gas use vary the most across models.

In all three models, the electricity sector plays a central role in Path 4CA. Chart 6.9 contrasts the predicted impact of Path 4 on the use of fossil fuels across the three models. The CaSGEM results lie between those of CIMS and MARKAL. In all three models, coal use declines sharply. CIMS shows the largest decline in coal use, MARKAL shows the smallest. Natural gas use rises in CIMS, but falls in MARKAL. CaSGEM's prediction lies between those two; there is a decline in natural gas use, but it is not as dramatic as the decline predicted by MARKAL.

**Chart 6.9**
**Comparison of Fossil Fuels Used in Electricity Production Path 4CA**
percent change vs BAU

| Fuel | CIMS | MARKAL | CaSGEM |
|---|---|---|---|
| Coal | -63 | -51 | -55 |
| Natural Gas | 11 | -35 | -18 |

It is possible to summarize the macroeconomic aspects of Path 4CA by comparing the impact on industries. Chart 6.10 shows the industries with the largest declines in GDP in the simulations from TIM and CaSGEM.[28] The models have differing industrial structures and close correlation is unlikely. As expected, there is a closer correlation with the TIM/CIMS/MARKAL combination, although two industries (coal mining and natural gas distribution) are common to all three models.

**Chart 6.10**
**Comparison of Sectors with Largest Decline in GDP Path 4CA**

| | INFORMETRICA | | |
|---|---|---|---|
| | CIMS | MARKAL | CaSGEM |
| Largest Decline | Consumer Electronics | Coal Mining | Gas Pipeline |
| 2nd Largest | Coal Mining | Gas Distribution | Steel |
| | Truck & Bus Body Assembly | Truck & Bus Body Assembly | Cement |
| | Miscellaneous Transport Equipment | Iron Ore Mining | Ind Chem |
| | Beverage Manufacturing | Consumer Electronics | Pete & Coal |
| | Iron Ore Mining | Refineries | Pulp & Paper |
| | Leather Goods Manufacture | Electronics, Computers & Office Machinery | Non-ferrous Smelting |
| | Telecommunications Equipment | Beverage Manufacturing | Secondary Metal |
| | Garments & Clothing Manufacture | Miscellaneous Transport Equipment | Air Transport |
| 10th Largest | Gas Distribution | Electric Power Utilities | Coal Mining |

Chart 6.11 contrasts the provincial GDP results across the models. It shows that there is very little coherence in the results across TIM and CaSGEM. Comparing TIM/CIMS to CaSGEM shows that GDP losses would occur in 8 of 10 provinces. The major difference being Quebec, which TIM/CIMS expects a loss of GDP, but CaSGEM expects a gain. The TIM/MARKAL comparison with CaSGEM shows the same sign on GDP in four provinces. There are many sources for these discrepancies, including the different results for the national sectoral GDP impacts that underlie the provincial results, and the particular treatment of the distribution of electricity production used for the CaSGEM results. Moreover, certain assumptions regarding natural gas and crude oil exports are different from TIM.

**Chart 6.11**
**Comparison of Provincial GDP Path 4CA**
**2013 - 2018**
**percent change vs BAU**

| Province | TIMS - CIMS | TIM - MARKAL | CaSGEM |
|---|---|---|---|
| Newfoundland | -0.5 | 0.5 | -0.4 |
| PEI | -1.3 | 0.3 | -0.7 |
| Nova Scotia | -1.3 | 0 | -2.8 |
| New Brunswick | -0.4 | -0.2 | -2.3 |
| Quebec | -1.5 | 0 | 1.2 |
| Ontario | -2.8 | -0.5 | -1.8 |
| Manitoba | -1.5 | -1.0 | -0.8 |
| Saskatchewan | -2.4 | -0.7 | -1.7 |
| Alberta | -1.9 | 0 | -1.1 |
| BC and Territories | -1.2 | 0.2 | 0 |
| Canada | | | -0.8 |

Despite these differences in the quantitative results, the qualitative conclusions stated at the beginning of the chapter generally apply to the results of all of the models.

28 To make this comparison, the results from TIM were aggregated up to the 51 sectors that are represented in CaSGEM.

# Chapter 7
# Environmental and Health Impacts

This chapter of the report focuses on the environmental and health impacts (EHI) associated with the mitigative actions to reduce GHG under the various Paths and Scenarios. It is part of the overall assessment of the economic, environmental and social impacts associated with implementation of the Kyoto Protocol. The full results for EHI can be found in the document *The Environmental and Health Co-benefits of Actions to Mitigate Climate Change*.

**Key Learnings**

- The analysis indicates that there are co-benefits associated with the actions to mitigate GHG. Relative to the benefits from GHG emissions reduction, co-benefits are immediate, local and reasonably certain. The net present value of these co-benefits, discounted at 10 percent, is between $2.7 billion and $4.5 billion. These estimates should not be compared to the changes in GDP. There may be similarities between the co-benefits and the costs identified elsewhere in this Report. However, the estimates from the energy-technology models exclude welfare costs and the co-benefit assessment is incomplete. For this analysis they should not be compared.

- The EHI assessment, may be described as range-finding. The results should be viewed in conjunction with the framework and the assumptions on which they are based.

- The co-benefit estimates indicate that the benefits under the Kyoto Loose Scenario would be less than those for the Canada Acts Alone scenario.

- The assessment indicates that actions to mitigate climate change can make a important contribution to Canada-Wide Standards (CWS). It achieves most of the $NO_X$ reduction, some of the $SO_x$ and makes minor contributions to $PM_{2.5}$ and VOC.

- The estimates tend to be conservative, since they do not cover all of the pollutants and omit the contribution of sulphate reductions in western Canada.

## 7.1 Introduction

The early part of this chapter focuses on the cost-effectiveness. The benefits comprise two parts: the primary benefits; and the secondary or co-benefits. The primary benefits relate to the contribution that these actions make to an overall improvement in the climate and the resulting impacts on the environment, economy and society (prepared by the Science Impacts and Adaptation Group (SIAG)). The secondary or co-benefits include those associated with the impact of the proposed GHG initiatives on the conventional pollutants, such as oxides of sulphur and nitrogen, volatile organic compounds (VOC) and particulates.

