Assessing the Cost of GHG Abatement Policies: A Methodology and a Case Study

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ABSTRACT

Two different modelling approaches provide the bulk of the costs figures associated with greenhouse gas abatement policies. "Bottom up" models, rich on detail, are said to underestimate abatement costs because they poorly reflect economic feedbacks including the behavioural response of consumers to changes in fuel price or increased costs. "Top down" models typically use production or consumption functions or some other aggregate relationship between the inputs and outputs of an economy that reflect historic consumer preferences. But often, they miss important parameters regarding the role of new technologies in an altered future world. Researchers have recognized the issue for some time but have done little to address the discrepancy between these modelling regimes. Given that both "technologies" and "consumer preferences" matter, we propose here a modelling tool that assimilates both "top down" and "bottom up" approaches; the Canadian Integrated Modeling System (CIMS) is both technologically explicit and seeks to be behaviourally realistic.

Like other countries, the Canadian government is probing the cost of meeting a prescribed target to reduce greenhouse gas (GHG) emissions below 1990 levels. In 1998, it mandated fifteen consultative Issue Tables, composed of experts, interest groups and government officials, to produce an inventory of actions in all sectors to contribute to the national objective of 6% below 1990 levels of emissions. These many inputs needed to be integrated ("rolled up") to assess their interdependence and potential for interaction. As expected, the cost of meeting the target engendered great discussion and was of primary concern to the stakeholders. We focus here on the methodological issues of designing and using CIMS in its recent national application to this case study. The specific results are of less interest than what lessons might be learned from this methodology, a modelling approach all too rare in our view.

We describe model structure and function, how it is applied to the various sectors, review data issues, and discuss how behavioural parameters are set in the model. We touch briefly on the results to assess what kinds of lessons can be learned and how this modeling approach can compliment the slate of tools that governments might use to assess their GHG abatement options. Finally, we comment on the strengths and weaknesses of our approach relative to the alternatives.

Approaches to Modelling

In the wake of the Kyoto Protocol, decision makers in many countries have estimated or re-evaluated the costs they would see were measures to stimulate greenhouse gas (GHG) abatement enacted. Two modeling approaches dominate the analyses.

Bottom Up and Top Down Approach

If one considers emissions reduction based primarily on technologies available to accomplish the task, the model used is considered to be "bottom up". Based simply on the apparent financial costs of technologies that, if widely deployed, lead to dramatic reductions in GHG emissions, reaching reduction targets appears attainable at little cost. This approach, generally characterized by great detail on technologies, is simplistic in its representation of firm and household decision making: technologies that provide similar services (heating, lighting, mobility) are indistinguishable in terms of non-financial preferences and perceived risks. Unless exogenously modified, bottom up models show minimal or no representation of standard economic feedbacks, even if technology and cost changes would suggest adjustments in sector structural and total output.

Conventional economic analysis focuses on aggregate relationships between inputs and outputs in the economy, usually in some "feedback loop" equilibrium. Application of such aggregate, "top down" methods means that energy forms and associated GHG emissions are inputs whose cost changes are correlated with changes in their use relative to other inputs (i.e., elasticities of substitution), yielding a production function for firms and a consumption function for households. Ideally, the relationships are statistically supported by market data that represent revealed preferences on behalf of the consumer. But, while these relationships may hold for the short term, we question their usefulness when the mix of available technologies in the future may differ fundamentally from that of the past. Furthermore, with a focal shift to GHG reduction, policies like regulations, grants and tax concessions may be concentrated on individual technologies that can alter these historic relationships.

From this, we can see the limitations of both approaches. A bottom up focus on technologies will not show all the costs of GHG abatement. For example, consumers have a preference, with associated value, for using a car over public transit, even though they could be considered to provide the same service for certain mobility requirements. If one ignores this value when estimating the costs of GHG reductions, one underestimates the social welfare cost of GHG reduction.[1] On the other hand, to ignore the potential impacts of novel, future technologies on emissions reduction could significantly overestimate the ultimate costs of GHG abatement. With increased research on processes and technologies that could reduce GHG emissions, relative costs of alternative processes and specific technologies are changing rapidly, and thus affect the elasticities of substitution described above.

