A Quantitative Analysis of Selected Climate Policies in British Columbia

Final Report

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Introduction

Context

The Climate Action Secretariat has retained MK Jaccard and Associates to analyze draft policy recommendations being considered by the Climate Action Team. MK Jaccard and Associates uses a detailed energy-economy model called CIMS to evaluate energy and climate change policies and to determine the cost of reducing greenhouse gas emissions. A description of CIMS is provided as an appendix to this report.

In this project, the CIMS model is used to estimate the magnitude of greenhouse gas reductions that would be obtained throughout British Columbia's economy when different types and strengths of policy signals are applied (e.g., various levels of emissions charge applied through a cap-and-trade system, or direct regulation of absolute emissions and emissions intensity).

We use the concept of a reference scenario and policy scenario to determine the greenhouse gas abatement opportunities in British Columbia over time. The reference scenario shows how British Columbia's economy might evolve in the absence of specific policies to reduce greenhouse gas emissions. The policy scenario shows how the economy might evolve under a given policy. The difference between the two scenarios is due to the effect of the policy.

The purpose of this report is to explore the effect of implementing policies in addition to those announced in British Columbia's *Climate Action Plan*.

Results from the analysis of the Climate Action Plan

The analysis of British Columbia's *Climate Action Plan* has been fully documented in the appendix of the plan, and we only highlight key assumptions and results from that analysis in this report.

Reference scenario

The reference scenario described in this report is based on internally consistent assumptions about how the economy may evolve over the coming 12 years to 2020. Many key assumptions underlying the reference scenario are highly uncertain, and if the economy evolves differently than as shown in this reference scenario, energy consumption and emissions will also differ from what we show here. We have used credible sources to guide key assumptions wherever possible, but no amount of research allows perfect foresight into the future of the economy. As a result, the scenario described here should be considered a single scenario out of an array of possibilities. We consider the results to be a good forecast, based on historic trends and research into likely future technological and economic evolution, but the uncertainty remains large.

In this report, we only publish one reference case based on the high energy price scenario from the *Climate Action Plan*, where the price for crude oil steadies at $85 per barrel ($US) from 2011 through to 2020, based on expert estimates of the long term supply cost of oil at today's consumption quantities.

CIMS uses an external forecast for the economic or physical output of each economic sector to develop the business as usual forecast, which can be internally adjusted when a policy is applied. For all demand sectors, the external forecast through 2020 is based on the same data used by Natural Resources Canada to develop the *Canada's Energy Outlook*.[1] The population forecast used here is based on the growth scenario reported by BCStats.[2] During each policy simulation, the output of each sector may change in response to changes in the end-use and production costs of the sector. For example, an increase in the cost of air travel is likely to cause a decline in the person kilometers travelled by air.

Analysis of British Columbia's Climate Action Plan

As documented in British Columbia' *Climate Action Plan*, MKJA simulated a number of the key policies announced as part of the *Plan*. The analysis was not comprehensive, that is it did not include all of the announced policies, but instead focussed on those with the greatest potential to generate significant GHG reductions at a reasonable cost. Additionally, the policies as simulated do not always correspond perfectly to the way the policy will finally be implemented. For example, the carbon tax on combustion greenhouse gas emissions will rise in one year increments when implemented. In CIMS, we have approximated the projected rise in the carbon tax by increasing it in five year increments, because CIMS solves in five-year increments to normalize the effect of the business cycle. Descriptions of the announced policies and the simulation results are available in the appendix of British Columbia's *Climate Action Plan*.

Quantitative analysis of policy options

MKJA simulated several of the policy options under consideration by the Climate Action Team. Several of these policies are incremental to the policies announced in the *Climate Action Plan*; but some strengthen the announced policies (e.g., revisions to the residential and commercial building codes). The policies simulated in this analysis do not include all the policy recommendations developed by the Climate Action Team; some of the recommendations require more work to specify policies (e.g., improvements in road freight energy efficiency), and some of the recommendations cannot be simulated in the current version of CIMS (e.g., CIMS does not currently simulate abatement opportunities in the BC agriculture sector).

The policies simulated in this scenario include:

- **Revision to the residential building code.** After 2015, all new residential buildings must be approximately 50% more energy efficient than current standard practices.
- **Revision to the commercial building code.** BC's current Green Building Code requires commercial buildings to meet the requirements of ASHRAE 90.1 (2004).

[1] Natural Resources Canada, 2006, "Canada's Energy Outlook: The Reference Case 2006", Analysis and Modelling Division, Natural Resources Canada.
[2] BCStats, 2007, "Population Projections – BC and Regional : 2007-2036", available from: http://www.bcstats.gov.bc.ca/DATA/pop/pop/popproj.asp.

