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APPENDIX A

Reference Case Scenario

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SUB-APPENDICES

A1. INTRODUCTION

A1.1 BACKGROUND AND GOAL

Representatives from the federal government (NRCan), provincial governments and industry (CGA, CEA) have come together under the auspices of the CEM Demand-Side Management (DSM) Working Group to collaborate on advancing the role and presence of energy efficiency/DSM in Canada. As a result of this collaboration, the Working Group agreed to undertake a national study to look at DSM potential across Canada. With the goal of bringing DSM to the forefront of energy and economic policy discourse in the country, the Working Group has commissioned an analysis of sufficient depth and scope to provide policy makers with credible and reliable data on which to base policy decisions. Specifically, the goal of this project is to supply the DSM Working Group with credible estimates of the market achievable potential of energy management in Canada for the period of 2005 to 2025.

This paper is one milestone in that process, and presents the Reference Case from which the market achievable potential of energy management will be calculated. Accompanying the Reference Case is an estimate of the Economic Potential (not included in this draft), which represents an upped bound of the market potential.

A1.2 STUDY SCOPE

The study includes national and provincial coverage of the industrial, commercial and residential sectors and their associated fuels. More specifically, the scope is defined as follows:

- **Sector Coverage:** This study addresses three sectors: residential, and commercial and industrial.

- **Geographical Coverage**: The study results are presented for seven regions, including British Columbia and the territories, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, and the Atlantic. Further disaggregation of the regions, and BC and Atlantic in particular, are not feasible given the level of data aggregation present in Statistics Canada energy end use data. The implications of this region aggregation will be discussed where appropriate.

- **Jurisdictions:** DSM and energy efficiency measures are contemplated for utilities and for all levels of government in Canada, including municipal, provincial and federal.

- **Energy Types:** All energy types are covered including natural gas, electricity, refined petroleum products and others such as biomass. This comprehensive coverage of energy types ensures that the results will also provide an indication of the fuel switching that could occur in response to DSM and energy efficiency measures implemented by both governments and utilities.

- **Study Period**: This study also covers a 25-year period. The base year is the year 2000, with milestone periods at 5-year increments: 2005, 2010 2015, 2020, and 2025.

- **Technologies:** This study addresses all foreseeable energy efficiency technologies or measures that are expected to be commercially viable through 2025. This includes options classified as distributed generation and fuel switching.

A1.3 OVERVIEW OF THE REPORT

The remainder of this report is presented as follows:

- Section 2 provides an overview of the modelling framework, with additional detail provided in Sub-Appendix A1;
- Section 3 provides the reference case, including the parameters that "drive" the estimated energy use by sector over the 2005 to 2025 period;
- Section 4 provides the economic potential including the approach and results (to be submitted once the reference case is approved).

A1.4 HOW THIS DOCUMENT DIFFERS FROM THE PREVIOUS REFERENCE CASE

In generating the second Reference Case, a number of initiatives were undertaken. Notably, the Team:

- Conducted a careful review of the model and removed modelling features that had been introduced to calibrate CIMS to the NRCAN CEOU99. Section 3.6 provides the detail of this review;
- Reviewed technology market shares (including fuel switching) and made adjustments where unrealistic market shares were identified. A typical example of this is fuel switching in residential space heating from electric baseboards to furnace/forced gas systems;
- Ensured base year calibration is in line with the latest Statistics Canada energy use data for the year 2000. Sub-Appendix A6 has been added to demonstrate that the model is calibrated; and,
- Conducted spot checks with utility provided end-use data and adjusted the model accordingly.

The detailed Reference Case **provincial** results are provided in Sub-Appendix A5.

A2. ANALYTICAL APPROACH: THE CIMS MODEL

The CIMS model was used as the platform for the study. CIMS is an integrated energy-economy model that portrays technology acquisition in the economy over time. Technologies are represented in unique sub-models that meet energy service demands in the residential, commercial, transportation, electricity supply, and industry sectors. It is therefore possible to specifically represent the evolution of a technology, or group of technologies, in a forecast and to alter model inputs to simulate alternative forecasts and policy scenarios.

CIMS is a hybrid simulation model; it uses an extensive database of technologies and existing stocks (a bottom-up approach to modelling), but its annualized life cycle cost function takes into account behaviourally-defined consumers' choice (a top-down approach) as well as financial costs to determine the set of technology stocks required to meet demand for services and products. Capturing the behavioural component of choice requires an understanding of market-driven phenomena such as time preference and risk, market variability (not everybody sees costs the same, has the same sort of market opportunity, nor do they view investments in the same way) and non-financial preferences or intangibles (a representation of those characteristics of goods and services not captured in financial costs). If one alters the conditions under which choices are made (introducing a tax, providing a rebate, or other policy tools), one alters the choice regime and the behavioural response consumers exhibit, and thus the technology stocks in the future. The model is designed to translate policy interventions into changes in a wide suite of economic, energy and environmental outcomes.

CIMS has been in continuous development since 1986 by the Energy and Materials Research Group in the School of Resource and Environmental Management at Simon Fraser University.[1] Since the model is based on Statistics Canada data aggregation, the model currently represents seven regions in Canada (See Table A1 for the regions). As noted above, the model emphasizes the micro-economic level of analysis in that it simulates in considerable detail the equipment and building decisions of firms and households in response to changes in financial costs consumer preferences, market conditions and availability of alternatives.[2] However, it can also incorporate indirect feedbacks that are normally associated with macro-economic models, namely the interaction between sectors that use energy and those that produce or transform it, and shifts in the demand for final and intermediate products as their costs of production change.

In the CIMS model, energy use in the Canadian economy is represented by 13 unique sub-models that are described uniquely for different regions. Additional detail on the sub-sector models is provided in Sub-Appendix A1. These sub-models (listed in Table A1) represent stocks of technologies that produce and or consume energy in a particular sector, in terms of the annual quantity of intermediate and final products or services they provide (i.e., tonnes of newsprint, cubic metres of refined petroleum products). Product and energy service demands are linked in sector flow models that describe the sequence of key energy consuming activities required to generate that product or service (See Sub-Appendix A1).

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[1] The energy demand component of the model, previously called ISTUM, was first developed in the early 1980s by the U.S. Department of Energy as an energy use model of the industrial sector.

[2] In this respect CIMS resembles models developed and applied by the electric utility industry in the 1980s for estimating the effects of policies intended to influence technology choices for energy efficiency and fuel switching objectives. CIMS has been used by electric and gas utilities in Canada for this purpose.

Forecasts of these service demands drive the model simulation in five-year increments, thus allowing for detailed assumptions about industrial output (by product), growth in commercial floor space and households, and energy supply. The rate of technological change is influenced by a retirement function that captures the normal, technical lifespan of energy-using equipment, as well as the technology acquisition algorithm that determines the new stocks required to meet additional growth.

Table A1
Sub-models in CIMS

Sub-model	**BC**	**AB**	**SK**	**MA**	**ON**	**PQ**	**AT**
Industry							
Chemical Products	✓	✓	-	-	✓	✓	-
Coal Mining	✓	✓	✓	-	-	-	✓
Industrial Materials	✓	✓	-	-	✓	✓	✓
Iron and Steel	-	-	-	-	✓	✓	-
Metal Smelting	✓	-	-	✓	✓	✓	✓
Mining (metals, uranium, potash)	✓	-	✓	✓	✓	✓	✓
Natural Gas Extraction	✓	✓	✓	*	*	*	✓
Other Manufacturing	✓	✓	✓	✓	✓	✓	✓
Petroleum Refineries	✓	✓	✓	-	✓	✓	✓
Petroleum Crude Extraction	✓	✓	✓	-	✓	-	✓
Pulp & Paper	✓	✓	✓	-	✓	✓	✓
Residential	✓	✓	✓	✓	✓	✓	✓
Commercial	✓	✓	✓	✓	✓	✓	✓

* Transmission only

These sub-models are integrated in an overall modelling framework that simulates the interaction between sectors that use energy (industrial, residential, commercial and transportation) and sectors that produce or transform energy (electricity generation, petroleum crude extraction, petroleum refining, and natural gas extraction and processing). Modelling the interaction between these sectors is important to capture energy price dynamics that guide decision-making; for instance, the widespread adoption of high efficiency electric motor and auxiliary systems would impact the demand for electricity, with potential price impacts that would affect energy-related decisions throughout the economy. Another interesting aspect of the model is that fuel switching in response to DSM measures can be captured. This feature is particularity interesting in that past DSM studies may not have fully contemplated the implications of fuel switching potential across all regions, sectors and fuels.

Because CIMS is integral to constructing the Reference Case baseline and subsequent analysis of both economic and achievable potentials, we describe the model in more detail in Sub-Appendix A1. The following section presents the general approach to modelling scenarios in CIMS.

A2.1 RUNNING A SIMULATION IN CIMS

A CIMS simulation involves seven basic steps:

1. *Assessment of Demand*: Technologies are represented in the model in terms of the quantity of service they provide. This could be, for example, vehicle kilometres travelled, tonnes of paper, or m^2 of floor space heated and cooled. A forecast is then

provided of growth in energy service demand.[3] This forecast drives the model simulation, usually in five year increments (i.e., 2000, 2005, 2010, 2015, etc.).

2. *Retirement*: In each future period, a portion of the initial-year's stock of technologies is retired. Retirement depends only on age.[4] The residual technology stocks in each period are subtracted from the forecast energy service demand and this difference determines the amount of new technology stocks in which to invest.

3. *New Technology Competition / Retrofit Competition*: Prospective technologies compete for this new investment. The objective of the model is to simulate this competition so that the outcome approximates what would happen in the real world. Hence, while the engine for the competition is the minimization of annualized life cycle costs, these costs are substantially adjusted to reflect market research of past and prospective firm and household behaviour.[5] Thus, technology costs depend not only on recognised financial costs, but also on identified differences in non-financial preferences (differences in the quality of lighting from different light bulbs) and failure risks (one technology is seen as more likely to fail than another). Even the determination of financial costs is not straightforward, as time preferences (discount rates) can differ depending on the decision maker (household vs. firm) and the type of decision (non-discretionary vs. discretionary). The model also allocates market shares among technolgoies probabilistically.[6] More detail regarding the technology competition algorithm is provided in Sub-Appendix A1.

4. *Retrofitting:* In each time period, a similar competition occurs with residual technology stocks to simulate retrofitting (if desirable and likely from the firm or household's perspective).7 The same financial and non-financial information is required, except that the capital costs of residual technology stocks are excluded, having been spent earlier when the residual technology stock was originally acquired.

5. *Equilibrium of Energy Supply and Demand*: Once the energy demand sub-models have chosen technologies, the resulting demands for energy are sent to the energy supply models. These models then choose the appropriate supply technologies, assess the change in the cost of producing energy, and if it is significant, send new energy prices back to the demand models. This cycle goes back and forth until energy prices and energy demand have stabilised at an equilibrium.[8]

6. *Equilibrium of Energy Service Demand*: Once the energy supply and demand cycle has stablized, the macro-economic cycle is invoked, which adjusts demand for energy

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[3] The growth in energy service demand (e.g., tonnes of steel) is often derived from a forecast provided in economic terms (e.g., dollar value of output from the steel sector).

[4] There is considerable evidence that the pace of technology replacement depends on the economic cycle, but over a longer term, as simulated by CIMS, age is the most important and predictable factor.

[5] With existing technologies there may be data on consumer behaviour. However, with emerging technologies (especially the heterogeneous technologies in industry) firms and households need to be surveyed (formally or informally) on their likely preferences.

[6] In contrast, the optimizing models will tend to produce outcomes in which a single technology gains 100% market share of the new stocks.