This assessment is critically dependent on both the framework and assumptions on which it is based. The assessment framework is both qualitative and quantitative. The qualitative portion is based on expert opinion. The quantitative assessment is based on a sequential modelling framework that begins with inputs from the energy-technology assessment (Chapter 4). The energy-technology models define the input fuel demands from which the changes in air emissions are estimated.

The three path-scenario combinations that were assessed for the EHI analysis - Path 2CA, Path 2KL and Path 3CA - provide a reasonable range of results (Chart 7.1). The physical and monetary analysis of co-benefits is mainly focused on sulphates and ozone for which there is fairly good data and modelling. By focusing on a selected subset of pollutants the level of uncertainty is reduced.

**Chart 7.1**
**Paths and Scenarios**
**For EHI Analysis**

| | Canada Acts Alone | Kyoto Tight | Kyoto Loose |
|---|---|---|---|
| Path 0 | | | |
| Path 1 | | | |
| Path 2 | X | | X |
| Path 3 | X | | |
| Path 4 | | | |

## 7.2 Approach

*Broad Framework*

The framework for the EHI analysis relies on the work undertaken by the Tables, the SIAG and the AMG. The Issue Tables were asked to carry out an analysis of the environmental and health impacts outlined in the guidelines supplied by the AMG.[29] In addition, the Tables estimated and reported changes in emissions of criteria air contaminants ($NO_X$, VOCs, $SO_X$ and PM). These assessments are included with the

[29] Framework for the Analysis of Environmental and Health Impacts, Analysis and Modelling Group, February 16, 1999.

AMG's overall assessment of options. The AMG estimated the clean-air ancillary, or co-benefits, of GHG mitigative actions and provided a broad qualitative assessment of the environmental and health impacts.

It was not possible for the SIAG to estimate the primary avoided impacts resulting from the implementation of the Kyoto Protocol. Nonetheless, it was requested to describe the potential known impacts of climate change on Canada's physical environment.

*Quantitative Assessment*

Climate change actions, in addition to reducing greenhouse gas emissions, can also lead to reductions in conventional pollutants such as CO, $SO_2$, $NO_X$/VOCs, and particulate matter. These other pollutants lead to deteriorating air quality and can have negative health and environmental impacts. Therefore, climate change measures to reduce GHGs which also reduce these other emissions can yield positive co-benefits from the improvement in air quality. These co-benefits can be viewed as a "bonus" and should be considered in the assessment and selection of strategies for reducing GHGs.

The quantitative assessment involves the following four steps:

- Estimating changes in conventional air pollutants, known as criteria air contaminants (CAC), from the baseline;
- Estimating changes in ambient concentrations of pollutants (air quality) corresponding to the CAC emission changes;
- Estimating the physical health and environment impacts associated with the changes in air quality; and
- Estimating the economic value of the effects that would be avoided by reducing the emissions.

*Qualitative Assessment*

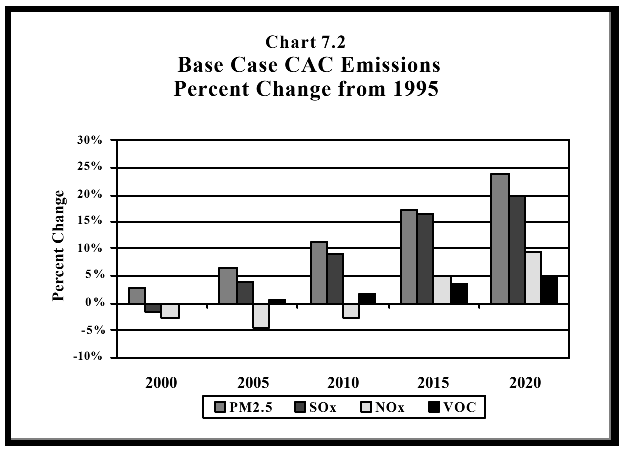
Climate change actions, in addition to reducing greenhouse gas emissions, could have a range of environmental impacts. The EHI framework categorizes these potential impacts as being related to atmospheric, aquatic and terrestrial effects. Some of these impacts can be quantified in either physical or monetary terms, and are the subject of the quantitative assessment. Other impacts are less amenable to quantification due to incomplete information on the potential implications. These are examined in a qualitative manner.

## 7.3. Observations and Results

To fully interpret the results of the analysis of CAC and co-benefits it is important to understand the baseline economic and policy assumptions. The CEOU was used as the reference case, with some EHI specific inclusions and exclusions:

- Tier I vehicle emission standards are included, Tier II[30] are not.
- Lower sulphur regulations for gasoline are included, but not for diesel.
- The proposed Canada Wide Standards[31] are not included.

In general, policy pronouncements that are not yet fully articulated could reduce the size of the impact on CAC and co-benefits. The assumption on Canada-Wide Standards is the most significant.




The reference case growth rates for four of the seven CAC examined are shown in Chart 7.2. These four contaminants were selected because of their relative importance to air quality, and these pollutants are the most affected by the actions to reduce GHG emissions. The growth estimates are shown in five year intervals from 2000 to 2020. With the exception of $NO_X$, which shows minor declines until 2010, all other contaminants increase. By 2020, $PM_{2.5}$, $SO_X$, $NO_X$ and VOC are respectively 24 percent, 20 percent, 10 percent and 5 percent higher than the 1995 levels. Based on the assumptions in CEOU, the overall trend is upward. However, the sector and regional trends vary significantly from the totals. Highlights of these trends are provided below.

In the reference case, the largest percentage increases in $NO_X$ and VOC are in the electricity sector (27 percent and 43 percent) due to increased natural gas generating capacity. Increases in $SO_X$, mainly from the upstream oil and gas (33 percent), petroleum refining (29 percent) and base metal smelting and refining (14 percent) are somewhat offset by declines in the electric power generation sector. All emissions from transportation are

30 Tier I and Tier II are U.S. EPA emission reduction programs for light duty vehicles.

31 Canada-Wide Standards are national standard for ozone and $PM_{2.5}$. By 2010 $PM_{2.5}$ is to average 30Fg/m$^3$ over a 24 hour period. Ozone is to average 65 ppb over an 8 hour period.

expected to decline due to improvements in fuel quality and emissions intensities: $SO_X$ (-15 percent), $NO_X$ (-20 percent), VOC (-42 percent) and $PM_{2.5}$ (-17 percent).