ASHRAE is targeting a 30 percent improvement for the 2010 version. The policy simulation includes a further 20% improvement by 2015.

- **Zero-emission buildings.** All new commercial and residential buildings built after 2015 are required to employ technologies that do not produce direct greenhouse gas emissions (for example, ground source heat pumps, solar, zero emissions electricity).
- **Incentives to retrofit existing commercial buildings.** The Climate Action Team considered a suite of options to improve the energy efficiency of existing buildings. The policy simulation included one element of this – zero-interest financing for energy retrofits of commercial buildings.
- **Electric oil and gas fields and pipelines.** All pumps, auxiliary equipment and compressors for new oil and gas fields and pipelines must be electric after 2010.
- **Doubled mode share for walking and cycling** in the transportation sector.
- **Emissions pricing.** The Climate Action Team endorsed emissions pricing as a core policy. We modelled a scenario in which emissions pricing, through either a revenue neutral carbon tax or cap and trade system, is extended to cover all process greenhouse gas emissions in the industrial sectors. In 2015, the emissions price rises to \$50/tonne CO_2e, and to \$100/tonne CO_2e in 2020. These prices are in the same range as estimated trading prices for the EU ETS and it potential successors for these time periods.

By 2020, these additional policies could reduce emissions by an additional 8.1 Mt CO_2e beyond the reductions from the policies announced in the Climate Action Plan. These results are shown below in Table 1. As noted in the Climate Action Plan, the results are sensitive to a number of assumptions, especially oil prices and their subsequent substitution effects on natural gas, coal and electricity prices.

Table 1: Annual emissions reductions from additional policies

	Units	*Reductions*		
		2010	*2015*	*2020*
Demand Sectors				
Residential	*Mt CO_2e*	0.0	0.4	1.2
Commercial	*Mt CO_2e*	0.0	0.3	0.7
Transportation	*Mt CO_2e*	0.0	0.5	1.5
Manufacturing Industry	*Mt CO_2e*	0.0	0.4	2.0
Waste and Agrosystems	*Mt CO_2e*	0.0	0.0	0.0
Supply Sectors				
Electricity Generation	*Mt CO_2e*	0.0	0.0	0.0
Petroleum Refining	*Mt CO_2e*	0.0	0.1	0.2
Crude Oil	*Mt CO_2e*	0.0	0.8	0.8
Natural Gas	*Mt CO_2e*	0.0	1.3	1.2
Coal Mining	*Mt CO_2e*	0.0	0.0	0.0
Ethanol	*Mt CO_2e*	0.0	0.0	0.1
Biodiesel	*Mt CO_2e*	0.0	0.0	0.0
Electricity Generation Offsets	*Mt CO_2e*	0.0	0.0	0.0
Total	*Mt CO_2e*	0.0	3.7	8.1

Appendix – The CIMS Model

Introduction to the CIMS model

CIMS has a detailed representation of technologies that produce goods and services throughout the economy and attempts to simulate capital stock turnover and choice between these technologies realistically. It also includes a representation of equilibrium feedbacks, such that supply and demand for energy intensive goods and services adjusts to reflect policy.

CIMS simulations reflect the energy, economic and physical output, greenhouse gas emissions, and CAC emissions from its sub-models as shown in Table 2. CIMS does not include solvent, or hydrofluorocarbon (HFC) emissions. CIMS covers nearly all CAC emissions in Canada except those from open sources (like forest fires, soils, and dust from roads).

Table 2: Sector Sub-models in CIMS

Sector	*BC*	*Alberta*	*Sask.*	*Manitoba*	*Ontario*	*Quebec*	*Atlantic*
Residential	■	■	■	■	■	■	■
Commercial/Institutional	■	■	■	■	■	■	■
Transportation	■	■	■	■	■	■	■
Personal	■	■	■	■	■	■	■
Freight	■	■	■	■	■	■	■
Industry							
Chemical Products	■	■			■	■	
Industrial Minerals	■	■			■	■	■
Iron and Steel					■	■	
Non-Ferrous Metal Smelting*	■			■	■	■	■
Metals and Mineral Mining	■		■	■	■	■	■
Other Manufacturing	■	■	■	■	■	■	■
Pulp and Paper	■	■			■	■	■
Energy Supply							
Coal Mining	■	■	■				■
Electricity Generation	■	■	■	■	■	■	■
Natural Gas Extraction	■	■	■	■	■	■	■
Petroleum Crude Extraction	■	■	■		■		■
Petroleum Refining	■	■	■		■	■	■
Ethanol	■	■	■	■	■	■	■
Biodiesel	■	■	■	■	■	■	■
Agriculture & Waste	■	■	■	■	■	■	■

* Metal smelting includes Aluminium.