[7] Where warranted, retrofit can be simulated as equivalent to complete replacement of residual technology stocks with new technology stocks.

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

services according to their change in overall price, based on price elasticities. If this adjustment is significant, the whole system is rerun from step 1 with the new demands.

7. *Output*: Since each technology has net energy use, net energy emissions and costs associated with it, the simulation ends with a summing up of these. The difference between a business-as-usual simulation (reference case) and a policy simulation (economic and achievable potentials) provides an estimate of the likely achievement and cost of the scenario.

A2.2 CALIBRATING TO THE BASE YEAR, 2000

CIMS represent stocks of technologies that produce and or consume energy in a particular sector. The sum of energy represented by these technologies in a sector, or where possible sub-sector, is calibrated to official statistical data for the year 2000. CIMS was calibrated to the amount of fuel use, in each province, for each sector to within 5%. The tables below demonstrate the National calibration for Natural Gas and Electricity, by sector. Natural gas liquids are included with natural gas. In these tables, source data for Residential, Commercial and Total Manufacturing are from Statistics Canada, supply and demand of primary and secondary energy in terajoule.[9] Data for mining are from Natural Resources Canada, Annual Census of Mines.

The provincial calibration tables are presented in Sub-Appendix A6.

Table A2
National Natural Gas/NGLs Calibration (2000, GJ)

	CIMS	Source Data	Difference
Commercial	512,404,479	504,339,000	1.6%
Residential	658,983,664	644,977,000	2.2%
Industrial	906,923,660	912,112,604	-0.6%
Total Manufacturing*	792,340,836	798,080,000	-0.7%
Total Manufacturing including cogeneraton**	882,038,082	887,777,246	-0.6%
Mining***	24,885,578	24,335,358	2.3%
Total	2,081,143,178	2,061,428,604	1.0%

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[9] Table 128-00021,2, E-STAT Accessed September 1, 2005. <estat.statcan.ca/>

Table A3
National Electricity Calibration (2000, GJ)

	CIMS	Source Data	Difference
Commercial	447,607,591	453,838,000	-1.4%
Residential	496,564,662	498,180,000	-0.3%
Industrial	669,933,217	671,324,583	-0.2%
Total Manufacturing*	688,232,877	690,247,000	-0.3%
Total Manufacturing including cogeneraton**	628,835,563	630,849,686	-0.3%
Mining***	41,097,654	40,474,897	1.5%
Total	1,614,054,233	1,623,342,583	-1%

*includes Chemical Products, Industrial Minerals, Iron and Steel, Non-ferrous Metal Smelting, Pulp and Paper, Petroleum Refining and Other Manufacturing

** The CIMS industrial sector sub-models portray cogeneration within an industrial sector, while Statistics Canada allocates fuels consumed to produce electricity as part of Net Supply. Natural gas is calibrated to Statistics Canada's value for Total Manufacturing plus an estimate of the fuel used in cogeneration that would have been allocated to net supply. Electricity is calibrated to Net Electricity Demand: This is Total Manufacturing (e-stat) minus an estimate of electricity produced by cogeneration

Estimates of fuel consumption and electricity production are based on cogeneration facility data described in:

Canadian Industry Energy End-use Data and Analysis Centre (CIEEDAC). 2003. Canadian Cogeneration Database: An Update. Burnaby, British Columbia. http://www.cieedac.sfu.ca

*** Mining includes metal, uranium and potash mining.

A3. REFERENCE CASE

A3.1 INTRODUCTION

The first scenario generated in this study is the Reference Case or Business-as-Usual (BAU) case. The BAU is a projection of future energy consumption to 2025, in the absence of any new and incremental utility and other institutional market interventions after the base year of 2000. It is the baseline against which the scenarios of energy savings are calculated in the economic and achievable potential scenarios. The BAU takes into account that, even in the absence of incremental market interventions, there will be an independent "natural conservation" effect that will drive a change in the average intensity of energy end-uses over time plus the on-going effects of DSM programs implemented before 2000.

The discussion is organized according to the following subsections: Developing the Reference case; Reference Case Results and Interpretation of the Results.

A3.2 DEVELOPING THE REFERENCE CASE

To develop the Reference Case we pursued three main sub-tasks with the aim of verifying and updating a wide range of numerical values in the CIMS model, including:

1. Baseline energy end use profiles;
2. Fuel prices; and,
3. Economic growth projections.

We also discuss how we reflect DSM programs in the baseline.

A3.2.1 Baseline Energy End Use Profiles

The baseline energy end use profiles are the foundation of the analysis. Reviewing and updating the inventory of technologies and practices that can be addressed by DSM and energy efficiency (DSM/EE) measures was an important first task. The study team conducted a thorough review of the baseline energy end use profiles in each of the CIMS sector modules, including industrial, commercial and residential, to ensure they are robust and up to date. An overview of the results and some high level observations are presented below.

Residential

The review and update for the residential sector was conducted as follows:

STEP 1: Validate the model archetypes and net space heating loads

The CIMS model uses five housing archetypes to model energy use in the residential sector. Each archetype has a specific net space heating load associated with it for each of the seven regions[10]. These net space heating loads were then compared to the net space

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[10] Net space heating load is the space heating load of a building that must be met by the space heating system over a full year. This is equal to the total heat loss through the building envelope minus solar and internal gains.

heating loads of similar archetypes from past Marbek projects (see Sub-Appendix A1, Section A1.15.4). The past Marbek projects covered four of the seven regions, so there was a substantial basis for comparison. The comparison showed that the CIMS data was within the same order of magnitude as the past project data (i.e. all with 100% percent difference, with one exception), however, there were no general trends that could be used to develop a scale to improve on the CIMS data.

Without a strong basis for altering the CIMS data, it was important to check the source of this data to determine whether it was sufficiently reliable. The archetype heating loads used in CIMS were calculated from the disaggregated source data that was used to develop the *Energy Use Data Handbook, 1990 to 2000.* The original source for this document is from Statistic's Canada's exhaustive report entitled *Energy Balance: Report on Energy Supply-Demand in Canada.* This report is developed from 14 feeder surveys of the producers and large distributors of petroleum products, major electric utilities, industrial electricity producers, coalmines and the natural gas utility industry. Information for the residential sector is based off the survey entitled "*The Annual Electricity Supply and Disposition Survey*", that reaches over 370 respondents from gas and electric utilities across Canada[11].

Based on the above findings, we felt that the data used to determine the net space heating loads for the archetypes was from a robust and reliable source.

STEP 2: Update the technology costs, life and energy use

Updating the technologies involved reviewing all 587 technologies and inspecting the capital costs, operating costs, technology life, service requirements and energy use[12]. These parameters were all verified and/or updated, with new technology upgrades being added as needed.

STEP 3: Calibrate the model and run the first simulation

The model was re-calibrated with the new technology energy uses. Calibration involved updating the technology market splits in the base year where necessary.

STEP 4: Evaluate the simulation results and fix anomalies

Activities here included:

- Interpret the simulation results
- Check fuel trends and technology market shares to 2030
- Identify the cause of anomalies
- Modify the inputs to avoid scenarios that are not plausible
- Re-run the simulation and repeat earlier steps

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[11] Personal communications, Justin Lacroix, Statistics Canada

[12] The 587 technologies includes technologies that were modelled differently for regional variations, or for differences due to the varying archetypes.

Commercial

A number of steps were followed to review and update the commercial sector:

STEP 1: Review inputs used in the commercial CIMS

This includes:

- Equipment efficiencies and COP's values used in CIMS
- Ratio of HVAC electricity consumption to energy consumption
- Ratio of cooling load to heating load
- Electric fuel shares of different heatpump technologies
- Fuel shares of cooling technologies
- Technology costs

The above values were reviewed for each commercial building segment. The results of this review were incorporated into the CIMS model. In particular the allocation of electricity consumption between plug load, cooking and refrigeration and auxiliary motor was altered to better reflect shares found in Marbek's source files.

STEP 2: Review commercial sector end-use energy use intensities

The CIMS model bases its energy end-use intensities for heating from NRCan's National Energy Use Database (NEUD). The NEUD intensities for each commercial building segment were compared against Marbek's in-house regional database of commercial EUIs. The database covered four of the seven regions. Some segments were not reviewed due to the type of segment. This included recreation facilities, other institutions and religious institutions.

STEP 3: Calibrate the model and run the Reference Case

The review revealed a significant difference in the weighted average sector EUI for space heating. For example in Ontario, the weighted average of space heating EUIs for all building segments based on Marbek data is 785 MJ/m^2 versus 964 MJ/m^2 in the NEUD data drawn on by CIMS. Nevertheless, the total energy accounted for by space heating by the two sources may not digress significantly, assuming that data on building floorspace is uncertain. The reference case proceeded with heating intensities that were already present in the CIMS model.

STEP 4: Evaluate the simulation results and fix anomalies

The same steps were followed as residential.

Industrial

STEPS 1 and 2: Technology Review and Intensities

The industrial technology database in CIMS provides one of the few comprehensive energy end-use pictures of Canadian industry. The database has been in development over the past ten years, and is maintained by the Canadian Industrial End-use Data and Analysis Centre at Simon Fraser University. In addition, the database is updated with non-confidential information gained by consulting projects. For instance, a recent project concluded in March 2005, reviewed and updated the technology details for the National Energy Use Database, Natural Resources Canada.[13] This update included:

- An assessment of the technologies represented in CIMS against other end-use technology databases;
- the greater inclusion of emerging industrial technologies;
- A reassessment of current cost and feasibility of technology alternatives (technologies that may have been promising, but have not been adopted in production),\; and
- The integration of more recent information from industry sources about current stock characteristics.

Another recent project improved the characterization of cogeneration systems in the database, as well strengthening the picture of industrial cogeneration production by specific industry sectors.[14]

For the current project, we designated a budget for additional industry technology review. Based on priorities identified, this work included:

- A review and cost update of motor auxiliary technologies;
- A review and technology update of industrial lighting;
- A review of information in Industrial Sector Report of the BC Hydro Conservation Potential Review (2003), including data from the model set-up files provided by Willis Energy Services Consulting; and,
- The recalculation of main process splits & coefficients in Other Manufacturing.

In addition, we incorporated some changes to the representation of peak, shoulder and base technologies in the electricity generation sector in CIMS. While this did not relate specifically to the DSM technologies in this project, the accurate representation of the electricity is important to the energy market and price feedbacks in the model.

STEP 3: Calibrate the model and run the first simulation

Some of the industrial sub-models required calibration to the base year following technology changes. The reasonableness of the current physical production growth rates

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[13] M.K. Jaccard & Associates, Inc. *End-use technology data enhancement in CIMS*. Completed for Office of Energy Efficiency, Natural Resources Canada, 2005.

[14] M.K. Jaccard & Associates, Inc. *Strategic options for combined heat and power in Canada.* Completed for Office of Energy Efficiency, Natural Resources Canada, 2004.

was assessed in-house based on observed production trends since 2000, and based on sector information (for instance planned mines, trends in petro-chemical production based on increased natural gas prices). The industrial models were then simulated with the adjusted growth rates and techno-vert energy prices.

STEP 4: Evaluate the simulation results and fix anomalies

As per the other sectors, the simulation results were analyzed, adjusted and re-run. Among other things, this process identified an issue with the coal prices, in which considerable fuel switching to coal occurred for steam and heat end-uses, due to a low relative coal price. The coal prices in the National Energy Board Techno-vert forecast were assessed, and an alternative forecast adopted. This issue is outlined in more detail in Sub-Appendix A3.