In the reference case, the largest $NO_X$ reductions are expected in Quebec (-23 percent), Manitoba (-11 percent) and the Atlantic Region (-10 percent), with significant increases in Alberta (+16 percent). The largest $SO_X$ increases are in Saskatchewan (37 percent), British Columbia (31 percent), Ontario (20 percent) and Alberta (19 percent), whereas emissions decline significantly in the Atlantic Region (-27 percent). The biggest increases in $PM_{2.5}$ are expected in Alberta (27 percent) and Ontario (20 percent).

Several sensitivity analyses were conducted on the reference results to examine the implications of changes in key forecast parameters:

- Significantly reduced sulphur levels for Canadian motor diesel fuel to match U.S. EPA's proposed levels for on-road vehicles (15 ppm) and planned potential levels, from 500 to 15 ppm, for off-road diesel vehicles; and

- Tier II emission standards applied to Canada's light duty gasoline vehicles.

- Reductions in the sulphur content of diesel fuels lower transportation sector $SO_X$ emissions by an additional 30 percent relative to the BAU, and lead to a total reduction of transportation sector $SO_X$ emissions of 41 percent by 2010 relative to 1995 levels (vs. 15 percent in the BAU). By contrast, the impact of the Tier II vehicle emissions program suggests more modest reductions in $NO_X$ and VOC emissions of 8 percent and 5 percent relative to the base case forecast in 2010. Relative to 1995 levels, transportation sector $NO_X$ and VOC emissions decline by 27 percent and 45 percent (vs. 20 percent and 42 percent in the BAU).

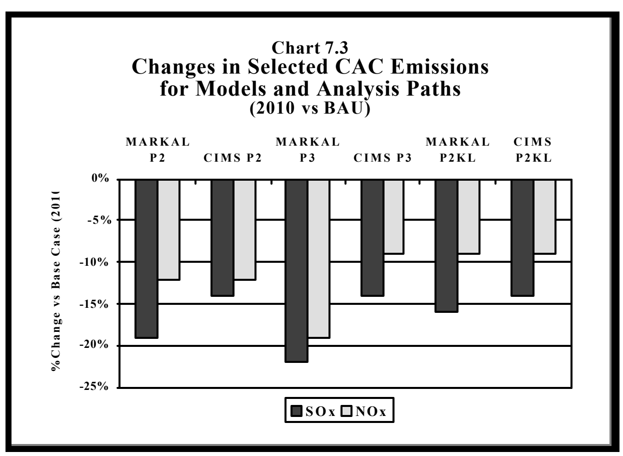



Chart 7.3 provides a sample of the changes in CAC in 2010 for both energy technology models across three of the Paths and Scenarios analyzed. All Paths and Scenarios examined show significant declines in $NO_X$ (ranging from 9 percent to 19 percent) and $SO_X$ (ranging from 14 percent to 22 percent). Generally, the reductions are larger for MARKAL; also, the Canada Acts Alone Scenarios have larger reductions than the International Scenarios. There are slight declines in other CAC, with the exception of $PM_{2.5}$ which shows increases in some Paths, largely due to increased residential biomass use in the MARKAL results. These results mask significant sectoral

and regional variations in changes in CAC emissions. A detailed comparison of these results is provided in the EHI Report.

In June 2000, CCME Ministers endorsed Canada-Wide Standards (CWS) for particulate matter and ozone. Previous analyses of options for these standards had estimated the changes required in emissions by province in order to achieve these standards. The required reductions in CAC emissions by region to achieve the CWS for PM and ozone are shown in Chart 7.4. Generally, the results indicate that the reductions from any of the climate change options are insufficient to achieve all of the VOC targets and most of the PM targets. However, the options sometimes exceed or provide a portion of the required reductions for $SO_X$ and $NO_X$. Further details on this comparison are contained in the EHI Report.

**Chart 7.4**
**Required Reduction in CAC Emissions by Region to Achieve CWS for PM and Ozone (percent change from 1995 levels)**

| Regional Targets | PM2.5 | $SO_X$ | $NO_X$ | VOC |
|---|---|---|---|---|
| Atlantic (Nova Scotia) | 0 | 0 | -30 | -30 |
| Quebec | -20 | -20 | -35 | -35 |
| Ontario | -30 | -30 | -45 | -45 |
| Manitoba | 0 | 0 | 0 | 0 |
| Saskatchewan | 0 | 0 | 0 | 0 |
| Alberta | 0 | 0 | -20 | -20 |
| B.C. | 0 | 0 | -10 | -10 |

The Air Quality Valuation Model (AQVM) was used to estimate the physical and economic health and environmental benefits associated with the Paths and Scenarios examined. To improve the transparency of the AQVM results, it was shared with stakeholders to provide a better understanding of the operating characteristics of this model. The physical effects associated with the various Paths and Scenarios were estimated using the concentration-response functions in the model. The model then uses market and non-market information to convert these physical impacts into monetary terms - the most controversial of these being the values used to estimate reductions in the risk of death. The central estimate in the model of $4.1 million, for the value of a statistical life, implies that the “average individual” would be willing to pay approximately $400 to reduce their risk of premature mortality by 1 in 10,000.

Data limitations made it impossible to estimate benefits for the full set of pollutants. The analysis examined impacts from three pollutants - sulphate aerosols ($SO_4$)[32], ground-level ozone, and sulphur dioxide ($SO_2$). A range of human health impacts and a small group of environmental impacts, associated with these pollutants was analyzed. Although it is

32 $SO_4$ or sulphate aerosol, comes primarily from the oxidization of sulphur content in fossil fuels upon combustion. Major combustion sources containing sulphur include: coal, gasoline and diesel fuel, heavy and light fuel oil. Processing related sources of sulphate include calcium sulphate in cement processing and oxidization of sulphur in the smelting of crude grades of mineral ore.

expected that these pollutants should provide a good sense of the order of magnitude of total benefits, the impacts from other pollutants were not included in this analysis.

The only measure of particulate matter (PM) used in this analysis was $SO_4$. This has the potential to understate the estimated impacts since it does not include many of the other elements of the complex mixture composing PM. However, as many concentration-response functions were developed based on reported sulphate aerosol measurements, it is uncertain to what degree results are underestimated.