Model structure and simulation of capital stock turnover

As a technology vintage model, CIMS tracks the evolution of capital stocks over time through retirements, retrofits, and new purchases, in which consumers and businesses make sequential acquisitions with limited foresight about the future. This is particularly important for understanding the implications of alternative time paths for emissions reductions. The model calculates energy costs (and emissions) for each energy service in the economy, such as heated commercial floor space or person kilometres travelled. In each time period, capital stocks are retired according to an age-dependent function (although retrofit of un-retired stocks is possible if warranted by changing economic conditions), and demand for new stocks grows or declines depending on the initial exogenous forecast of economic output, and then the subsequent interplay of energy supply-demand with the macroeconomic module. A model simulation iterates between energy supply-demand and the macroeconomic module until energy price changes fall below a threshold value, and repeats this convergence procedure in each subsequent five-year period of a complete run.

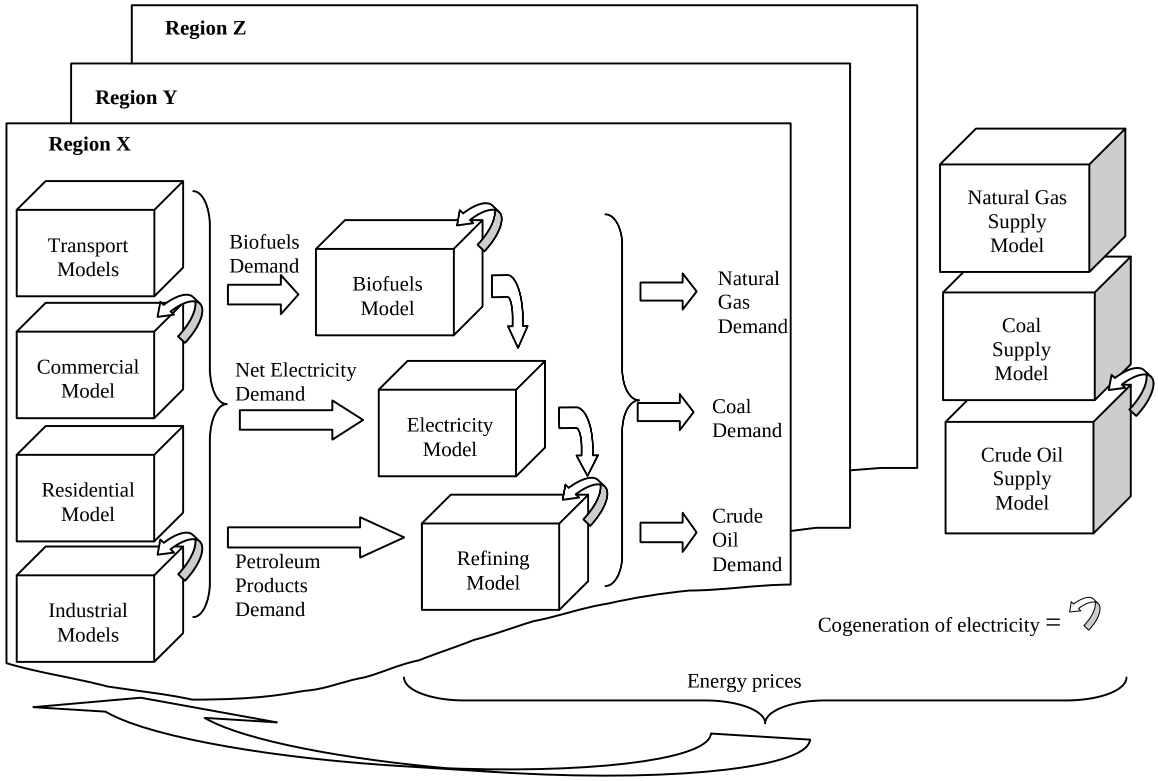
CIMS simulates the competition of technologies at each energy service node in the economy based on a comparison of their life cycle cost (LCC) and some technology-specific controls, such as a maximum market share limit in the cases where a technology is constrained by physical, technical or regulatory means from capturing all of a market. Instead of basing its simulation of technology choices only on financial costs and social discount rates, CIMS applies a definition of LCC that differs from that of bottom-up analysis by including intangible costs that reflect consumer and business preferences and the implicit discount rates revealed by real-world technology acquisition behaviour.

Equilibrium feedbacks in CIMS

CIMS is an integrated, energy-economy equilibrium model that simulates the interaction of energy supply-demand and the macroeconomic performance of key sectors of the economy, including trade effects. Unlike most computable general equilibrium models, however, the current version of CIMS does not equilibrate government budgets and the markets for employment and investment. Also, its representation of the economy's inputs and outputs is skewed toward energy supply, energy intensive industries, and key energy end-uses in the residential, commercial/institutional and transportation sectors.