A3.2.2 Energy Prices

With our assumed planning horizon in the order of 25 years, the sensitivity of the technology mix and behavioural responses to fuel price assumptions is likely high. Prior to this study, the energy prices in CIMS were based on NRCan's *CEOU99 update 2000*. This forecast is very dated, with the low price forecast of natural gas being one glaring weakness. We therefore updated the energy price forecasts in the model to better reflect current forecast prices. An important consideration of this update was to use an internally consistent set of fuel price data with regional, sectoral and fuel coverage. Thus, an ad hoc adjustment to the *CEOU99 update 2000* was ruled out in favour of using a consistent set of data.

NRCan is currently developing a national energy use and price forecast to be released in late 2005 and therefore the most recent energy forecast with provincial and sectoral coverage is NEB's *Canada's Energy Future*.[15] Two scenarios are presented by the NEB that bound possible outcomes in the future:

- The ***Supply Push*** scenario represents a world in which technology advances gradually and Canadians take limited action with respect to the environment. The main theme of this scenario is security of continental energy supply and the push to develop known conventional sources of energy.

- The ***Techno-Vert*** scenario represents a world in which technology advances rapidly and Canadians take broad action with respect to the environment and the accompanying preference for environmentally-friendly products and cleaner-burning fuels.

In our view, the Techno-vert assumption likely provides the most conservative approach (in that it will trigger a low potential estimate since we decrease the estimate of what we can achieve assuming more energy efficiency in the baseline), since energy prices are higher to reflect the emissions price embodied in fossil fuels. As well, continued growth

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[15] National Energy Board, "Canada's Energy Future" Scenario's for Supply and Demand to 2025. (Supply Push and Techno-Vert scenarios). http://www.neb-one.gc.ca/energy/SupplyDemand/2003/index_e.htm

of gas demand in the power generation sector and in particular the possible replacement in Ontario of coal-fired generation with natural gas lends itself to scenario with higher energy prices. The techno-vert scenario also provides the greatest allowance for technology to maximize conventional natural gas extraction from the Western Canadian Basin, which is one of the most salient differences between the scenarios. In contrast, the Supply Push scenario assumes that conventional natural gas from this source runs out somewhere around 2010 and is assumed replaced with coal bed methane and shale gas. Despite this, the price of gas falls steadily and smoothly over this period. The Techno-vert scenario assumes that more technology (side drilling, better seismics, etc) will allow Canada to maintain the energy supply status quo until approximately 2025. This fits much better with the smooth fuel price forecasts that are provided in the Techno-vert scenario.

Our recommendation, accepted by the study's Steering Committee, was to use of the Techno-vert or high fuel price scenario. Sub-Appendix A2 provides the detailed fuel prices by region and sector and Table A4 and Table A5 provide the national data. Prices were converted to $1995 from $1986 based on consumer price index information from Statistics Canada.[16]

One exception to the use of the NEB price data is coal, which we believe is exceedingly low in the NEB scenario. After a review of coal prices, our recommendation, again accepted by the Steering Committee, was to retain the *CEOU99* coal price forecast. Sub-Appendix A3 provides a discussion of our reasoning for adopting the *CEOU99* coal forecast, and Table A4 provides the national values by gigajoule (GJ) and Table A5 provides the values by fuel unit.

Table A4
National Fuel Prices Adopted in the Model*

	Canada					
	2000	**2005**	**2010**	**2015**	**2020**	**2025**
Residential ($1995/GJ)						
Electricity	$21.24	$21.08	$22.51	$21.95	$21.35	$20.52
Natural Gas	$7.60	$8.90	$9.33	$9.10	$8.87	$8.62
Light Fuel Oil	$12.83	$11.67	$12.77	$12.65	$12.51	$12.38
Commercial ($1995/GJ)						
Electricity	$17.21	$18.83	$19.85	$19.35	$18.76	$17.92
Natural Gas	$6.27	$7.80	$8.23	$8.02	$7.79	$7.52
Light Fuel Oil	$12.99	$11.05	$11.50	$11.61	$11.81	$11.67
Heavy Fuel Oil	$7.18	$5.24	$5.22	$4.99	$4.64	$4.02
Industrial ($1995/GJ)						
Electricity	$12.39	$13.32	$14.02	$13.66	$13.22	$12.63
Natural Gas	$4.19	$5.59	$6.02	$5.76	$5.51	$5.23
Heavy Fuel Oil	$5.42	$5.11	$5.06	$4.83	$4.59	$4.31
Coal	$2.36	$2.30	$2.25	$2.25	$2.25	$2.36

*Provincial detail is provided in Sub-Appendix A2

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[16] Consumer Price Index, Historical Summary. CANSIM, table 326-0002 and Catalogue nos. 62-001-XPB and 62-010-XIB. < www40.statcan.ca/l01/cst01/econ46.htm> [

Table A5
National Fuel Prices Adopted in the Model*

Canada	2000	2005	2010	2015	2020	2025
Residential ($1995)						
Electricity ($/kwh)	$0.077	$0.076	$0.081	$0.079	$0.077	$0.074
Natural Gas ($/m^3)	$0.29	$0.34	$0.35	$0.35	$0.34	$0.33
Light Fuel Oil ($/L)	$0.33	$0.30	$0.33	$0.33	$0.32	$0.32
Commercial ($1995)						
Electricity ($/kwh)	$0.062	$0.068	$0.072	$0.070	$0.068	$0.065
Natural Gas ($/m^3)	$0.24	$0.30	$0.31	$0.30	$0.30	$0.29
Light Fuel Oil ($/L)	$0.34	$0.29	$0.30	$0.30	$0.31	$0.30
Heavy Fuel Oil ($/L)	$0.17	$0.13	$0.13	$0.12	$0.11	$0.10
Industrial ($1995)						
Electricity ($/kwh)	$0.045	$0.048	$0.051	$0.049	$0.048	$0.046
Natural Gas ($/m^3)	$0.16	$0.21	$0.23	$0.22	$0.21	$0.20
Heavy Fuel Oil ($/L)	$0.13	$0.12	$0.12	$0.12	$0.11	$0.10
Coal ($/tonne)	$66.08	$64.40	$63.00	$63.00	$63.00	$66.08

*Provincial detail is provided in Sub-Appendix A2

3.2.3 Economic growth projections

Adequately capturing final economic demand in the baseline is material since it fixes energy demand under which fuels and technologies compete. While changes in economic growth, such as floor space and production, will alter overall energy demand and shift the relative price of energy, economic growth forecasts tend to be somewhat uniform over time and between forecasts. That is, growth forecasts vary but not considerably. From a modelling perspective, therefore, adequately capturing the economic growth forecast is less important than adequately capturing fuel prices. Nevertheless we ensure that the growth forecasts in CIMS are reasonable and reflect recent updates.

All sector sub-models in CIMS describe a base year physical demand and use annual growth rates to calculate forecasts overtime. Currently, CIMS bases these rates on the economic forecast inherent in NRCan's *CEOU99* update 2000. CIMS directly adopts projections of commercial floor space, transportation demand and households, but uses industrial gross output forecasts as guidelines for the physical growth rates in CIMS. These have been updated where possible by new assumptions relating to revisions in the federal government's 'official' greenhouse gas emissions forecast, which assumes greater economic growth (by one percentage point) across all sectors, and a significant increase in anticipated oil and gas production. Detailed research into industry trends also inform relative production growth within an industry sub-mode (e.g. relative growth in secondary vs. primary steel, newsprint vs. other paper, etc.) that have important implication for future energy demand.

The growth rate in the first period has also been reviewed and adjusted where applicable against growth trends shown in recent data (2000-2003/4). Tables A4 and A5 provide the provincial annual growth estimates assumed for commercial and residential whereas Table 6 provides the national industrial rates. Sub-Appendix A4 provides the provincial detail for industry.

Table A6
Average Annual Growth Projections for Commercial By Province and Period

Prov.	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025
BC	2.6%	2.7%	2.2%	1.5%	1.1%
AB	1.7%	1.7%	1.5%	1.5%	1.3%
SK	2.0%	1.7%	1.5%	1.5%	1.5%
MB	1.4%	1.3%	0.9%	0.6%	0.7%
ON	1.9%	2.2%	2.3%	2.1%	2.0%
PQ	1.7%	1.2%	1.0%	0.9%	0.7%
ATL	1.9%	1.5%	1.3%	1.1%	1.0%

Source: CEOU 99, in-house

Table A7
Average Annual Growth Projections for Residential By Province and Period

Prov.	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025
BC	1.53%	1.55%	1.51%	1.72%	1.72%
AB	2.08%	1.39%	1.50%	1.40%	1.31%
SK	1.09%	1.10%	1.03%	0.98%	0.94%
MB	0.97%	0.97%	0.99%	0.94%	0.90%
ON	1.70%	1.28%	1.55%	1.44%	1.34%
PQ	1.07%	1.22%	1.31%	1.23%	1.16%
ATL	0.70%	0.36%	0.71%	0.69%	0.67%

Source: CEOU 99, in-house

Table A8
Average Annual Growth Projections for Industry National by Period*

Sector	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025
pulp and paper	0.3%	1.3%	1.3%	1.4%	1.5%
chemical manufacturing	-0.1%	1.7%	1.8%	1.6%	1.6%
iron & steel	0.0%	1.3%	1.2%	1.2%	1.2%
metal smelting & refining	1.8%	3.5%	0.8%	0.5%	0.5%
metals-mineral mining	-0.8%	0.3%	0.5%	0.6%	0.6%
coal mining	2.0%	1.3%	1.9%	1.9%	2.0%
other manufacturing	1.8%	1.0%	0.9%	0.9%	0.9%
industrial minerals	0.3%	1.1%	0.9%	1.9%	1.9%
petroleum refining	2.7%	1.1%	1.3%	0.9%	0.9%

Source: CEOU 99, in-house

* Provincial Tables are provided in Sub-Appendix A4.

3.2.4 DSM Programs in the Baseline

Initial technology stocks and their energy intensities reflect past purchasing choices that are autonomous, price induced, and DSM influenced. Calibrating CIMS to known energy intensities[17] by end-use ensures that the initial stock in the Reference Case base year, 2000, reflects past energy efficiency uptake. The Reference Case is not further influenced by DSM programs implemented after the base year 2000. That said, improvements attributable to DSM may have occurred in the 2000 to 2005 period. However, we are dealing with a long-term planning horizon with significant stock turnover. Thus, over the 25-year time horizon and given technology turnover by that period (and considering technology inertia between 2000 and 2005) we submit that the impacts of DSM improvements in the 2000 to 2005 period are likely insignificant to the overall modelling results.

A3.3 REFERENCE CASE RESULTS

The following sections provide the national level results for the Reference Case while Sub-Appendix A5 provides the provincial detail. Tables A9, A10, and A11 show the national results from the commercial, residential and industrial models respectively. These results are also displayed graphically in Figures A1 through A7. Recall from Section A2.2 and Sub-Appendix A6 that the base year in all regions is calibrated to within +/-5% to the latest 2000 energy supply and demand data from Statistics Canada. The high level national results by sector are as follows:

- **Commercial**. Table A9 shows that in the commercial sector the total energy use increases from 1,078 PJ in 2000 to 1,431 PJ in 2025, with an annual increase of 1.14%. The model results also show that the split between fuels remains relatively constant in the commercial sector, with natural gas increasing from 52% to 55% by 2025, and electricity's share falling slightly from 43% in 2000 to 37% in 2025. Energy intensity shows a small improvement over time with an average annual change (or decrease) of 0.56%. This is consistent with NRCAN energy intensity decomposition work that has shown small efficiency gains in commercial. The commercial sector described in this forecast includes activities related to trade, finance, real estate, public administration, education and commercial services (including tourism).