Because of limitations on the air quality data, estimates for $SO_4$ are only available for central and eastern Canada. Therefore, there is a potentially serious omission of possible benefits from cleaner air in western Canada.

The co-benefits reported are an estimate of the societal benefits that could be realized in various regions of Canada, resulting from the avoided non-market health and environmental impacts provided by the analysis. These societal benefits represent the value which Canadians place on these co-benefits, as determined by estimates of their willingness-to-pay to achieve these avoided impacts. In the context of EHI analysis, willingness-to-pay is the maximum amount of money or other goods a person is prepared to forgo in order to avoid the negative health or environmental outcome.

The changes in ozone range from less than 1 ppb-day per year in Newfoundland (MARKAL Path 2) to 180 ppb-day per year in Southern Ontario ( MARKAL Path 3). These ozone index changes, measured at air quality monitoring stations correspond to a maximum 0.5 ppb change in mean daily peak hour ozone.[33] This is roughly equivalent to 5-10 percent of changes required by Canada-Wide Standards. Chart 7.5 shows the maximum changes in $SO_4$ and $SO_2$ by Path from $SO_X$ reduction, interpolated from analysis using the acid deposition and oxidant mechanism.

**Chart 7.5**
**Maximum Ambient Air Concentration Change**

| | $SO_4$ ig/m$^3$ | $SO_2$ µg/m$^3$ |
|---|---|---|
| MARKAL Path 2 CA | 0.76 | 3.97 |
| CIMS Path 2 CA | 0.46 | 2.38 |
| MARKAL Path 3CA | 0.76 | 4.01 |
| MARKAL Path 2 KL | 0.57 | 3.01 |

33 This takes into account the relative local emission contribution to local ozone formation, so that the maximum changes in the index do not necessarily occur where the maximum base index values occur.

Chart 7.6 shows estimates of the avoided physical impacts associated with MARKAL Path 2CA in 2010. To put these physical impacts into perspective - total air pollution is estimated to cause about 5,000 premature deaths per year in Canada.[34] The avoided death estimate under this Path is about 3 percent of this number. These estimates do not include any contribution from sulphate reductions in western Canada.

**Chart 7.6**
**Physical Impacts -2010**
**MARKAL Path 2 CA**

| | Atlantic | Quebec | Ontario | Western Canada | Total |
|---|---|---|---|---|---|
| Mortality | 5 | 45 | 95 | 0 | 140 |
| Hospital Admissions (Respiratory/Cardiac) | 5 | 50 | 110 | 0 | 160 |
| Emergency Room Visits | 10 | 125 | 275 | 1 | 410 |
| Chronic Bronchitis (Adults) | 15 | 155 | 325 | 0 | 490 |
| Acute Bronchitis (Children) | 200 | 1,950 | 4,300 | 0 | 6,450 |
| Restricted Activity Days | 3,000 | 31,000 | 78,000 | 1,000 | 115.000 |
| Asthma Symptom Days | 6,000 | 65,000 | 145,000 | 500 | 220,000 |
| Days with Acute Respiratory Symptoms | 20,000 | 210.000 | 480.000 | 2,000 | 715.000 |

Attempts have been made to ensure the more serious effects are separated from the more numerous effects, to eliminate double counting
Non-health impacts have not been tabulated in physical terms, but are included in the calculation of monetary impacts

The physical impacts were simulated for two years: 2010 and 2020, and then monetized to yield economic estimates of the benefits in those two years. A linear interpolation from 2000 to 2020, was then performed to derive the net present value and annualized stream of benefits over the period. Chart 7.7 presents a comparison of the estimated economic co-benefits associated with the Paths that were examined. These benefits exclude any contribution from sulphate reductions in western Canada.

The ranking of the Paths from most to least co-benefits follows the order of the Paths ranked by $SO_X$ emission reductions. This is to be expected, since the primary contribution to total benefits comes overwhelmingly from $SO_4$, which is a secondary pollutant formed in the atmosphere from primary $SO_X$ emissions. One important consequence of these results is that the level of overall uncertainty on the total estimates is reduced, since $SO_X$ emissions are fairly straightforward to model.

**Chart 7.7**
**Estimated Co-benefits**
**(96 $ million)**

| | Net Present Value | | Annualized | |
|---|---|---|---|---|
| | 7 percent | 10 percent | 7 percent | 10 percent |
| MARKAL Path 3 CA | 6,200 | 4,500 | 580 | 520 |
| MARKAL Path 2 CA | 6,000 | 4,300 | 550 | 500 |
| MARKAL Path 2 KL | 4,500 | 3,200 | 410 | 370 |
| CIMS Path 2 CA | 3,800 | 2,700 | 350 | 320 |

Comparing results from MARKAL, Path 2KL yields significantly less domestic co-benefits. This is to be expected, since the purchase of international permits under the KL Scenario reduces the required level of domestic action. These domestic mitigation activities produce local CAC reductions, and hence improved air quality and the realization of more

34 This estimate is derived from the results in: *The Effects of the Urban Air Ambient Pollution Mix on Daily Mortality Rates in 11 Canadian Cities*, R. Burnett, S. Cakmak and J. Brook, Canadian Journal of Public Health, Volume 89, Number 3.

EHI co-benefits for Canada. This points to the trade-offs involved in the pursuit of international GHG emissions trading programs.
The existence of thresholds has not been resolved.[35] Therefore, a sensitivity analysis was performed on this key parameter. The results show that when thresholds were applied to $SO_4$ and ozone, the economic benefits declined by about 50 percent.

A useful benchmark by which to evaluate these results is to compare them to other analyses of co-benefits that have been made internationally. A number of developed and developing country studies on this issue have been performed recently. In 2010, these analyses indicates a range of $3 to $5 per tonne of $CO_2$-equivalent. These are average benefits and should not be compared with marginal costs from the energy-technology models. However, this range is comparable to similar studies conducted in the US.

The co-benefits estimates should not be compared with changes in GDP, but there may be similarities between the co-benefits and the energy-technology model costs. However, those cost estimates exclude welfare costs and the co-benefit assessment only addressed a portion of the benefits. Thus for this analysis they should not be compared.