A Hybrid Approach

While GHG researchers have acknowledged the limitations of these approaches for some time, we have found few methodological developments that address the issue. As we will show, it does require significant resources to develop and maintain a model that overcomes these respective deficiencies. One would need to track, in detail, technological change as some how driven by estimates of consumer preferences. Thus, one would have to meld in some way the models' divergent views of "the consumer" and "available technologies". For example, an economist's model (usually top down) sees the consumer as

[1] Known as consumers' surplus, consumers would be willing to pay a premium to own and operate a car in addition to the costs they actually incur.

the prime mover and, in simulation, seeks to attain some level of equilibrium. On the other hand, the technologist (and perhaps even the environmentalist) uses models that typically assume that technological potential can change the economy's relationship between inputs and outputs (i.e., that consumers will naturally choose more efficient processes and technologies, and so bring about GHG reductions).

If we acknowledge the fundamental legitimacy of both approaches, we can then state that both "technologies matter" and "preferences matter". With this concept in mind, we have developed a policy tool, the methodology and an application of which we reported in an earlier paper (Jaccard, Nyboer & Bailie 2001). Our model, the Canadian Integrated Modeling System (CIMS), is both technologically explicit and seeks to realistically reflect consumer behaviour. This difficult task requires that we collect data on the financial costs and operating characteristics of technologies and couch them in some matrix of what consumers think about them, now and in the future. There are key GHG-reducing technologies for which no market data exists because the technologies are new. So, we piece together information about what consumer preferences may be when faced with the new circumstances of the future in the following way.

First, market information on how consumers respond to certain technology attributes exists, attributes that are shared by past and future technologies alike ("revealed preferences"). For example, we have a long market history of the trade-offs consumers make between up-front capital costs and operating cost savings (their time preference or discount rate). We also have evidence of how consumers behave when faced with the uncertainties of new products; that is, their attitudes and decision-making responses to risk. Research on market behaviour has tracked, to some extent, the role key characteristics of a technology may play in consumer choice; for example, the value people place on greater horsepower in a private vehicle.

Second, marketing agencies often conduct surveys that ask consumers to state their preferences between various technologies in terms of a monetary premium or discount ("stated preferences"). These responses are subject to large uncertainties (i.e., what they say and what they do may be quite different), but they at least provide some basis for what is already speculative in model simulations.

CIMS uses this kind of information in simulating choices of firms and households as they purchase or retrofit new technologies. Thus, CIMS simulates the mix of technologies likely to emerge under new conditions and new policies based on information about technologies and the preferences of decision makers. We begin with "bottom-up", explicit technological information and then include the behavioural dimension into an algorithm that simulates decision making when acquiring technologies. The model iteratively estimates the broader equilibrium effects of concern to economists by integrating energy supply and demand feedbacks as well as feedbacks related to total output and structural change. We explain this further in the methodology section.

Application of the Model

In 1998, the Canadian government established the National Climate Change Implementation Process. Its secretariat set up fifteen Issue Tables focused on different sectors or issues, each comprised of experts, interest groups and government officials. Each Table was asked to produce a set of actions that would allow Canada to meet its national objective, a target of 6% below 1990 levels of emissions by 2008 - 2012. By mid-1999, the

Analysis and Modelling Group (AMG)[2] choose two modeling teams to integrate Table outputs under various implementation policies and assumptions focused primarily on permit schemes and a positive international response to the Kyoto protocol. Two different types of models were chosen to allow comparison between a simulation model (our CIMS model) and an optimization model (MARKAL, used world wide in various analyses). While these models have a broader macro-economic equilibrium capability (i.e., changes in the demand for final and intermediate products occur as technologies and costs change), these options were turned off to allow the direct results to act as inputs to two macro-economic models: CASGEM, a general equilibrium model of the Canadian Department of Finance, and TIMS, a model developed and used by Informetrica Ltd., a consulting firm in Ottawa. We report no part of this latter analysis at this time.