- **Residential**. Table A10 shows the total energy use increased from 1,383 PJ in 2000 to 1,663 PJ in 2025, or at an average rate of less than one percent annually. Once again the split between fuels remains relatively constant. The share of natural gas fluctuates around 48%, and the share of electricity rises slightly from 36% to 39%. Annual growth rates for both fuels are in the order of 1% annually whereas growth in refined petroleum products (RPP) are lower (0.33%) and other fuels (wood) decline about 0.8% annually. Energy intensity shows an improvement greater than the commercial sector and in the order of 0.59% annually;

- **Industrial**. Table A11 shows that in the industrial sector total energy use rising from 2,714 PJ in 2000 to 3,296 PJ in 2025, or at a rate of 0.73% annually. In this sector natural gas and electricity both exhibit declines in their share of the total fuel use,

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[17] *Energy Data Handbook, 2005*

> although the absolute demand for both these fuels continues to rise throughout the forecast period. Refined petroleum products and fuels classified as other both see a slight increase as a percent of the total energy demand. The industrial sector forecast represents manufacturing and metals and mineral mining, and does not include energy supply sub-sectors (upstream oil and gas, coal mining and electricity supply sub-sectors). Construction and forestry are also not included.

These Reference Case results represent a conservative forecast of future demand, where demand rises gradually overtime at modest levels.

Table A9: National Results, Commercial

	2000	2005	2010	2015	2020	2025	Average Annual Change
Total Energy (GJ)	1,077,749,345	1,130,050,842	1,191,500,550	1,274,630,739	1,351,791,693	1,430,622,025	1.14%
Electricity (GJ)	447,556,354	461,973,477	477,142,265	499,509,137	518,806,592	539,780,440	0.75%
Natural Gas (GJ)	550,841,525	583,521,295	626,115,630	680,031,414	732,122,294	785,223,046	1.43%
Refined Petroleum Products (GJ)	79,351,467	84,556,070	88,242,655	95,090,188	100,862,807	105,618,539	1.15%
m2 floorspace	578,300,000	635,882,177	698,622,626	762,356,942	823,280,758	883,330,211	1.71%
GJ / m2	1.86	1.78	1.71	1.67	1.64	1.62	-0.56%

Figure A1: National Results, Commercial
GJ by Fuel Type

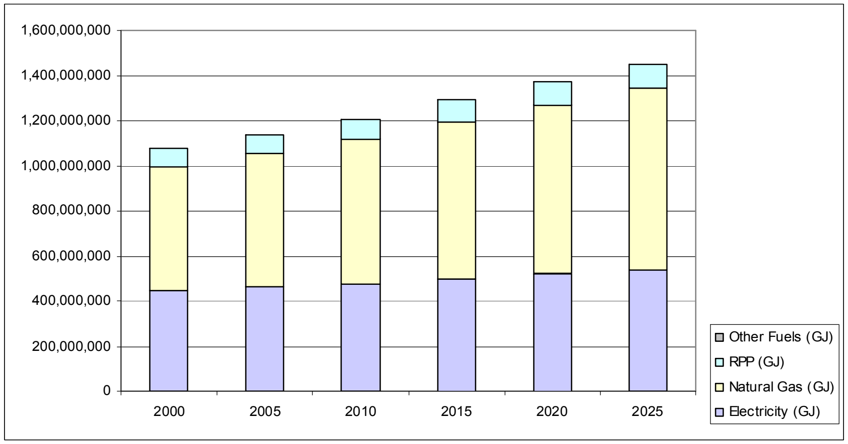


Figure A2: National Results, Commercial
Share of Total Energy by Fuel (%)

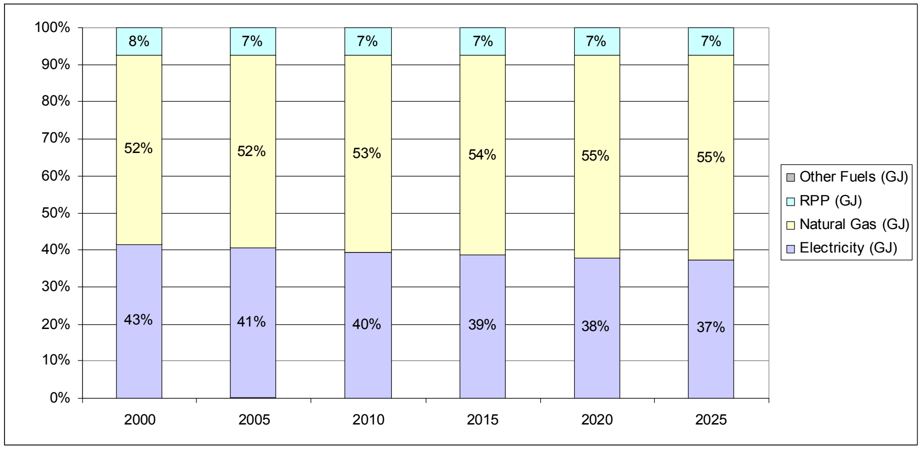


Table A10: National Results, Residential

	2000	2005	2010	2015	2020	2025	Average Annual Change
Total Energy (GJ)	1,384,447,089	1,419,396,388	1,443,592,442	1,501,071,708	1,576,323,254	1,662,628,478	0.74%
Electricity (GJ)	496,564,662	515,613,407	528,583,164	556,589,368	599,751,814	643,245,710	1.04%
Natural Gas (GJ)	658,983,664	676,374,193	692,201,750	721,570,561	753,287,731	795,017,341	0.75%
Refined Petroleum Products (GJ)	132,436,834	134,919,860	134,047,528	137,871,109	142,306,819	144,950,547	0.36%
Other Fuels (GJ)*	96,461,929	92,488,928	88,760,000	85,040,670	80,976,890	79,414,880	-0.77%
Households	12,666,100	13,600,002	14,458,286	15,487,535	16,552,870	17,635,282	1.33%
GJ / hsld	109.3	104.4	99.8	96.9	95.2	94.3	-0.59%

* wood use.

Figure A3: National Results, Residential

PJ by Fuel Type

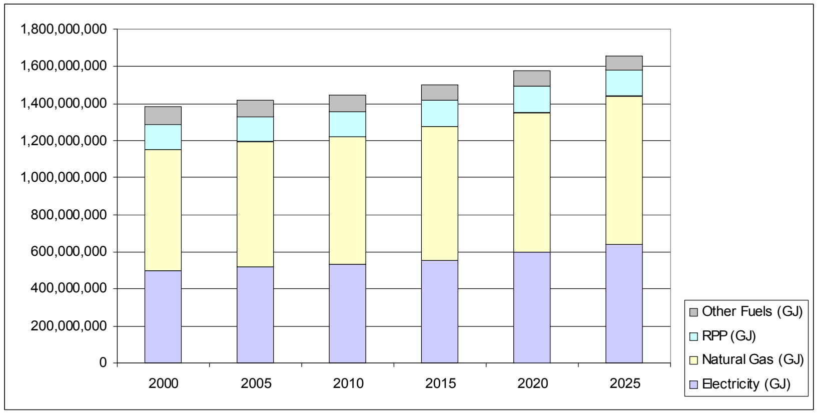


Figure A4: National Results, Residential

Share of Total Energy by Fuel (%)

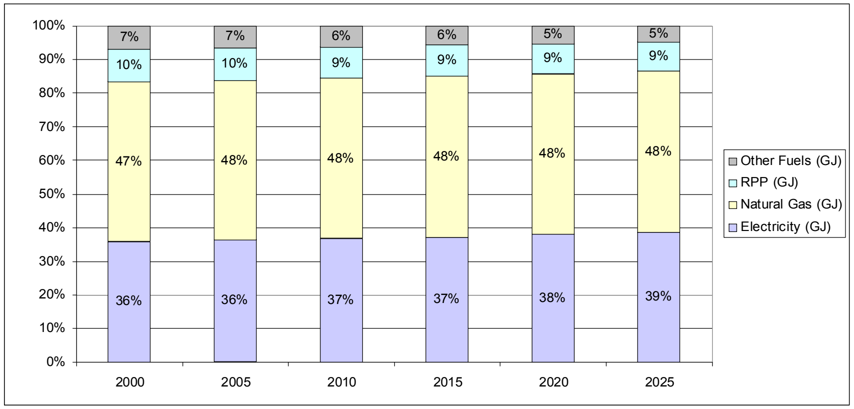


Table A11: National Results, Industrial

	2000	2005	2010	2015	2020	2025	Average Annual Change
Total Energy (GJ)	2,714,146,057	2,785,266,943	2,931,498,026	3,053,013,478	3,154,109,285	3,295,679,423	0.78%
Electricity (GJ)	669,933,217	675,940,734	715,992,295	727,822,436	738,377,835	756,991,514	0.49%
Natural Gas (GJ)	921,917,735	919,533,447	924,871,678	945,152,007	960,049,804	999,428,232	0.32%
Refined Petroleum Products (GJ)	161,397,392	166,006,419	177,376,619	191,180,661	206,131,032	219,705,306	1.24%
Coal, Petroleum Coke, Waste Fuels, Off gases (GJ)	462,956,655	514,405,408	566,899,892	607,228,278	653,092,289	700,210,503	1.67%
Wood Waste/ Spent Pulping Liquor (GJ)	497,941,058	509,380,935	546,357,542	581,630,096	596,458,325	619,343,868	0.88%

Figure A5: National Results, Industrial
GJ by Fuel

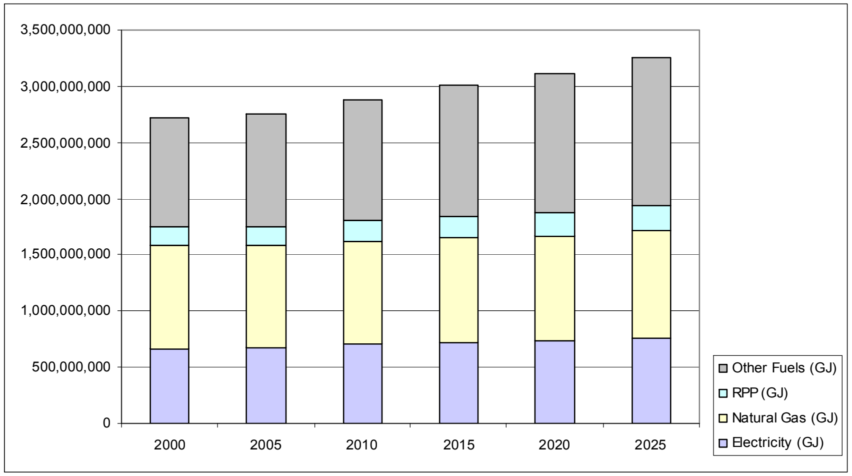
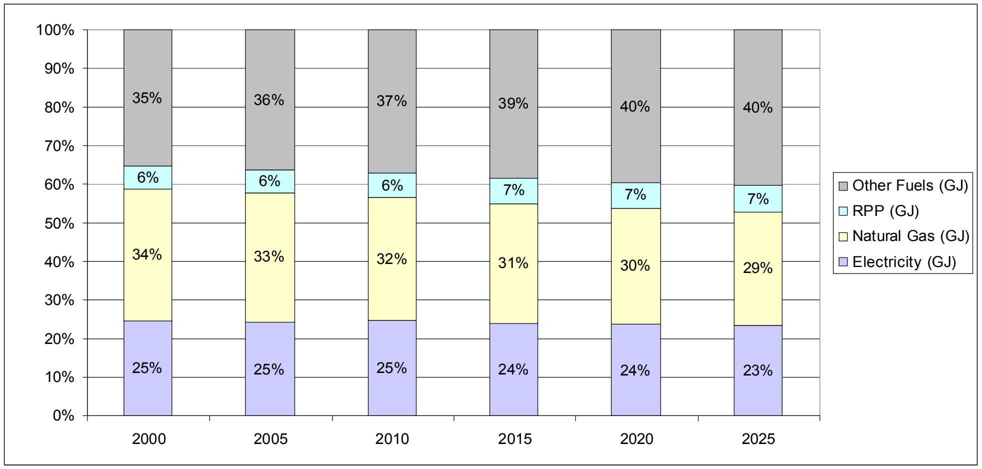


Figure A6: National Results, Industrial
Share of Total Energy by Fuel (%)



A3.4 COMPARISON WITH PREVIOUS REFERENCE CASES

This section compares our reference case with publicly availably reference cases, namely the two NEB scenarios (Techno-vert and Supply Push) and the *CEOU99 update*. National level comparisons are presented below by fuel and sector. Generally, we find good consistency with previous national forecasts. Note however, that differences between the previous forecasts are inevitable since each forecast uses different data and assumptions. Detailed results by province are provided in Sub-Appendix A5.