There is a legitimate concern about "double counting" benefits from improving air quality. Caution must be exercised in establishing the policy baseline. The EHI analysis uses the CEOU as its policy baseline. These assumptions are fairly stringent in that they only included future policies that were well articulated. In this analysis, the clean air co-benefits are attributed to GHG mitigation measures, since there are no future clean air policies in the BAU. For example, GHG co-benefits that are created through reductions in $SO_2$ cannot also be attributed to new acid rain actions. The reasoning is that climate change mitigation actions, reducing $SO_2$ emissions, shifts the $SO_2$ emissions baseline downward so that new emissions reductions caused by acid rain action must be referenced to the new, lower, $SO_2$ emissions baseline. Care must be taken with air issue analyses regarding the policy baseline so that the same emission reduction benefits are not counted twice. It is important to note that the assumptions surrounding the policy baseline impacts both costs and benefits.

Uncertainties affect the results in three categories:

- Policy uncertainties, such as the implementation of Canada-Wide Standards for PM and ozone;
- Translation of Issue Table measures and options into the energy-technology models in the context of future technology; and

---

35 A threshold is an ambient concentration level for a given pollutant below which negative health or environmental impacts do not occur.

- Inaccuracies arising from the chain of analysis in deriving quantitative EHI results.

The focus is on the third category since uncertainty surrounding policy and future technologies are discussed elsewhere.

Qualifications for key EHI uncertainties are noted below:

- $SO_X$ estimates from energy use are reasonably accurate since sulphur content in fuels is well known.
- $NO_X$ and VOC changes are uncertain, but are of lesser importance to the EHI benefit estimates (benefits from ozone reduction are small relative to those related to sulphate reductions).
- Ambient air quality analysis was based on an interpolation of complex photo-chemistry modelling.
- Uncertainty regarding environmental and health impacts from changes in ambient air quality are explicitly demonstrated as uncertainty ranges in the AQVM estimates.

The inability to accurately forecast future technologies was identified as having a significant effect on the EHI analysis. The absence of impacts from particulate matter in western Canada implies that benefits are missing for part of Canada. The use of $SO_4$ only, as a particulate measure, obscures the potential for worsened air quality that could come from biomass combustion, as indicated in the MARKAL Path 2 results.

### 7.4 Qualitative Assessment

The qualitative assessment is focussed on Paths 3 and 4 as they represent the most interesting comparison from the point of view of a strategic policy assessment. The key points from the relative comparisons are:

The relative emphasis on electricity sector reductions in Path 4, lead to less coal use and consequent decreases in acid deposition and sulphate aerosol particulate matter. However, increased use of large-scale hydro electric development may lead to habitat fragmentation and biogenic release of mercury.

The relative emphasis on reductions from transportation and industry, in Path 3, will likely lead to lower $NO_X$ and VOC emissions implying less ground level ozone formation. This indicates improved urban health benefits and decreased ozone impacts on agricultural productivity.

From the point of view of complementing the quantitative EHI analysis, the qualitative assessment lead to the following key points:

- The possible extensive penetration of biomass combustion, as expected in the MARKAL results, could potentially lead to urban particulate matter problems. Policy-makers need to consider standards for alternative fuel use in order to ensure that there is a GHG benefit to alternative fuels without increasing harmful particulate emissions.

- Canada's use of Kyoto flexibility mechanisms, as implied in Kyoto Loose and Tight Scenarios, will likely mean fewer beneficial EHI impacts in Canada.

- Long-range transport of heavy metals (mercury, lead, cadmium), into the Arctic could decrease as a result of less combustion of fossil fuels. Although not all heavy metal deposition is from Canadian sources, decreased Canadian reliance on fossil fuels for combustion would lead to some decline in heavy metal deposition in the Arctic.

## 7.5 Future Work

This is the first time that such a detailed assessment of environmental and health impacts has been undertaken in Canada. It clearly represents both a milestone and starting point. At the August CCEAF workshop, stakeholders voiced their concerns that insufficient resources and time have been allocated to this area. These comments clearly support the need for additional research and development into the environmental and health impacts associated with changes in air pollution. In particular:

***Historical CAC Data.*** Improvements can be made in both coverage and accuracy of the base data. Information is currently collected on a voluntary basis, consideration should be given to mandatory provision of this information

***CAC Projections.*** Technological change is an exogenous input into the CAC model. Greater emphasis should be placed on trying to estimate the potential for technological change.

***Air Quality Models.*** The weakest link in the analytical framework is the methodology used to estimate air quality changes. A library of model results was examined and used to estimate the changes in air quality associated with the GHG actions. It was not possible to run these detailed models because of time and resource constraints. In the future, consideration should be given to creating simplified versions of these air quality models to facilitate their use in policy analysis.

***Air Quality Valuation Model.*** The most significant improvement that could be made to the AQVM is to expand the number of environmental impacts which the model can examine.

***Integrated Policy Analysis.*** Concerns about potential double counting and the implications of climate change measures on air quality highlights the usefulness of more integrated analysis of both climate change and clean air policy options.

# Chapter 8
# Conclusions

In April 1998, federal, provincial and territorial Ministers of Energy and Environment launched the National Climate Change Process (NCCP), a wide-ranging inquiry into the feasibility and implications of Canada's Kyoto Protocol commitment.

The Analysis and Modelling Group (AMG) is one of a number of Issue Tables and working groups that were formed to address the various dimensions of the challenge posed by the Kyoto Protocol. The AMG's principal task was to undertake the so-called "roll up" of the options, associated analysis and other insights developed by the Issue Tables. The AMG conducted its analysis in an open, transparent, step-by-step process to ensure broad stakeholder review of the results.

The analytic approach to the roll up considered, among other important components, a series of complex policy packages, designed by the National Air Issues Coordinating Committee, and referred to as "paths" and framework assumptions.

The roll up results provided in this report should not be viewed as a plan of action. The results would be best described as a "range finding" exercise. They provide policymakers with a directional guidance on some fundamental issues related to the achievement of the Kyoto Protocol.

It is important to note that implementing the Kyoto agreement in Canada would likely be done through a "package" of measures. Some elements of that package would be aimed at reducing emissions. Other elements would be aimed at reducing the uneven impact of emissions-reductions measures across sectors and regions. The analysis presented here considers chiefly measures to reduce emissions; the overall impact of a complete policy "package" has yet to be analysed.