Here we focus on the methodological issues of designing and using CIMS in this recent national application as a case study. So, while we present some results, they are of less interest than what lessons might be learned from this methodology, an approach all too rare in our view. We describe how we applied the model and then assess what kinds of lessons can be learned from it. Finally, we show how this modelling approach can compliment the tools governments might use to assess GHG abatement options.

The next section describes the CIMS methodology in greater detail. Then, we discuss data issues, how behavioural parameters are set in the model and the key results. Finally, we return to the methodology debate to comment on the strengths and weaknesses of our approach relative to the alternatives.

Method

Since 1986, the Energy and Materials Research Group (EMRG) at the School of Resource and Environmental Management at Simon Fraser University has been developing CIMS for regional and national use; in principle, one can apply it to any region or country.[3] The model currently has data and parameter values for seven regions in Canada. It is "micro-economic" in that it simulates in detail the equipment and building decisions of firms and households in response to changes in information, costs and availability of alternatives.[4] In a more basic way, it also models shifts in demand for intermediate and final products of industry and, thus, consequent changes in aggregate economic parameters like government budget, external trade patterns, interest rates, etc.

As we've said, CIMS is like most bottom up models in that it has significant levels of technologic details. But it makes choices endogenously between technologies by simulating the behaviour of firms and households, not as cost minimisers, as optimization models tend to do, but rather as consumers are likely to behave. Rather than using a "normative" approach, CIMS' matrix of data on actual behaviour generates a more "predictive" result; they tell decision-makers what is likely to happen if more than financial costs mattered. In other words, CIMS, acts like a top-down model in the simulation of firm and household preferences in its technology choice algorithm.

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[2] The AMG acted as the coordinators of the project and were assigned the task of integrating all the various actions proposed by the Tables.

[3] The energy demand component of the model, called ISTUM, was originally developed as an energy model by the U.S. Department of Energy in the early 1980s.

[4] It also includes simulation of urban infrastructure and land use zoning decisions by governments.

Simulation algorithms. In spite of the model's apparent complexity, its simulation algorithm is quite simple and can be described in a few basic steps.

1. CIMS lists types and quantities of technologies in terms of the quantity of intermediate products and final products / services they provide (person kilometres, homes, floor space, tonnes of product, etc.). Economic forecasts drive the model simulation. We use regression analysis or judgment by industry experts to convert monetary estimates of sectoral economic growth to the physical products and services needed by CIMS, a critical link to determining the output required of the set of technologies. In CIMS, any change in the cost of production of a commodity or service will alter the demand in the macro feedback loops through the use of elasticities. Estimating these elasticities is a problem common to that of any econometric model.[5] Presently, we ignore other macro-economic balances, like employment levels, total investment, cost of capital, government budget and trade. In this case study, model outputs were directly delivered to a macro-economic model that included these dimensions.
2. In each future period, CIMS retires a portion of the initial-year's stock of technologies. Retirement is time-dependent, but options exist, through the "retrofit function" to lengthen or shorten the life of any technology based on economic conditions, obsolescence or regulation.[6] When it knows the level of base stocks retained, CIMS checks to see if retrofit options are available and runs a retrofit algorithm. When this is completed, CIMS determines if the remaining stocks will be sufficient to provide for expected demand and then, if necessary, runs a competition algorithm to fulfill that demand with new technologies.
3. The competition algorithm simulates technology choice so that the outcome approximates what would happen in the real world. Capital and operating cost is combined using a discount rate, obtained from literature, into a life-cycle-cost. CIMS adjusts this cost into an "expected" life-cycle-cost to reflect information on risks and risk perceptions, and revealed or stated consumer preferences. CIMS may also apply other constraints of a physical, technical or regulatory nature. Finally, CIMS probabilistically determines the relative market shares of the competing technologies as found in the consumer choice research literature. That is, competing technologies with similar costs will win similar market shares.[7] These shares adjust in a non-linear, logistic fashion as the life-cycle-costs move apart.
4. For each time period, CIMS iterates between demand and supply sectors, including macro-economic adjustments if these feedback loops are activated, until energy prices and energy demand have stabilized at equilibrium.[8] With details on technology costs and energy use known, one can obtain an estimate of the likely achievement and cost of a policy or package of policies compared to the base case or business as usual.