National, Commercial

Table A12 is derived by dividing the commercial fuel demand from CIMS by the average of the three forecasts. The table illustrates that there is good consistency with the previous forecasts over the period in which the forecasts overlap, with CIMS being at worst within 11% of the average total demand in the other forecasts. Base year levels are nearly identical with the other forecasts, total demand, oil, and natural gas are consistently higher and electricity is lower. The difference in gas is primarily the result of the three scenarios predicting a drop in natural gas demand in the 2000 to 2005 period, followed by a slow rate of increase over time (averaging about 5% for the total 20-year forecast period). CIMS does not match this drop and predicts modest demand growth over time, averaging 1.14% annually. This is more inline with recent utility forecasts (see Section 3.5 below). For electricity, CIMS base year has a lower value and assumes a slightly lower growth rate over time, and thus predicts lower values than all three forecasts. Figure A10 indicates that the trajectory of total demand at the national level in the commercial sector is consistent with higher than previous forecasts. This difference can be partially explained by higher recent growth in the commercial sector, which is much higher than the earlier forecasts had predicted.[1]

Table A12
Comparison of CIMS Commercial Reference Case, National
CIMS Energy by Fuel divided by Average of Other Cases

Year	Electricity	Natural Gas	Oil	Total
2000	97%	106%	102%	99%
2005	94%	118%	111%	106%
2010	90%	126%	115%	108%
2015	88%	134%	127%	111%
2020	85%	137%	138%	111%

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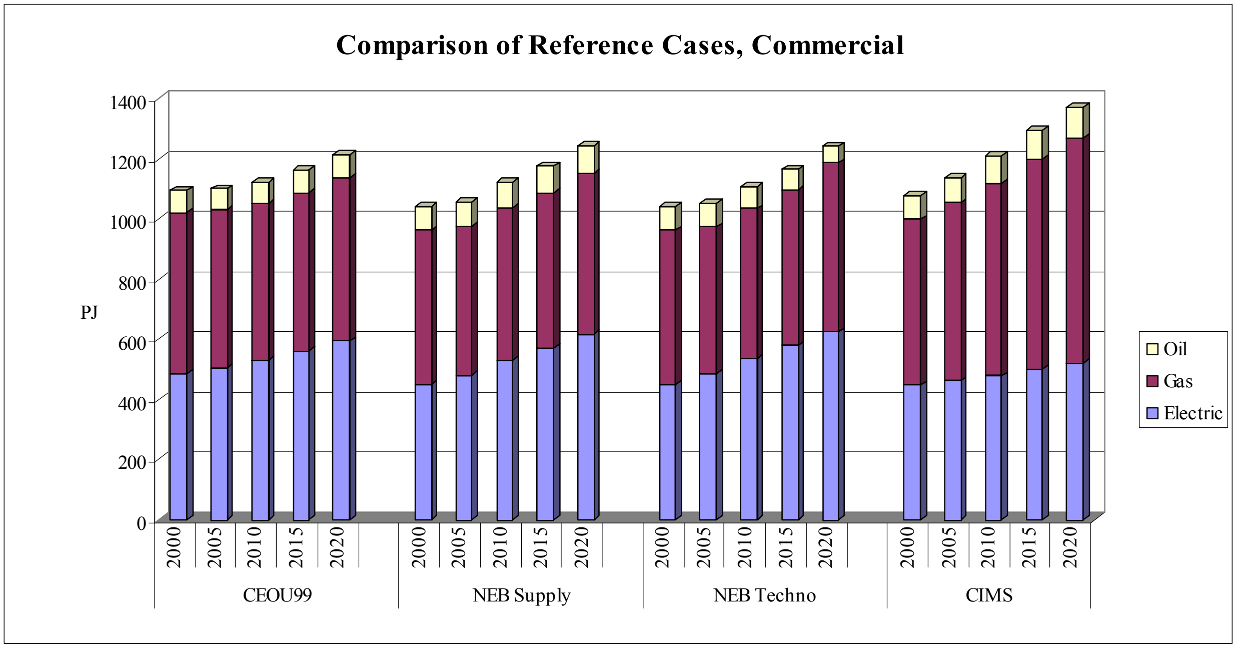
[1] *pers. com.* Informetrica

Figure A7: Comparison of Reference Cases, Commercial National



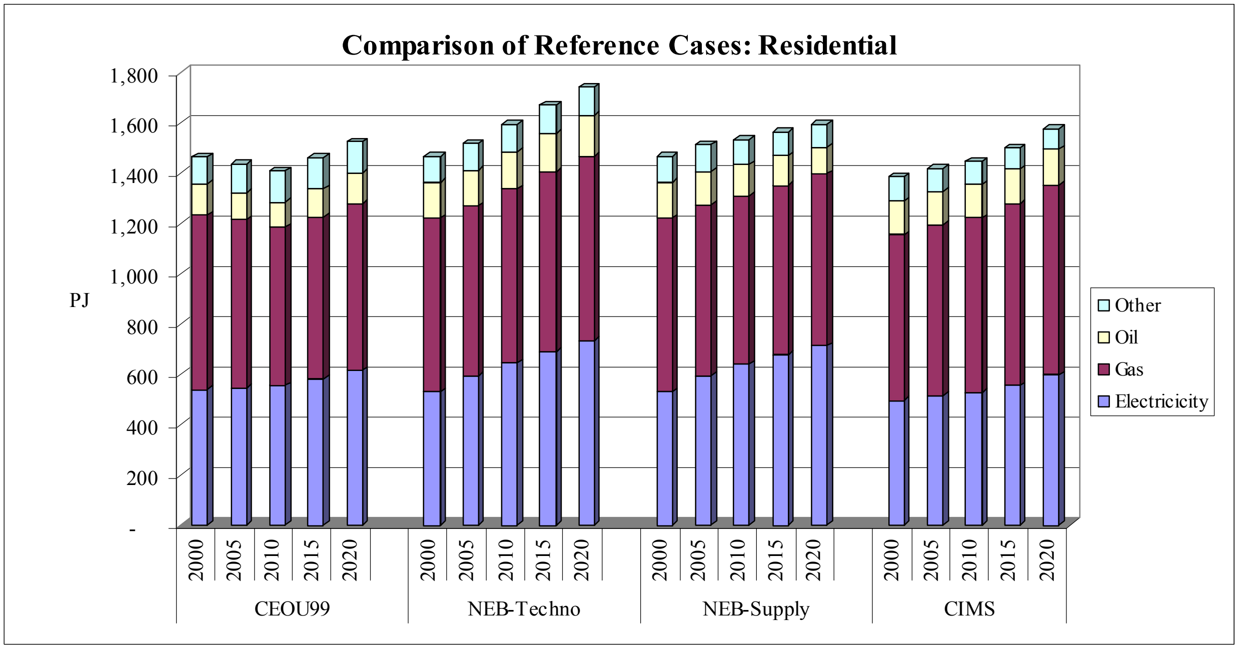
National, Residential

In Table A13, total residential fuel demand from CIMS is lower than the other forecasts, but becomes closer over time, and never deviates from the average by more than 5%. Natural gas and oil follow the other forecasts closely, whereas electricity is consistently lower over time, likely the result of a relatively lower oil price in the forecast. Again, electricity in the base year is lower in CIMS (from Statistics Canada data) and the relative difference appears greater by 2020 because electricity grows more slowly in the CIMS forecast. For other fuel (i.e. biomass) there is no general agreement between all of the scenarios, with each one assuming either growth or decline. Other fuels (i.e. biomass) as a share of total energy however, is small (about 7% in 2000 and dropping to 5% after 2010) and therefore the divergence does not significantly impact the Reference Case.

Table A13
Comparison of CIMS Residential Reference Case, National
CIMS Energy by Fuel divided by Average of Other Cases

Year	Electricity	Natural Gas	Oil	Other	Total
2000	93%	96%	97%	93%	95%
2005	89%	100%	106%	85%	95%
2010	86%	105%	108%	80%	96%
2015	85%	107%	109%	78%	96%
2020	87%	109%	110%	74%	97%

Figure A8: Comparison of Reference Cases, National Residential



National, Industrial

While total demand is lower than the average in Table A13, the difference is attributable to differences in industry universe (notably the exclusion of upstream oil and gas sectors, allocation of off-road diesel and gasoline use associated with industry[2], treatment of non-fuel use, cogeneration within an industry sub-sector, the inclusion of purchased steam, and the treatment of self-generated fuels and wood waste). To allow for greater comparability (and because it is not a focus of this study), the natural gas extraction and distribution sub-sector is no longer included in the industrial reference case.

Over time, CIMS shows significantly less growth in energy relative to the other forecasts, particularly for natural gas and electricity. However, the CIMS forecast projects a comparable growth in historical energy growth trends. Data for Total Manufacturing and Mining (excluding upstream oil and gas) show that energy consumption grew only 9% from 1994 to 2004.[3] The CIMS forecast shows growth of about 8% per 10 year period.

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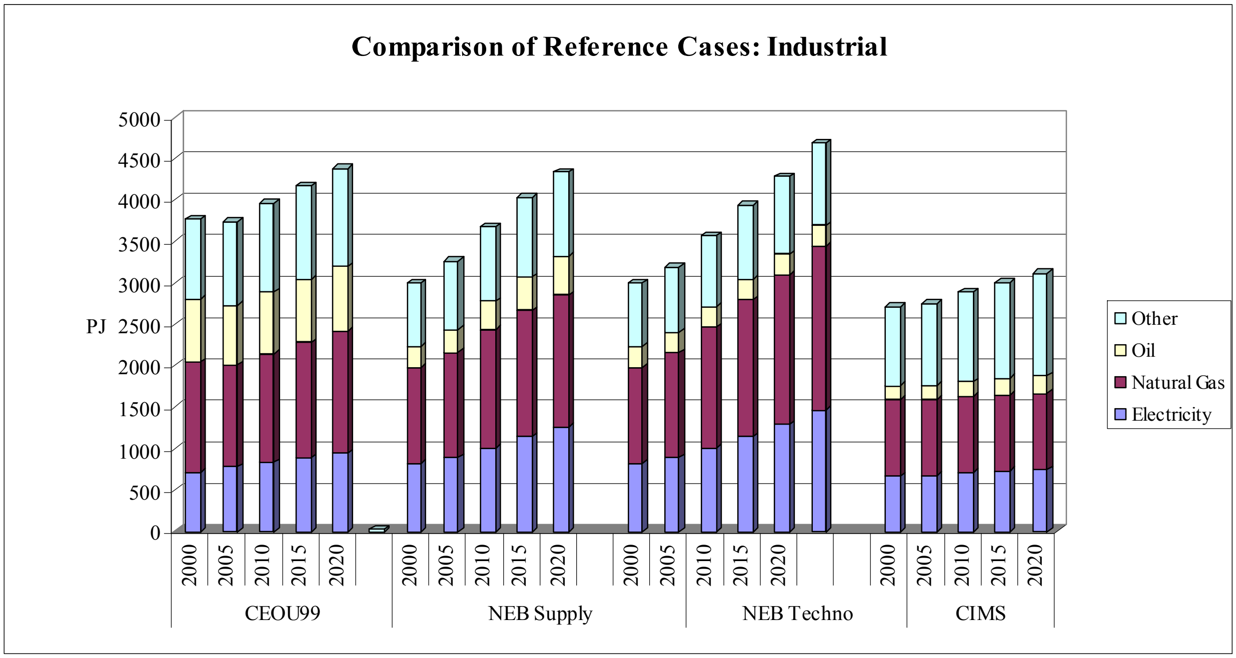
[2] CIMS allocates most of this energy use to the transportation sector.