To evaluate the various path-scenario combinations systematically, the AMG linked together a number of specialized models available from the private sector or within government into an overall modelling structure. The basic approach was to use micro models to aggregate the direct impacts of the various path-scenario combinations and then to use these results as the inputs to both macro and environmental and health models. The macro models incorporate all the linkages and address trade, competitiveness and fiscal and monetary policy issues.

While the quantitative results from the models (CIMS, MARKAL, TIM and CaSGEM) differ, the qualitative conclusions apply to all four sets of results and the key messages are generally consistent across the different analytical frameworks

**Main Learnings**

The AMG was asked to address the question "what are the economic and environmental consequences, for Canada, of achieving the Kyoto target?" While not a definitive answer, the analysis provides some important insights into this question. These Main Learnings are as follows:

- At the national level, attainment of the target results in sustained, long-term, negative economic impacts. In the long run, the reduction in gross domestic product (GDP), relative to the business-as-usual case, ranges from 0 to 3 percent depending on the path-scenario combination.

  It is important to provide perspective on these estimates. For example, a reduction in GDP of 3 percent in 2010 means that, over the decade, the economy will grow by about 26 percent instead of 30 percent as projected in the reference case. This is equivalent to the loss of roughly one year's growth, or, viewed in absolute terms, in 2010, the loss in annual economic output of approximately $40 billion (or $1100 per capita).

- The overall GDP impacts vary over time. Initially, economic activity increases modestly in response to increased investment in emissions reducing technologies. Thereafter, however, higher production costs, deterioration in competitiveness and lower incomes combine to reduce GDP below business-as-usual levels. The analysis also suggests that the adjustment process may not be completed until after 2010.

- The provincial GDP impacts are generally within 1.5 percentage points of the national average impact. The relative ranking of each province typically varies by Scenario. In the Canada Acts Alone Scenario, Newfoundland, Prince Edward Island, Quebec and British Columbia are less affected, relative to the national average, whereas Ontario and Saskatchewan are more negatively affected. The impact on Alberta is close to the national average. The results for Nova Scotia, New Brunswick and Manitoba vary between the studies.

  In the International Scenarios, Newfoundland, Prince Edward Island and British Columbia remain in the "less affected" category and are joined by Manitoba. Saskatchewan remains in the "more affected" category, which now includes Alberta and New Brunswick. By contrast, Ontario's GDP impact is smaller than under Canada Acts Alone, becoming close to the national average. Quebec's position is largely unchanged across the Scenarios, although one study indicates that its GDP would be consistently higher than in the business-as-usual case. For Nova Scotia, one study indicates impacts that are greater than the national average, while the other suggests the opposite.

- The findings suggest the potential for substantial variability in GDP impacts across industries. Unfortunately, it is not possible to identify unambiguously the sectors that would be negatively or positively affected, since industry variation is not uniform across models and Paths.

- The greatest potential for emissions reduction appears to reside in the electricity generation sector – between 40 and 60 percent of the reduction. Two actions – capture and storage of $CO_2$ in aquifers in Alberta and Saskatchewan and enhanced interprovincial hydro-electricity trade, in particular from Manitoba and Quebec to Ontario – account for the bulk of this potential.

- Policies to reduce greenhouse gases will both reduce energy consumption and encourage switching from more to less carbon-intensive fuels. All of the analysis suggests some declines, relative to business-as-usual, in oil product and coal consumption. Interestingly, natural gas consumption also declines largely because the capture and storage of $CO_2$ and enhanced hydro electricity trade reduce the attractiveness of gas-fired electricity generation. Were these options not fully available, natural gas demand would increase.

- The industrial sector, particularly the oil and gas industry, and the transportation sector face significant challenges in achieving large emissions reduction.

- Were Canada to act alone in achieving its Kyoto target, the marginal cost of abatement in 2010 could range from $40 to $120 per tonne of $CO_2$. Were these costs to be incorporated in energy prices, gasoline prices would increase by 13 to 35 percent, natural gas prices (for residential use) by 30 to 75 percent, and average coal prices by 300 to 800 percent.

- The outcome of the negotiations concerning forestry and agriculture sinks is an important factor in the cost to Canada of achieving the Kyoto target. According to one estimate, a pessimistic assumption concerning this outcome, the effect of which widens the gap by about 20 percent, results in an increase in the marginal cost of abatement from $57 to $100 per tonne of $CO_2$. This result also suggests that the Canadian emissions abatement cost curve, constructed from the analysis and insights of the Issue Tables, becomes increasingly steep as the target is approached.

- The analysis supports the contention that competitiveness – measured by changes in productivity - will be adversely affected by the achievement of the Kyoto target. The impact is somewhat attenuated if Canada's trading partners are also committed to attaining their targets and Canada has access to flexibility mechanisms. However, under this Scenario, Canada's trading partners will also face reductions in economic activity, with adverse consequences for Canadian export performance. At the national level, the net impact of these two forces is to reduce the GDP loss by about 0.5 percentage points.

- The analysis strongly supports the conclusion that moving from individual sector targets to an economy-wide target will achieve the desired objective at significantly lower cost. Moreover, sector specific emissions targets do not distribute the economic burden evenly across sectors.

- Based on preliminary modelling of some characteristics of emissions permit trading, this instrument can be viewed as cost-effective mechanism for achieving emissions reductions in the industrial and electricity sectors. However, the analysis to date underscores the importance of the design of such an instrument, in particular the permit allocation mechanism. Each allocation method carries with it different distributive effects on the economy.

- Measures and actions to achieve the Kyoto target will also result in the reduction of sulphates, ozone and other atmospheric pollutants. These reductions will lead to ancillary benefits from improved air quality and improvements in human health. These co-benefits are immediate, local and reasonably certain and can make a significant contribution to the attainment of clean air goals as enunciated in the Canada-Wide Standards Initiative.

- The analysis indicates that the societal benefits of these improvements in human health are in the range of $300 to $500 million per year. Most of this value derives from reduced risk of mortality. These societal benefits represent the value that Canadians place on these co-benefits, as determined by estimates of their willingness-to-pay to achieve these avoided impacts. They are not comparable to the GDP impacts noted above. These estimates do not cover the full spectrum of pollutants and do not include sulphate reductions in western Canada.

- Although increased reliance on the international mechanisms to reduce greenhouse gases lowers the cost of achieving the Kyoto target for Canada, it also reduces the domestic clean air benefits. The analysis suggests that this reduction in societal benefits is on the order of $200 million per year.