[5] While CIMS' industrial sector has great technological detail, its level of sectoral disaggregation is much less than for a typical macro-economic model because, while a few, energy-intensive sectors are represented in great detail, the rest of the economy, tends to be lumped into a single, aggregate sector.

[6] The evidence suggests that the pace of technology replacement depends on the economic cycle, but over a longer term, as simulated by CIMS, age is a fairly reliable and simple predictor.

[7] In contrast with an optimization, bottom-up model where a technology that is only slightly cheaper than another will capture the entire market if it is not constrained in some way.

[8] This convergence procedure, modelled after NEMS of the US government, stops the iteration once changes in energy demand and energy prices fall below a threshold value.

Figure 1 shows the energy supply, energy demand and macro-economic components of CIMS. A central data system keeps track of information flows between the three main components, enabling the model to converge to a solution in each simulation period (usually a five year interval). Because rates of change are incremental and there are no highly elastic feedback loops, the model is stable, achieving a unique equilibrium outcome.

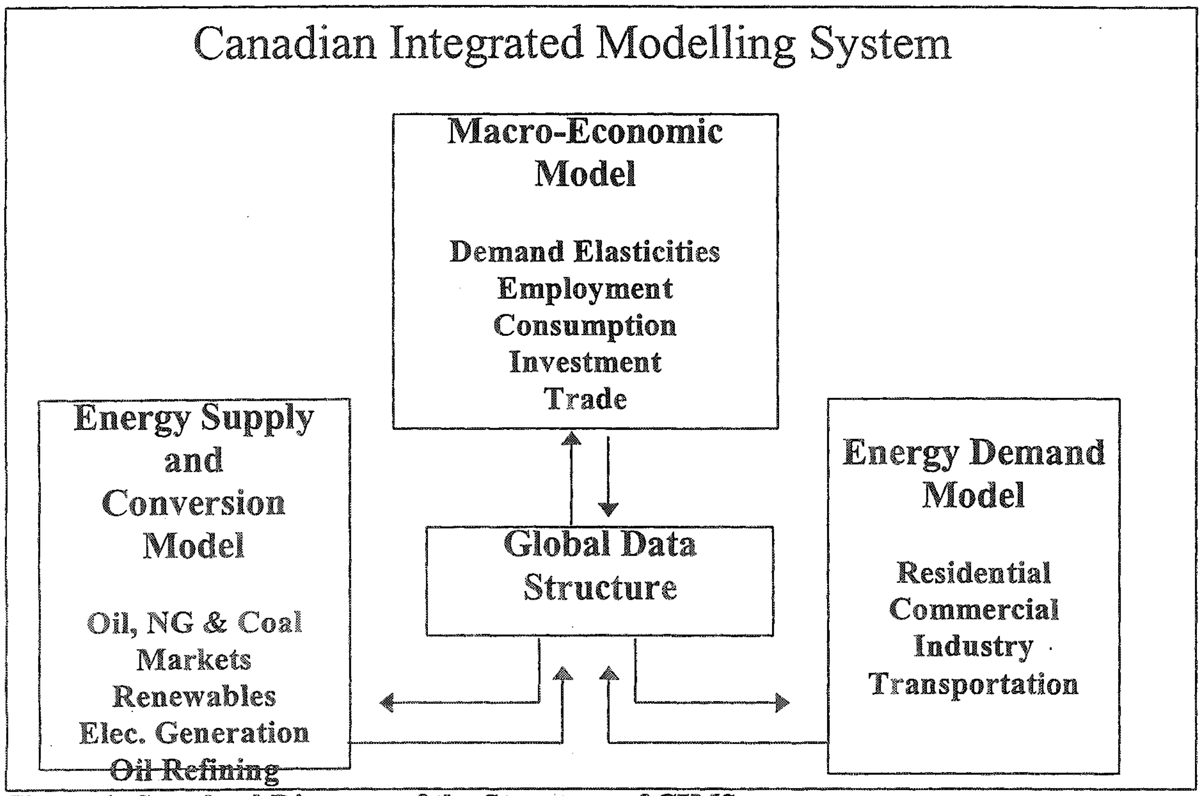

Figure 1. Standard Diagram of the Structure of CIMS

Application to Canada. The application of CIMS to this Canadian project presented some particular methodological requirements and challenges.