[3] 2004 are preliminary data. Canadian Industrial Energy End-use Data and Analysis Centre.

Table A14
Comparison of CIMS Reference Case, Industrial
CIMS Energy by Fuel divided by Average of Other Cases

Year	Electricity	Natural Gas	Oil	Other	Total
2000	85%	76%	38%	116%	84%
2005	79%	73%	40%	114%	81%
2010	75%	65%	41%	114%	77%
2015	69%	61%	42%	116%	74%
2020	63%	58%	43%	117%	72%

Figure A9: Comparison of Reference Cases, Industrial



A3.5 COMPARISON WITH UTILITY DATA

In this section the results from the CIMS forecast and Statistics Canada base year estimates (for 2000) are compared with all available forecasts from other relevant studies. The past forecasts used for comparison include utility supplied data as well as information from past Marbek Demand Side Management Evaluations for BC Hydro, Manitoba Hydro, Terasen Gas and Enbridge Gas.

The comparisons below are presented as "spot-checks" on each relevant jurisdiction. In many cases values were extrapolated or interpolated to present the data from different sources in a comparable way. Whenever this occurs in the tables below the extrapolated or interpolated values are presented in *italics*.

The comparisons below compare both the absolute value of annual energy use for the province and fuel (in PJ) as well as the average annual change in fuel use from 2000 to 2025. In general, the tables below show a very close similarity in annual growth between the CIMS values and the comparison data. The absolute values of energy use tend to be a little further off, although almost all comparisons are within a difference of less than 20%. The absolute values found in the CIMS results are dependent on the calibration to the year 2000 data (from Statistics Canada), therefore discrepancies in the absolute value represent a discrepancy between the utility data from the spot checks and the sources used for calibration (see Section 2.2, Calibrating to a Base Year). Other significant differences between the CIMS data and utility data can be explained as follows:

- **Sectoral definitions may differ**. For example, some utilities include greenhouses in commercial whereas Statistics Canada accounts for their energy use in agriculture.
- **Sectoral or geographical coverage**. Some rate pay classes may be excluded from past DSM studies.

Comparisons for residential, commercial and industrial sectors are provided below.

Residential Comparisons

Spot-check R1: Manitoba Electricity Use (PJ)

	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Avg. Annual Change**
CIMS	19.2	20.0	21.1	21.9	23.0	23.8	0.86%
MB Hydro	*22.0*	22.8	23.7	24.6	25.4	26.2	0.7%
% Difference	13%	12%	11%	11%	9%	9%	22%
Comments: Growth is similar and absolute value is in the right range. **Source:** Manitoba Hydro							

Spot-check R2: Manitoba Natural Gas Use (PJ)

	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Avg. Annual Change**
CIMS	25.0	24.2	22.7	22.3	22.4	23.24	-0.31%
MB Hydro	*24.5*	24.5	24.5	24.5	*24.4*	*24.4*	-0.02%
% Difference	2%	1%	7%	9%	8%	5%	1783%
Comments: Growth and absolute values are in the same range and direction. (The % difference of the Avg. Annual Change appears very large, but both values show small growth). **Source:** Manitoba Hydro							

Spot-check R3: BC Electricity Use (PJ)

	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Avg. Annual Change**
CIMS	60.2	61.6	65.3	71.0	78.0	84.0	1.34%
BC Hydro	55.4	59.1	64	69.5	*73.9*	*79.1*	1.43%
% Difference	9%	4%	2%	2%	5%	6%	6%
Comments: Growth is very similar. CIMS has a slightly higher absolute value. The BC Hydro Service Plan also estimated 1.5% annual growth in the absence of any PowerSmart initiatives. **Source:** BC Hydro							

Spot-check R4: BC Natural Gas Use (PJ)

	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Avg. Annual Change**
CIMS	80.6	84.1	86.2	88.7	94.7	103.1	0.99%
Terasen	*91.9*	99.19	105.7	113.4	*120.3*	*127.4*	1.32%
% Difference	12%	15%	18%	22%	21%	19%	25%
Comments: Growth is similar, but CIMS absolute values are lower. (Differences within <22%). **Source:** Terasen Gas Conservation Potential Review (Marbek, 2005)							

Spot-check R5: Ontario Natural Gas Use (PJ)

	2000	2005	2008	2010	2014	2015	Avg. Annual Change
CIMS	323.8	335.0		350.0	*367.7*	372	0.93%
Enbridge	*152.9*	169.2	177.5		195.2		1.76%
% Difference	111%	98%			88%		47%

Comments: The magnitude is off, but this should be expected, as Enbridge does not represent all of Ontario residential gas sales. The growth is in the same order of magnitude, though with a significant percent difference. No data to compare to 2025.
Source: Enbridge Gas Demand Side Management Study (Marbek, 2005)

Spot-check R6: Quebec Electricity Use

Hydro Quebec forecasts an average sales growth of 1.2% per year (for all sectors combined). CIMS growth for the residential sector electricity use in Quebec is 1.2% per year.

Spot-check R7: Quebec Natural Gas Use

Gas Metro has indicated a 10% drop in NG use from 2000 to 2005. The CIMS model shows a 5% drop between 2000 and 2005.

Commercial Comparisons

Spot-check C1: Manitoba Electricity Use (PJ)

	2000	2005	2010	2015	2020	2025	Avg. Annual Change
CIMS	14.0	14.9	15.8	16.5	16.7	17.0	0.78%
MB Hydro		19.7	20.7	21.6	22.6	23.7	0.93%
% Difference		24%	24%	24%	26%	28%	16%

Comments: Statistics Canada values are lower than the MH estimates, thus differences in 2005 are 23%. Growth is very close.
Source: Manitoba Hydro

Spot-check C2: Manitoba Natural Gas Use (PJ)

	2000	2005	2010	2015	2020	2025	Avg. Annual Change
CIMS	29.5	30.0	30.3	31.1	31.8	33.0	0.44%
MB Hydro	*26.7*	26.1	26.7	27.4	*28*	*28.6*	0.46%
% Difference	11%	15%	14%	14%	14%	15%	4%

Comments: Statistics Canada base year values are higher than the MB projections, but the growth is of the same order of magnitude.
Source: Manitoba Hydro

Spot-check C3: BC Electricity Use (PJ)

	2000	2005	2010	2015	2020	2025	Avg. Annual Change
CIMS	50.6	55.6	62.4	68.6	72.4	75.0	1.59%
BC Hydro	45.8	52.2	58.4	64.1	*70.3*	*76.4*	1.92%
% Difference	10%	7%	7%	7%	3%	2%	17%

Comments: Growth rate is close. CIMS absolute value is a little high, but in the same range.
Source: BC Hydro

Spot-check C4: BC Natural Gas Use (PJ)

	2000	2005	2010	2015	2020	2025	Avg. Annual Change
CIMS	62.9	66.3	69.9	77.7	84.4	90.3	1.46%
Terasen	*28.4*	32.2	36	39.8	*43.6*	*47.4*	1.95%
% Difference	121%	106%	94%	95%	93%	90%	25%
Comments: Growth is similar, but absolute value is far off from expected values. Terrasen study does not include all commercial rate payers. Size of omission is not known, growth rates are similar. **Source:** Terasen Gas Conservation Potential Review (Marbek, 2005)							

Spot-check C5: Ontario Natural Gas Use (PJ)

	2000	2005	2008	2010	2014	2015	Avg. Annual Change
CIMS	237.9	256.7	*272.6*	283.3	*308.7*	315.0	1.89%
Enbridge		157.9	165.5	173.5	189.2		2.03%
% Difference		63%	65%	63%	63%		7%
Comments: Growth is very similar, but magnitude is off, which could be expected since Enbridge does not represent all of Ontario commercial gas sales. **Source:** Enbridge Gas Demand Side Management Study (Marbek, 2005)							

Industrial Comparisons

The electricity consumption forecast by CIMS falls between the BC Hydro and National Energy Board forecasts. The annual growth rate suggested by CIMS matches the BC Hydro forecast very well for 2005 to 2015, and is much lower than National Energy Board forecast between 2015 and 2025.

Spot-check I1: Manitoba Electricity Use (PJ)

	2000	2005	2010	2015	2020	2025	Avg. Annual Change
CIMS		22.29	24.67	27.09	29.68	32.02	1.83%
MB Hydro		29.38	34.92	34.44	36.48	38.31	1.34%
% Difference		24%	29%	21%	19%	16%	37%
Comments: Growth is very close but Statistics Canada values are lower than the MH estimates, thus differences in 2005 are 27%. **Source:** Manitoba Hydro							

Spot-check I2: Manitoba Natural Gas Use (PJ)

	2000	2005	2010	2015	2020	2025	Avg. Annual Change
CIMS		18.63	18.97	20.03	21.06	22.09	0.85%
MB Hydro		30.2	32.7	33.3			0.98%
% Difference		38%	42%	40%			13%
Comments: The growth is of the same order of magnitude but Statistics Canada base year values are lower than the MB projections, likely due to universe differences. **Source:** Manitoba Hydro							

A3.6 INTERPRETATIONS AND CAVEATS

This section provides insight on how the second reference case was developed, and specifically, the areas addressed to improve the first reference case. Each sector is discussed in turn.

Commercial

The model shows total energy use in the commercial sector increasing at a rate of 1.14% per year. This growth rate is significantly lower than the historic energy growth rate, estimated in the *Energy Use Data Handbook, 1990 and 1997 to 2003* to be 2.78% per year over the last 13 years. This difference can be partially attributed to the decreased energy intensity in the commercial sector found in the model results: the *Energy Use Data Handbook* estimates that the average commercial energy intensity (in GJ/m^2) grew by 0.7% per year from 1990 to 2003 whereas CIMS forecast indicates a decrease of approximately 0.5% per year, a more realistic trend. However it is likely that energy efficiency will be accelerating, particularly after 2015, due to:

- Aging of the existing stock which will force significant renovation and demolition activity;
- The green construction revolution will significantly accelerate and likely transform the market after 2015;
- Research efforts to improve the efficiency in some end-uses such as lighting will bear fruit after 2015 with available products; and,
- Continued pressure on energy prices will bring about more aggressive energy efficiency.