CIMS estimates the effect of a policy by comparing a business-as-usual forecast to one where the policy is added to the simulation. The model solves for the policy effect in two phases in each run period. In the first phase, an energy policy (e.g., ranging from a national emissions price to a technology specific constraint or subsidy, or some combination thereof) is first applied to the final goods and services production side of the economy, where goods and services producers and consumers choose capital stocks based on CIMS' technological choice functions. Based on this initial run, the model then calculates the demand for electricity, refined petroleum products and primary energy commodities, and calculates their cost of production. If the price of any of these commodities has changed by a threshold amount from the business-as-usual case, then supply and demand are considered to be out of equilibrium, and the model is re-run based on prices calculated from the new costs of production. The model will re-run until a new equilibrium set of energy prices and demands is reached. Figure 1 provides a schematic of this process. For this project, while the quantities produced of all energy commodities were set endogenously using demand and supply balancing, endogenous pricing was used only for electricity and refined petroleum products; natural gas, crude oil and coal prices remained at exogenously forecast levels (described later in this section), since Canada is assumed to be a price-taker for these fuels.

Figure 1: CIMS energy supply and demand flow model



In the second phase, once a new set of energy prices and demands under policy has been found, the model measures how the cost of producing traded goods and services has changed given the new energy prices and other effects of the policy. For internationally traded goods, such as lumber and passenger vehicles, CIMS adjusts demand using price elasticities that provide a long-run demand response that blends domestic and international demand for these goods (the "Armington" specification).[3] Freight transportation is driven by changes in the combined value added of the industrial sectors, while personal transportation is adjusted using a personal kilometres-travelled elasticity (-0.02). Residential and commercial floor space is adjusted by a sequential substitution of home energy consumption vs. other goods (0.5), consumption vs. savings (1.29) and goods vs. leisure (0.82). If demand for any good or service has shifted more than a threshold amount, supply and demand are considered to be out of balance and the model re-runs using these new demands. The model continues re-running until both energy and goods and services supply and demand come into balance, and repeats this balancing procedure in each subsequent five-year period of a complete run.

Empirical basis of parameter values

Technical and market literature provide the conventional bottom-up data on the costs and energy efficiency of new technologies. Because there are few detailed surveys of the annual energy consumption of the individual capital stocks tracked by the model

[3] CIMS' Armington elasticities are econometrically estimated from 1960-1990 data. If price changes fall outside of these historic ranges, the elasticities offer less certainty.

(especially smaller units), these must be estimated from surveys at different levels of technological detail and by calibrating the model's simulated energy consumption to real-world aggregate data for a base year.

Fuel-based greenhouse gas emissions are calculated directly from CIMS' estimates of fuel consumption and the greenhouse gas coefficient of the fuel type. Process-based greenhouse gas emissions are estimated based on technological performance or chemical stoichiometric proportions. CIMS tracks the emissions of all types of greenhouse gas emissions, and reports these emissions in terms of carbon dioxide equivalents.[4]

Both process-based and fuel-based CAC emissions are estimated in CIMS. Emissions factors come from the US Environmental Protection Agency's FIRE 6.23 and AP-42 databases, the MOBIL 6 database, calculations based on Canada's National Pollutant Release Inventory, emissions data from Transport Canada, and the California Air Resources Board.

Estimation of behavioural parameters is through a combination of literature review, judgment, and meta-analysis, supplemented with the use of discrete choice surveys for estimating models whose parameters can be transposed into behavioural parameters in CIMS.

Simulating endogenous technological change with CIMS

CIMS includes two functions for simulating endogenous change in individual technologies' characteristics in response to policy: a declining capital cost function and a declining intangible cost function. The declining capital cost function links a technology's financial cost in future periods to its cumulative production, reflecting economies-of-learning and scale (e.g., the observed decline in the cost of wind turbines as their global cumulative production has risen). The declining capital cost function is composed of two additive components: one that captures Canadian cumulative production and one that captures global cumulative production. The declining intangible cost function links the intangible costs of a technology in a given period with its market share in the previous period, reflecting improved availability of information and decreased perceptions of risk as new technologies become increasingly integrated into the wider economy (e.g., the "champion effect" in markets for new technologies); if a popular and well respected community member adopts a new technology, the rest of the community becomes more likely to adopt the technology.

[4] CIMS uses the 2001 100-year global warming potential estimates from Intergovernmental Panel on Climate Change, 2001, "Climate Change 2001: The Scientific Basis", Cambridge, UK, Cambridge University Press.