1. Disable the macro-economic feedback loop. While this allowed participants and Issue Table members to understand the separate stages of the modelling exercise, it created an extra challenge in achieving a general equilibrium in the separate micro and macro models.
2. Selection of the models after the Issue Tables had already launched their research efforts caused great challenges because a significant amount of Issue Table data was not at the same resolution as the models, especially in terms of the definition of costs.

Technologically explicit modelling at a national level requires considerable resources and may explain why hybrid modelling has been used only minimally. The CIMS team involved 10 people, many of them working almost full-time, over a 5 month period. NEMS, a model use by the US government, also operates at this level of technological and behavioural detail and has as many as 40 people working with the model.

Methodologically, how does one define costs in terms of GHG abatement? To be behaviourally realistic, CIMS' decision algorithm must include all costs perceived by firms and households, including taxes and even risk premiums (we call these "perceived private costs"). Any GHG tax or permit costs to reach a Kyoto commitment would need to be high enough to overcome these costs so that consumers take the action proposed. These are not equivalent to "social costs" because:

- the consumer sees taxes when making choices but such transfers are netted out from social costs;
- the evidence suggests that some consumers are either overly suspicious of the cost risks, or unaware of expected cost differences, i.e., they focus on up-front cost or other decision factors (security, convenience, familiarity, etc.) to their own detriment. In other words, they must be "bribed" to make the right choice on technologies.[9]
- social costs include changes in consumers' surplus. Rarely are technologies that provide the same service seen as identical substitutes by the consumer. For example, what premium would consumers pay for the perceived values of cars over transit (privacy, flexibility, transporting ability, status, etc.)? Consumers' surplus may be difficult to estimate, but policy-makers ignore it at their peril. While we produced no social welfare account in this study, CIMS can estimate such an account.

While perceived private costs and social welfare accounts help policy-makers determine how effective policies may be, they will also want to know what happens to the national account of the economy, GDP. Because we turned off the macro-economic equilibrium component of CIMS, we estimated the "expected resource financial costs" that are the direct result of the GHG abatement actions induced by various policies (see results below). These cost estimates provided the raw material for simulations by the macro-economic models used in this exercise.

Finally, governments have great interest in the fiscal impact of policies to abate GHG emissions. Unfortunately, few Issue Tables provided the necessary detail to include this in any more than a crude manner in this study. However, CIMS' accounting structure can track government fiscal impacts from tax revenues, foregone taxes, subsidies and changes in value-added taxes because of changes in final product output.

Input Data And Model Parameters

The AMG directed the modellers to use the information from the Issue Tables under five different analytical paths. To simulate a situation where permits could be bought and sold internationally, we applied two permit price scenarios to two of the paths (see table 1). All analytical paths and variants were measured in terms of change from a business-as-usual (BAU) forecast generated for the AMG and released as *Canada's Emissions Outlook – An*

[9] Here we see contention between two world-views. Some economists argue that analysts should not presume to discover any profitable investment opportunities for consumers, that if one does so, one has overlooked critical decision factors or the unrecognized wisdom of consumers. Technology-focused analysts argue that the marketplace is inefficient and that policy makers would benefit all society if they could move consumers toward certain types of investments, notably those for energy efficiency and fuel switching. This debate will not be resolved from empirical analysis; it is a question of world-views. One can do sensitivity analyses to test the importance of these differing world-views to the estimate of costs.

Update (CEOU) (AMG 1999). It provided sectoral and regional forecasts of domestic energy prices and consumption in the absence of new, substantial energy / environment policy initiatives.