The AMG recognizes that there are many uncertainties regarding projections of this nature, which have been noted earlier. In order to test the robustness of the "range" various sensitivity analyses were conducted. The three more important areas are forestry and agriculture sinks, $CO_2$ capture and storage and inter-provincial electricity trade. Of these three, the most dramatic effect is given by the forestry and agricultural sinks. This is because of the assumption that 16 Mt of $CO_2$ could be sequestered at no cost. This would also be equivalent to increasing the "gap" by 16 Mt. This particular sensitivity underlines the importance of the assumptions used in the analysis and the significance of the reference case.

Analysis is most useful when it succeeds in resolving issues. Even when it fails to do so, however, it is still valuable if it points to gaps in our understanding. The AMG has identified the following areas where future analysis should yield useful insights:

- Much greater effort is required to measure welfare benefits and costs. Attention should focus on the welfare implications of transportation and "life style" change initiatives.

- Some progress has been made in identifying competitiveness impacts, but a much more sophisticated understanding of this issue is required. In particular, there is a need to evaluate the importance of the so-called "leakage" issue: the possibility that some industries will lose market opportunities and investment to countries that have lower, or no costs, to industry under the Kyoto Protocol.

- Much more analysis of the implications of the various approaches to the design of an emissions trading system is required. The suggested priority area is the allocation mechanism.

- More province-specific analysis is needed. The current macro-models develop provincial impact estimates by distributing the national results according to the industrial mix in each province. This approach is reasonable if the characteristics of an industry are similar across provinces, but questionable if this is not the case. More refinement of this assumption is required.

- The assumptions concerning how the United States might address the Kyoto Protocol requirements are too simplistic to comprehend the complex ways in which that country's climate change policies could affect both Canada's economy and its policy options.

- The analysis, to date, has not comprehensively modelled how Canada's other trading partners might respond to their commitments under the Kyoto Protocol.

- Despite considerable progress, the quantitative co-benefits analysis requires further development.

In addition to this report, the AMG has generated a large number of studies focussing on the microeconomic, macroeconomic and environmental and health phases of the roll up analysis. These, in turn, are supported by numerous reports, prepared by CCEAF and others on specific topics. The AMG believes that this research will form a valuable base for further climate change analysis.

# Annex 1

The Conference Board of Canada

CANADIAN ENERGY RESEARCH INSTITUTE

## Climate Change Economic Analysis Forum

## MOVING FORWARD: Stakeholder Perspectives

**August 31, 2000**

# Executive Summary

The CCEAF *Moving Forward: Stakeholder Perspectives* report is a collection of viewpoints from the various parties involved in the National Climate Change Process (NCCP). It was prepared separately from the AMG report. The main objectives of the "Moving Forward" project are to characterize the analytical dimensions of "unfinished business" and future research. In particular, the project aims to identify and describe:

Analysis that would have been useful to do, had sufficient time and resources been available;

- Data gaps discovered through the NCCP;
- Sensitivity analyses that would contribute valuable future insights to existing work; and
- Process improvements for future consideration.

Based on the reports from CCEAF workshops from 1998 to 2000, and structured interviews with stakeholders and modellers, key messages for "moving forward" have been grouped around the following six themes and needs.

1. ***Framing the Analysis.* There is a need to establish clear objectives, questions and decision contexts to guide future analysis.**

   Analysis and modelling choices need to be driven by the questions and decisions they are intended to inform. Although the overall goal of the exercise - to examine the costs, benefits and impacts on Canada of implementing the Kyoto target - was clear, objectives became fuzzier at more detailed levels. Issue Tables were sometimes unclear about their goals, and modellers were sometimes unclear about what they were to deliver. Given the involvement of such a large and diverse group of stakeholders, strong co-ordination was required. For example, if the Tables had known the composition of the Paths and Scenarios before they commenced their work, their proposed options might have been different.

   The use of decision structuring, and other techniques of decision analysis, will enable future analysis to be more sharply defined. This in turn will reap benefits in terms of matching model strengths to questions, and sequencing inputs required from various sources.

2. ***Institutional Capacity-Building*. There is a need to ensure that Canada has a long-term capability to address future analytical challenges.**

Given that climate change mitigation will be a long-term process with many uncertainties along the way, and that Canada's actions to mitigate will similarly be a long-term affair, there is a concern about the institutional capacity to address the issue over the short and longer term. Repeated comments were made about the time constraint (two years) for an undertaking as ambitious as the current NCCP. Modellers need opportunities, outside the constraints of severe deadlines, to understand data inputs and the structures of other models. Some individual modelling frameworks require further development, while an integrated modelling capability is required to treat with consistency the various analytical components. It was recognized that the process developed much "human capital" through networked relationships, and that preserving this capital is essential in building a long-term analytical capability.

3. ***Iterative Processes*. There is a need to engage stakeholders and modellers in parallel, iterative processes of mutual understanding**.

If analysis and modelling are viewed as means to the end of enhanced understanding, then stakeholders and modellers need a "back and forth" process. An early choice of modelling frameworks, with preliminary runs provided by modellers, would have generated considerable learning for stakeholders and modellers. Modellers working together with Issue Tables would have provided natural, continuous "bilaterals" for resolving issues such as technology representation, data adequacies, and sectoral aggregation. A peer review process for the Tables may have improved the quality of the options proposed for the roll-up.

4. ***Data Adequacy*. There is a need to ensure that a long-term, co-ordinated process is established to fill data gaps, guided by the value of information in decision contexts.**

The process provided an opportunity to identify, and in some cases address: data issues, missing or uncertain data, or data in “wrong” formats. An important next step is addressing the data gaps identified by the analysis and modelling process to date. However, the acquisition and maintenance of data is costly; it must be guided by the value of the information for expected future decisions. Overall, there is a need to improve the reliability level around the inputs used at various stages of analysis.

5. ***Coping With Uncertainty.* There is a need for analysis that supports the development of strategies that will be robust against a range of uncertain outcomes.**

Uncertainties pervade the climate change issue. Leaving aside the "science" uncertainties, there are many arising from the fields of technology, economics, policy and international agreements. Difficulties are compounded when uncertainties must be carried forward from one analytical framework to another. Sensitivity analyses and scenario methods are two of the major tools for dealing with uncertainty that have been explored in this process. Their use could be extended, and other tools for dealing with uncertainty might also be explored.