The forecast reflects a careful examination of technology outcome by region, and in particular, the intensity of new stock, rate of stock turnover, consideration of growth rate (particularly in first period). Also, in the past, parameters in the model had been introduced to 'calibrate' this model to the federal government's official forecast (CEOU99). This includes not permitting oil for heating (in some regions) and introducing factors to influence the share of natural gas.[4] These are now eliminated. While we have taken the utility forecast and NEB forecast into consideration, the new CIMS forecast does not represent a calibration to another forecast. Rather, a divergence between forecasts focused our assessment of CIMS' forecast assumptions. The following represent key drivers in the commercial forecast:

- The forecast is sensitive to the type of heating assumed. The fuel shares of replacement heating equipment in existing buildings and in new buildings has now been calibrated to estimated fuel shares for heating equipment for 2003 in NEUD. While relative energy costs dictate the acquisition of new equipment towards these shares overall (for instance electricity for heating is higher in regions with lower electricity prices), factors were introduced to influence the switch where there was a significant divergence. This is used to mainly limit oil (in keeping with its handling factor) and electricity for heating.

- New equipment is more efficient than the stock that it replaces. This includes both end-use intensity changes from equipment replacement in existing buildings and from new equipment in new buildings. Most reductions in energy intensity occur in heating, cooling

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[4] This had been necessary because the CEOU forecast, whose price forecast had been adopted for the model, had low natural gas prices. Cost adders had been introduced to some technologies to prevent excessive fuel switching to natural gas.

and lighting end-uses, rather than plug load and water heating. The energy intensity of HVAC systems is on average 26% less than existing stock and is influenced by both improved equipment efficiencies (in new and existing buildings) and improved shells (in new buildings). Lighting energy intensity is on average 16% lower. The degree is specific by region and influenced by energy prices. Fuel switching in the forecast can also lead to a change in energy intensity.

- CIMS does not encompass weather variation in its forecast but instead assumes same heating degree day/cooling degree days inherent in 2000 base year.
- Intangible cost parameters (or cost adders applied to capital costs to account for non-financial preferences for technologies) are used to limit the new stock penetration of some heating equipment, notably cogeneration, solar heating and ground source heat pumps so that neither receive more than 3%, 1% and 1% of total market share, respectively. The penetration would otherwise be unrealistically high (6-10%) for all technologies.
- Intangible cost parameters are also used to represent preferences for natural gas in commercial cooking applications, to limit efficiency improvements of new HVAC/shell so that they fall in accordance with expected efficiency improvements relative to existing building stock, and to represent unfamiliarity and incomplete substitutability of super-T8, compact fluorescent and high intensity fluorescent lighting. Ultimately, these parameters are used to adjust unrealistic market shares that the model predicts.
- The commercial floor growth rates were adjusted in regions where the first period growth rate diverged significantly from 5 year historical trends in the NEUD database (1998-2003).

Region-specific forecast differences are highlighted by region in Sub-Appendix A5.

Residential

The results from the residential reference case show an average annual growth of 0.74% per year, which is similar to the NEUD historic trend of a 1% growth per year over the last 13 years. This forecast reflects a more careful examination of technology outcomes by region, and in particular, the intensity of new stock and end-use trends. Also, in the past, parameters in the model had been introduced to 'calibrate' the residential model to the federal government's official forecast (CEOU99). This included adjustments made to the heat load of new housing stock. These adjustments have been removed.

While we have taken the utility forecast and NEB forecast into consideration, the new CIMS forecast (reference Case 2) does not represent a calibration to another forecast. Rather, a divergence between forecasts focused our assessment of CIMS' forecast assumptions. Key revisions and attributes to note in the forecast are discussed below by end-use:

- **Appliances**. Recent statistical data is showing strong electricity growth, which is not depicted in the simulation in the first period (once other electricity forecast issues resolved). The portrayal of minor appliance growth was therefore revisited in the model, and the penetration of this end-use increased.[5] Recent growth in electricity consumption by these appliances is estimated to be 4% a year (based on 1998-2003) in NEUD. This growth rate is now reflected in the Reference Case forecast.

While electricity consumption is increasing due to the greater penetration of minor appliances, newly acquired appliances replace more inefficient equipment resulting in a decrease in the electricity intensity per appliance, particularly for refrigerators and freezers. On average new appliances are lower in energy intensity (per appliance) by 15%.[6]

- **Space Heating.** Energy intensity in space heating declines in the forecast due to two key factors. First, the replacement of the current furnace equipment stock with new equipment results in significant efficiency savings – a standard new furnace (78% efficiency) represents a 26% savings over average efficiency of current stock (62% efficiency). Second, insulation and building practice in new home construction is considerably more energy efficient, reducing heat loads an average of 33% from improved building envelopes. The replacement of space heating systems in existing homes is restricted in the following way:

1. No switching from electric baseboards systems to furnace/forced air systems is permitted.
2. Limited switching between fuel source in furnace/forced air systems. Switching is based on system cost differences (energy and capital costs), but only switching within 10% of base year fuel shares is allowed.[7]

The space heating system choice in new homes is a more direct result of the lifecycle cost competition (evaluated at a private discount rate of 30%). The competition outcomes are considered against base year shares and new heating systems trends described in the *1997 Survey of Household Energy Us*e and the *Survey of Canadian New Household Purchases*.[8] This includes trends in equipment choice by housing type (for instance, electricity for space heating is becoming more common, particularly for apartments and attached homes).

Where current trends are significantly different than the results in CIMS, intangible cost parameters (costs "adders") are used to influence the outcome so that market shares are more reasonable. For instance, in Alberta and Saskatchewan electricity and oil for heating capture significant market share, though the sources noted above indicate that space heating is significantly dominated by natural gas systems, particularly in single family detached homes. Cost adders are therefore used to lower the shares of oil and electric

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[5] Minor (or "Other") includes small appliances such as televisions, videocassette recorders, digital videodisc players, radios, computers and toasters.

[6] This number does not include savings in hot water consumption.

[7] The outcome is influenced by intangible cost parameters.

[8] Office of Energy Efficiency, National Energy Use Database, *Survey of Canadian New Household Purchases 1994 & 1995: Statistical Report* (Ottawa: Natural Resources Canada: 1997); Office of Energy Efficiency, National Energy Use Database, *1997 Survey of Household Energy Use – Summary Report* (Ottawa: Natural Resources Canada: 2000).

systems in these jurisdictions. However the model can switch out to these systems given significant energy price signals.

In the Atlantic region, natural gas systems are assumed to not be widely available for competition until 2006 and beyond. Intangible cost adders are again used to limit the take up, particularly in existing homes, so that overall penetration of natural gas is similar to that suggested by the NEB Techno-vert scenario.

- **Water Heating**. The technology outcomes were reviewed against the base year fuel shares. Intangible cost parameters were used to ensure that the resulting shares did not diverge by more than 10%. Water heating choice is generally consistent with space heating fuel choice, which is specific by region. The model simulation also reflects a general trend towards natural gas heaters.[9] Some efficiency gains in the reference case occur with the replacement of current water heaters. New water heaters are on average 8% less energy intense than current heaters.
- **Lighting**. The competition outcomes were reviewed. In a few regions, the penetration of compact fluorescents was quite high in early simulation periods. Intangible cost adders were therefore introduced to lower the resulting market share. The share of compact fluorescent lighting increases from 5% in the base year to around 30% of market share in 2015. New lighting is on average 11% less energy intense (GJ/per light bulb) than current lighting.
- **Air Conditioning.** The turnover of current air conditioning results in significantly less energy consumption for this end-use. New systems are on average 33% more energy-efficient.

Finally, our review of the first Reference Case results found several technology outcomes that resulted in an short-term energy drop in the forecast that were corrected:

1. The penetration of cogeneration was too high (over 15% of new stock) in apartments in provinces with higher electricity prices.[10] Intangible cost adders were used to limit the penetration to below 2%.
2. All existing households rapidly adopted low-flow showerheads and tap aeration devices in the first simulation period. The penetration has been slowed so that penetration of these devices climbs to 75% of households in 2010 from 28% in 2000. Newly built homes are equipped with these devices.

Sub-Appendix A5 provides the detailed residential results by province.

Industrial, National

In the forecast, many industries show fuel switching out of natural gas toward fuel oil. In the long-term this may be reasonable given the relative prices between natural gas and heavy fuel oil

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[9] This trend is noted in the *1997 Survey of Household Energy Use*.

[10] Cogeneration is limited to water heating for apartments. The system is sized to the hot water heat load.

in the forecast.[11] Industry will tend to prefer the ease of natural gas, but fuel switching will depend on the cost of steam and heat applications. Fuel switching is constrained by the rate of stock turnover and by some end-uses where switching is not possible. Recent historical energy consumption data show that the share of natural gas in total energy consumption declined from 30% in 1999 to 26% in 2004.[12] In some industries, fuel switching is particularly strong. For instance, historical data for the chemical industry show a significant trend away from natural gas in just five years (was 64% of total energy use in 1999; was 58% in 2004). The NEB forecast does not show the same fuel switching trend in the industry sector.

We investigated the strong rate at which fuel switching occurred in the first simulation period in some regions, and made revisions to the model as necessary, including to some technology parameters.[13] Also, we found there was a reporting error in still gas, which incorrectly reduced the 'other fuel' demand in petroleum refining. For example, 'other fuel' consumption in the Quebec petroleum refining sub-sector increases only 0.7% annually in the previous run; however, after revision, the annual growth rate is about 5%.

In the resource extraction sub-sectors, some changes were made to limit substitution from transport by diesel truck to transport by electricity conveyance. These changes reflect limitations associated with the electricity-based systems and result in increased energy usage. Previously, the analysis had included the upstream oil and gas sector; however these are no longer included to allow for better comparability to NEB and utility forecasts.

The total final industrial energy demand growth rate simulated by CIMS is significantly lower than the National Energy Board's techno-vert forecast (0.8% average annual growth vs. 1.8% average annual growth). One reason is that NEB techno-vert forecast assumes more optimistic macroeconomic assumption: their techno-vert forecast assumes 2.7% annual GDP growth while production forecasts for the industry sub-sectors in CIMS do not exceed 1.4% annually, and in many cases is less.[14] The industry sub-sector models include co-generated electricity. This is most significant in the chemical manufacturing, pulp and paper and to a lesser extent petroleum refining and the other manufacturing sub-sectors. The electricity generated reduces electricity demanded by these sub-models. So in cases where co-generation is growing in the forecast, the reported electricity consumption can decrease.

Because industry is heterogeneous sector and is fairly unique by region, provincial details are provided below.

British Columbia

The pulp and paper sub-sector dominates the energy picture. The make-up of the industry sector changes little over the forecast, though there is more relative production growth in chemical

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[11] The reference case scenario does not take energy price feedbacks into account; therefore, the strong growth in fuel oil demand does not affect the fuel oil price.

[12] CIEEDAC website (http://www.cieedac.sfu.ca), *Industrial Energy Consumption Database*, 'Total All Manufacturing Industries - Except mining'

[13] For example, retrofitting of tomlinson recovery boilers was limited in the first period. Also one water heater in other manufacturing incorrectly had a retirement lifespan of 6 years as opposed to 9 years.

[14] Average annual growth rates nationally are: 1.2% - pulp and paper , 1.3% - chemical manufacturing, 1.0% - iron & steel, 1.4% - metal smelting, 0.2% - mining, 1.8% - coal mining, 0.9% - other manufacturing, 1.2% -industrial minerals, 1.4% -petroleum refining

manufacturing, non-ferrous metal smelting and other manufacturing and less growth in pulp and paper and industrial minerals. There is negligible growth in petroleum refining. Additional observations include:

- Energy intensity declines in all industry sub-sectors with the exception of mining, which experiences a slight increase due to increased processing requirements from declining mineral ore content. In the other sub-sectors, energy intensity changes are between -0.1% and –0.8% annually.