Table 1. The Various Analytical Paths in the Canada-Wide Case Study

Path Name	Description
Path 0	Included all actions proposed by tables. Some sectors showed significant potential for reduction but the sum of all measures did not reach the Kyoto target and the costs of implementing these actions were high.
Path 1	Each sector was programmed to achieve the Kyoto target. CIMS pushed actions until the target was attained. While some sectors achieve this easily, others, like industry, did not have enough actions to reach the target. Thus, this path too failed to attain the Kyoto target and costs were high.
Path 2	CIMS integrated all sectors to find the most inexpensive way of attaining the target. While the target was attained, some sectors had to exceed –6% of 1990 levels while others did not (could not).
Path 3	A cap and trade system was imposed on the large emitters (industry, utilities, about 41% of total emissions). All other sectors followed Path 1.
Path 4	The cap was broadened to cover more sectors than in Path 3 to a total of about 95% of all GHG emissions.
Scenarios	Two permit price scenarios were applied to Path 2 and 4 in an effort to simulate the event that permits are available (or can be sold) internationally. Permit prices were about \$24 and \$58 per tonne CO_2.

The goal was that Canada achieve its Kyoto target. We allowed no change in non-energy output or activity levels from the BAU forecast with one exception; vehicle transportation could respond to measures aimed directly at reducing vehicle use.[10] Domestic oil and natural gas remained as in BAU; any changes in domestic demand means that exports and imports changed as well. However, we allowed the model to alter the domestic production of coal and electricity to reflect changes in demand for these fuels and held these imports and exports constant in the BAU and the paths. The simulation period was to the year 2030 with all policies enacted continuing at the same intensity to 2030.

A number of surveys of revealed investment behaviour suggest that stringent, often high, investment criteria be surpassed before implementation can occur. We use market-estimated discount rates for specific technology choices and these can be quite high.

Results and Discussion

Because of its highly disaggregate nature, CIMS provides detail on energy use, emissions reductions and costs by sector and region. Here we provide only some samples of data for a particular path or very aggregate review of the outcomes of this analysis. We focus more on costing issues than on outcomes with regard to energy or emissions.

[10] A measure is an action (buy fuel efficient cars) with a policy instrument (a rebate scheme). That is: measure = policy + action. In all, we modelled over 100 measures in this exercise.

Table 2 provides emissions outcomes of the simulation under each of the paths. Canada's estimated emissions under BAU are 759 Mt in 2010. Specific assumptions made at the request of the AMG related to agricultural and forestry sinks drops the total BAU level to 743 Mt.

Table 2. National Emission Reductions, Summary Table (Mt CO_2e)[1]

Path (Scenario)	Emissions in 2010 (Mt)	Growth of Emissions 1990-2010[2]	Kyoto Gap (Mt)	Proportion of Gap[4] (%)	Cost in Cdn $1995 (billion $)
BAU	743.2[3]	23.8%	178.7	---	---
Path 0	608.4	1.3%	43.9	75.4%	42.24
Path 1	592.8	-1.3%	28.3	84.1%	61.13
Path 2	562.8	-6.3%	-1.7	100.9%	44.47
Path 2 ($58)[4]	592.9	-1.3%	28.5	72.6%	12.01
Path 2 ($24)[4]	613.4	2.1%	48.9	84.1%	-6.80
Path 3	561.1	-6.6%	-3.4	101.9%	46.50
Path 4	562.3	-6.4%	-2.1	101.2%	44.94
Path 4 ($58)[4]	592.7	-1.3%	28.2	72.5%	12.56
Path 4 ($24)[4]	613.3	2.1%	48.8	84.2%	-4.46

[1] Emissions in 1990 are 600.5 Mt. Thus the Kyoto target is 564.5 Mt.
[2] The Kyoto target for Canada is –6% of 1990.
[3] 2010 BAU emissions include the forestry sink (10 Mt) and the agriculture sink (5.8 Mt).
[4] Reductions are domestic reductions. In Path 2 and 4, Canada purchases sufficient credits to make up the difference between domestic reductions and its target.