*6.* ***Communicating Results.*** **There is a need to ensure that communication of these results clearly portrays the level of uncertainties and notes the extent to which the results are preliminary**.

Some important issues need to be resolved in communicating results to a wider group. There is a need to determine what should be communicated and what is ready to be communicated. Distinguishing between data and information is extremely important when communicating results. Presentation of summary results will have to be done in a manner that clearly identifies the level of uncertainties, and correctly portrays the preliminary nature of these results. It was suggested that Workshops, Press Releases and other means of professionally communicating the results should be used.

**Post-JMM**

In addition to addressing the NCCP process to date, it is important to look beyond the October JMM. The analysis completed to date represents an important first step. Many gaps need to be filled. Future analysis and modelling should focus far less on broad impacts on the national economy, and much more on detailed study of individual promising policy measures capable of taking Canada to its Kyoto target and beyond into commitment periods post-2012. It is especially important to begin immediately detailed design work for a major economic instrument such as domestic emissions trading.

# Bibliography

**It is anticipated that these documents will be available on the NCCP website (http://www.nccp.ca).**


Canada. Department of Finance, Economic Studies and Policy Analysis Division. 2000. *A Computable General Equilibrium Analysis of Greenhouse Gas Reduction Paths and Scenarios.*

Canada. National Climate Change Process. Analysis and Modelling Group. 2000. "Atlantic Disaggregation Working Documents."

Canada. National Climate Change Process. The Analysis and Modelling Group. 1999. *Canada's Emissions Outlook: An Update.*

Canada. National Climate Change Process. Agriculture and Agri-Food Climate Change Table. 2000. *Reducing Greenhouse Gas Emissions from Canadian Agriculture.*

Canada. National Climate Change Process. Buildings Issue Table. 2000. *Commercial/Institutional Sector Options Report*.

Canada. National Climate Change Process. Buildings Issue Table. 1999. *Residential Sector Options Report*.

Canada. National Climate Change Process. Credit for Early Action Table. 1999. *Report of the Credit for Early Action Table*.

Canada. National Climate Change Process. Electricity Industry Issues Table. 1999. *Options Paper*.

Canada. National Climate Change Process. Enhanced Voluntary Action Issue Table. 1999. *Options Report*.

Canada. National Climate Change Process. Environmental and Health Impacts Subgroup of the Analysis and Modelling Group. 2000. *The Environmental and Health Co-benefits of Actions to Mitigate Climate Change*.

Canada. National Climate Change Process. Forestry Products Table. 1999. *Options for the Forest Sector to Contribute to Canada's National Implementation Strategy for the Kyoto Protocol*.

Canada. National Climate Change Process. Industry Table. 2000. *Overview Report*.

Canada. National Climate Change Process. Industry Table. 1999. *Petroleum Product Refining Plant-Level Analysis of Costs and Competitiveness Implications of Greenhouse Gas Emission Reductions*.

Canada. National Climate Change Process. Industry Table. 1999. *Options and Analysis Paper for the Industrial Chemicals and Synthetic Resins Sector*.

Canada. National Climate Change Process. Industry Table. 1999. *Aluminum Industry Options Paper*.

Canada. National Climate Change Process. Industry Table. 1999. *Cement and Concrete Options Paper*.

Canada. National Climate Change Process. Industry Table. 1999. *Industrial Minerals Options Paper*.

Canada. National Climate Change Process. Industry Table. 2000. *Iron & Steel Plant Level Analysis and Options Paper*.

Canada. National Climate Change Process. Industry Table. 1999. *Semi-Fabricating Metals Options* Paper.

Canada. National Climate Change Process. Industry Table. 1999. *Upstream Oil and Gas Industry Options Paper*.

Canada. National Climate Change Process. Industry Table. 1999. *Other Manufacturing: Technical Opportunities for Reducing Greenhouse Gas Emissions*. Draft.

Canada. National Climate Change Process. Industry Table. 2000. *Greenhouse Gas Options, Policy and Measures for the Canadian Transportation Equipment Manufacturing Industry*.

Canada. National Climate Change Process. Kyoto Mechanisms Table. 1999. *Options Paper*.

Canada. National Climate Change Process. Municipalities Table. 1999. *Munipalities Table Options Paper*.

Canada. National Climate Change Process. Sinks Table. 1999. *Land-Use, Land-Use Change and Forestry in Canada and the Kyoto* Protocol.

Canada. National Climate Change Process. Technology Table. 1999. *Enhancing Technology Innovation for Mitigating Greenhouse Gas Emissions*.

Canada. National Climate Change Process. Tradeable Permits Working Group. 2000. *Using Tradeable Emissions Permits to Help Achieve Domestic Greenhouse Gas Objectives*.

Canada. National Climate Change Process. Transportation Table. 1999. *Transportation and Climate Change: Options for Action*.

Climate Change Economic Analysis Forum. 1999. "Final Project Report: Kyoto Mechanisms." Report prepared for the AMG.

Climate Change Economic Analysis Forum. 2000. *Moving Forward: Stakeholder Perspectives*. Report prepared for the AMG.

Energy Information Administration. U.S. Department of Energy. 1998. *The Impacts of the Kyoto Protocol on U.S. Energy Markets.*

Energy Research Group/ MK Jaccard and Associates. 2000. *Integration of GHG Emission Reduction Options Using CIMS.*

Energy Research Group/ MK Jaccard and Associates. 2000. *Modelling of Energy / Technology Actions and Measures for Reducing Greenhouse Gas Emissions in the Industrial Sector (The Industry Challenge)*. Prepared for the Analysis and Modelling Group.

HALOA, Inc. 2000. *Integrated Analysis of Options for GHG Reduction with MARKAL*.

Hirshhorn, Ronald. 1999. *Characteristics of the Canadian Economy and the Implications for Climate Change*. Report prepared for Industry Canada.

Informetrica, Ltd. 2000. *Macroeconomic Impacts of GHG Reduction Options: National and Provincial Effects.*

Plourde, André. 1999. *Competitiveness and the National Implementation Strategy: Elements of a Framework Analysis*. Report prepared for the Analysis and Modelling Group.