Table 3 defines the contribution to total emissions reduction provided by each sector. The electricity and transportation sectors show the highest variability. In the electricity sector, shifts to natural gas from coal and investment in deep aquifer saline injection (a form of sequestration) provide the largest sources reduction.[11] While options to reduce are abundant and significant in the transportation sector, many questions regarding its actual potential and costs remain unanswered. Some of these are discussed below.

CIMS points out the variation in emissions reduction potential between sectors and regions,[12] as well as the costs of meeting the target. Table 4 provides an indication of the degree to which costs associated with CO_2e emitted would have to increase to induce emissions reductions sufficient for Canada to reach its target. As described earlier, the shadow prices for the scenarios run on Path 2 and 4 are $58 and $24 / t CO_2e; these are not listed in the table.

[11] This particular action generated significant discussion and, thus, became the focus of some sensitivity analyses. The outcome of the analyses suggests that, were this option not available, fuel switching from coal to natural gas would occur and that costs would not increase appreciably.

[12] Regional data are available in the main report and are not presented here.

Table 3. Sectoral Shares of Total Reduction in 2010 by Path and Scenario

	Electricity	Industry	Residential	Com. / Inst.	Transport	Other[2]	Permits
Path 0[1]	14%	21%	4%	8%	46%	8%	
Path 1[1]	24%	24%	1%	5%	38%	7%	
Path 2	43%	16%	5%	6%	24%	6%	
Path 2 ($58)	32%	19%	4%	5%	18%	6%	16%
Path 2 ($24)	27%	17%	3%	5%	15%	6%	27%
Path 3	43%	17%	0%	4%	31%	6%	
Path 4	43%	17%	5%	6%	24%	6%	
Path 4 ($58)	32%	19%	4%	5%	18%	6%	16%
Path 4 ($24)	27%	17%	3%	5%	15%	6%	28%

[1] Emissions reduction target not attained in this path
[2] Includes fluorocarbons, propellants, anaesthetics, agricultural sinks and land use emissions.

Table 4. Shadow Prices Required to Reach Target by Sector ($ / t CO_2e)

	Economy	Electricity	Industry	Residential	Com. / Inst.	Transport
Path 0			75[1]			
Path 1		30	300[1]	0	10	300[2]
Path 2	120					
Path 3		110	110[3]	10	10	300[2]
Path 4	120[4]					

[1] Did not attain target.
[2] Reflects the marginal cost of the highest cost measure that was included in the assessment, fuel tax level at $50 / t CO_2e.
[3] Except for 'other industry' ($170 / t CO_2e) and oil and gas processing (CH_4) and oil processing (CO_2) ($300 / t CO_2e), landfills, and other emissions.
[4] Except for oil and gas processing (CH_4) and oil processing (CO_2) ($300 / t CO_2e), landfills, and other emissions.

Table 5 provides an indication of the costs to Canada of attaining its target under the various paths and scenarios. These are NPV costs (at a 10% discount rate) in 2000 of 23 years of expenditures such that the targeted reduction is attained in 2010 and the government maintains the policies (not necessarily the target) past 2010. Simulations from both models in all the paths reflect a range of impacts on GDP of 0% to 3% of GDP, roughly a maximum of one year of economic growth. The table includes the costs of the permits for those paths that we subjected to international scenarios.

The costs noted in this table reflect only technical costs and include no premiums for lost welfare. Throughout the analysis, much discussion occurred regarding the size and scope of these costs. We calculated them as described above but using sectors' expected rate of return to make technology choices. Table 5 shows the degree to which variation occurs by sector.[13]

[13] As with emissions data, regional data are also available but are not presented here.

Table 5. Total Costs of Abatement by Sector, by Path and Scenario (1995 Cdn $billion)

	Elec.	Ind.	Com. / Inst.	Res.	Transp.	Other	Permits	Elec. Export	Total
Path 0	12.99	7.27	-5.10	1.54	37.93	0.60			42.24
Path 1	15.71	34.41	-2.76	-0.09	28.96	0.60			61.13
Path 2	28.63	11.19	2.68	10.52	19.47	0.60			44.47
Path 2 ($58)	10.20	8.04	-1.09	7.01	-4.59	0.60	6.71	-4.67	12.01
Path 2 ($24)	10.79	3.26	-5.78	2.82	-10.72	0.60	5.15	-2.14	-6.80
Path 3	25.81	12.56	1.63	3.37	28.35	0.60			46.50
Path 4	28.47	11.25	2.99	10.63	19.47	0.60			44.94
Path 4 ($58)	10.60	8.22	-1.05	6.98	-4.59	0.60	6.67	-4.27	12.56
Path 4 ($24)	9.41	3.96	-5.41	3.41	-10.72	0.60	5.19	-1.50	-4.46

Notes: - PV of 23 year costs in 2000 (Policy - BAU).
- 'Other' describes costs associated with the Afforestation and Agricultural measures.
- Electricity costs are excluded from the total because they are reflected in the electricity price changes in the demand sectors.

Certain sectors experience benefits under the international scenarios. While some of these benefits are the result of technology types that are profitable (penetration of cogeneration, for example), others we estimate are the result of cost issues related to perspectives on welfare costs associated with change in life style discussed in the conclusions. For example, the benefits associated with the transportation sector under the international scenarios arise because we include no social welfare losses and investments in capital (both vehicles and infrastructure) are reduced. Secondly, the table provided a list of measures and cost of each, some of which displayed negative costs (i.e., benefits). As the shadow price (in this case, the price of permits) declines, only the more cost effective measures remain in the mix and the net outcome for the transportation sector becomes increasingly positive.

Some of the Issue Tables provided administrative costs; others did not. Thus, we could provide no definitive view of administrative or transaction costs. The data presented include such costs as we could estimate; we are confident only in their order-of-magnitude. Issues related to these costs, allocated to the various levels of government, play an important role in decision made by those who design and enact policy.

Conclusions

When considering the merits of this hybrid approach, we begin with a warning; the statistical validity of aggregate production function models may convey a false sense of understanding. A challenge in all social sciences, we are tempted to substitute statistical validity for understanding the dynamics of a system at a level of analysis that is relevant to policy making, especially when the focus is decision making for the future rather than explaining the past. Policy making in this domain is frequently about new technologies and requires technological explicitness in its analysis. Past aggregate parameters may be of little use.

At the same time, a hybrid approach displays some limitations. Data requirements are intense (at least initially) and technology data can be irregular. With increased demand for information on other material inputs and outputs (effluents, emissions, water use), data requirements climb. The convergence procedure may require numerous iterations in its move toward general equilibrium. Incorporation of other factors, like interprovincial electricity trade and international energy and goods trade with the US and other countries, adds to the complexity of modelling. Thus, we are working to better develop the model to:

1. improve the macro / micro link by improving the macro-economic feedbacks through simple input-output frameworks or computable general equilibrium frameworks.
2. identify and keeping track of relevant material (particularly waste) and energy flows associated with each technology, including labour reduction policies.
3. include some systems analysis modules, like district heat, energy cascading, distributed generation in a simple input-output framework for key material and energy flows.
4. get a better confidence in our portrayal of behaviour realism, including (1) increased use of disaggregated consumer choice research (stated and revealed preference) conducted by others (utilities, governments, academics, etc.), (2) our own selected technology-choice surveys (stated and revealed preferences), (3) key parameter validation / calibration over recent historical time periods where we have detailed technology market share and cost estimates (say for efficiency - capital cost trade-offs).

References

AMG (Analysis and Modelling Group). 1999. *Canada's Emissions Outlook – An Update.* Natural Resources Canada. Ottawa.

Jaccard, M., J. Nyboer and A. Bailie. 2001. *The Debate on Costing GHG Abatement Policies: A Methodological Commentary and Case Study.* Working paper, Energy and Materials Research Group, School of Resource and Environmental Management, Simon Fraser University, Burnaby, 2001.

NEMS. 1998. *Transportation Sector Model of the National Energy Modeling System.* Office of Integrated Analysis and Forecasting, EIA, US DoE. Washington, DC. January 1998