- The drop in energy consumption in the first period is due mainly to mining and pulp and paper. In mining, recent national production data show that the production of copper, zinc and lead have declined significantly. In the pulp and paper sub-sector, natural gas use decreases due to an efficiency improvement in Tomlinson recovery furnaces (that use black liquor). This occurs in CIMS as a retrofit option as well through normal stock turnover. This offsets the steam required from standard boilers and co-generators.

- We corrected a few data errors – the mining growth rate had been wrong by a decimal place in the first period. Also, the negative growth rate for base metal smelting had incorrectly been applied in the aluminium sector as well.

Alberta

CIMS suggests that industrial electricity consumption declines slightly between 2000 to 2020, which is in sharp contrast with the National Energy Board's forecast of 2-3% annual increase during the same period. The reason is that CIMS includes growth in cogeneration in the chemical manufacturing, petroleum refining and other manufacturing sector which offsets purchased electricity. CIMS also assumes a lower production growth rate than the GDP forecast assumed in the Techno-vert scenario:

- The chemical manufacturing and other manufacturing sub-sectors dominate the energy picture. The sub-sector structure stays roughly constant over time, though there is more relative growth in other manufacturing. The relative shares of other sub-sectors decline slightly.

- Energy intensity declines in all industry sub-sectors by up to 0.8%.

Saskatchewan

The overall industrial energy consumption trend simulated by CIMS is similar with that of National Energy Board and higher than the forecast data provided by SaskPower. The CIMS forecast shows that industry in this province will consume a lower level of electricity and higher level of other fuels overtime than forecast provided by SaskPower. However, we feel that this is justified given that CIMS reports fuels consumed to produce cogenerated electricity, while reporting electricity as a net demand. Specific observations include:

- The mining and the other manufacturing sub-sectors dominate the energy picture. Energy intensity declines in all industry sub-sectors, between 0.3% and 0.4% annually, except for the mining sub-sector, where energy intensity keeps constant over time.

- In the mining sector, electricity consumption level increases moderately between 2000 and 2025 although its importance decreases over time. As we assume the share of diesel trucks in mining transport operations will stay at the current level, the refined petroleum product consumption level maintains a similar growth rate as tonnes mineral ores produced over time. We corrected for high growth rate in mining for first period.

Manitoba

In the previous simulation, CIMS showed that both electricity and gas consumption declining over time, in contrast to recent Statistics Canada, Report on Energy Supply and Demand (RESD) trends (2000-2003) and to NEB and Manitoba Hydro forecasts. We adjusted production growth for other manufacturing from 1.5% to 2.5% in the 2000-2005 period, given recent stronger economic growth in the province. We also introduced intangible cost parameters to influence future zinc smelting technology choice to be consistent with current production practices that use electric furnaces. After the revision, between 2000 and 2025, electricity and natural gas grow 1.18% and 1.34% annually, respectively. Other observations include:

- Generally, the other manufacturing sub-sector dominates the energy picture, but there is a structural shift in the composition of industry as mining becomes less dominant over time. The share of metal smelting stays almost constant.

- The drop in energy consumption in the first simulation period is associated with the mining sub-sector, where the production of copper, zinc and lead decline significantly based on national trends in the production in these metals (2000-2004).

- The other manufacturing sector was recalibrated because some natural gas consumption had been overlooked.

Ontario

Industrial energy consumption growth rate by CIMS and National Energy Board is 0.6% and 1.3% annually, respectively. CIMS generally suggests a much lower electricity growth but an increasing RPP consumption level from 2000 to 2025. In comparison, National Energy Board projects that the industrial oil consumption level decreases over time. Other relevant insight includes:

- There is no dominant industrial sub-sector in this province in terms of energy consumption. The sub-sector structure changes slightly over time; there is more relative production growth in chemical manufacturing, pulp and paper and petroleum refining. Energy intensity declines in all sub-sectors ranging from -0.2% to -1.2%.

- As in other regions, fuel switching to fuel oil occurs due to the relative prices of natural gas and oil. However, structural reasons underscore other fuel switching trends. Coal use increases for metallurgical applications (included in the 'other fuels'). This occurs after 2015, when the expansion of steel production in mini mills (electric arc furnaces) is assumed to reach its limit, and further production growth occurs in integrated operations (typically blast furnaces/basic oxygen furnaces that use metallurgical coal, though some direct reduced iron processes make some inroads in the reference case). Also, the stronger relative growth in pulp and paper increases biomass consumption.

- In the first period, pulp and paper and chemical manufacturing are responsible for most of the decline in energy use (particularly from natural gas). Production in chemicals declines slightly in the first period, while pulp and paper shows minimal growth.

Quebec

Pulp and paper is the largest energy user, following by non-ferrous metal smelting (including aluminium) and other manufacturing. Industrial energy consumption growth rate by CIMS and National Energy Board is 1.1% and 1.4% annually, respectively. Observations for Quebec include:

- Sub-sector structure only changes slightly, with metal smelting (and in particular aluminium) and petroleum refining consuming a greater share of total sector energy over time, and pulp and paper and other manufacturing, slightly less.

- We made a correction to the non-ferrous metal smelting growth rate -- the negative growth rate for base metal smelting had incorrectly been applied to the aluminium sector as well.

Atlantic

Pulp and paper dominates the energy picture. The sub-sector structure keep relatively constant over time. Energy intensity decreases in all sub-sectors. Reviews conducted on the Atlantic region include:

- We investigated why electricity consumption had been declining in the previous forecast. It was found too that the forecast in pulp and paper in particular diverged from observed trends in the 2000-2003 RESD, due to a switch away from electric-based paper drying. This was corrected.

- We reviewed the declining coke use in the mining sub-sector, and found that the trend derived in the previous run is not compatible with more recent energy statistics 2000-2003 (RESD). This has been corrected so that coke use in the mining sub-sector increases about 1% annually over the simulation period.

- We investigated the quick drop in oil use in industrial minerals, and found this trend is reasonable and is caused by: 1) lime kilns' shifting away from oil-fired kilns to coal-fired kilns; 2) the diminishing of oil-fired burners over time.

SUB-APPENDIX A1

Overview of Technology Competition Algorithm and Sector Models in CIMS

This section is comprised of four components:

1. A discussion of the technology competition algorithm;
2. The Residential model
3. The Commercial model, and;
4. The Industry models.

Technology Competition Algorithm

New market shares of competing technologies in CIMS are simulated at each end-use (competition node) based on their life cycle cost according to the following formula:[1]

$$MS_j = \frac{\left[CC_j * \frac{r}{1-(1+r)^{-n}} + MC_j + EC_j + i_j\right]^{-v}}{\sum_{k=1}^{K}\left\{\left[CC_k * \frac{r}{1-(1+r)^{-n}} + MC_k + EC_k + i_k\right]^{-v}\right\}} \quad (1)$$

Where MSj = market share of technology j, CC = capital cost, MC = maintenance and operation cost, EC = energy cost, i = intangible cost, r = private discount rate, and v = measure of market heterogeneity.

The main part of the formula (the part inside the square brackets) is simply the levelized life cycle (LCC) cost of each technology. In this formulation, the inverse power function acts to distribute the penetration of that particular technology 'j' relative to all other technologies 'k'. A high value of 'v' means that the technology with the lowest LCC captures almost the entire new market share. A low value for 'v' means that the market shares of new equipment are distributed fairly evenly, even if their LCCs differ significantly. Figure A1.1 is a graphical representation of the simple case where two technologies with different life cycle costs are competing for new market share with different values of 'v'.

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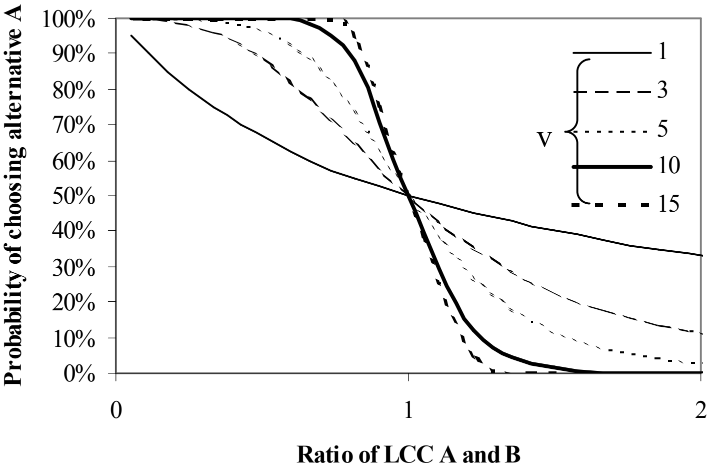
[1] CIMS can employ a number of hard controls to limit the penetration of technologies to certain levels (e.g., a maximum of one washing machine per household) as well as a declining capital cost function to simulate learning-by-doing and economies of scale exhibited particularly for new technologies.

Figure A1.1 CIMS Logistic Curve



The 'v', 'i' and 'r' preference parameters in CIMS are estimated from empirical studies of consumer and business decision-making, in some cases based on past consumption patterns and in some cases (especially with new technologies) based on surveyed preferences for specific technology attributes. The default value for 'v' in CIMS is 10, meaning that where a technology has an LCC advantage of at least 15% over its competitor(s) it would capture at least 80% of new stock. Default values for 'r' are discussed in the sub-model sections that follow. The default value for 'i' is zero. However, there are numerous cases in which research suggests a specific value for i. Also, i can be used as a calibration parameter when the values for 'v' and 'r' are inadequate for simulating the historical penetration rate of certain technologies.

A.1. RESIDENTIAL SECTOR

This document describes the structure and data inputs of the residential module of CIMS. It provides a general description of the sector its energy end-use processes, and the salient features of the model. The model was initially developed as ISTUM-R by Alison Bailie (1994).

A.1.1 Background

The CIMS residential sector sub-model attempts to capture all energy demand by residential buildings within Canada. This includes single family dwellings, duplexes, row housing, walk-ups and large apartments. Large apartment buildings are often considered commercial buildings by utilities, but, since their energy consumption patterns better fit within the residential sector, they have been included as part of this sub-model.

The number of households drives the residential sector models and is calculated exogenously, based on future population growth estimates. This variable directly determines the demands for all services, except for water heating and furnace fan demand. The technologies for services that require hot water and furnace fans establish those demands.

A.1.2 Energy Use and the Residential Sector

In 2002, the residential sector accounted for approximately 17% of all energy consumed in Canada. This energy provides services such as space heating, water heating, lighting, cooking, refrigeration and clothes drying. Space heating accounts for about 60% of residential energy consumption, water heating approximately 21% with the remainder going to lighting, appliances and other uses. The exact nature (i.e., quantity, fuel type etc.) of this consumption depends on many variables such as availability, climate, building type and occupancy patterns.

The following describes energy end-use services common to residence types incorporated into the model, the variables that affect the amount of energy consumed in providing the services, the relationship between the end-use and the driving variable at the primary node (number of households) and any other interrelationships that permit a more accurate simulation of the end-uses.

A.1.3 Space Heating

A variety of factors uniquely determine the energy consumption required to heat a household. These factors include the physical building envelope, the type of heating system, maintenance of both the envelope and heating system, climate and exterior landscape features, and thermostat settings. Modelling this service requires many assumptions and generalizations. Due to the multitude of housing types, the sector must be condensed into groups consisting of thousands of households which are represented in the model by one typical house archetype. All heating systems cannot be included, due to the large number of possibilities; thus the models contain only the most common systems and those considered likely to gain significant market shares in the future. Case studies and surveys provided estimates for geographical and behavioural assumptions.

Each space heating technology in the residential CIMS sub-model combines a shell archetype and a heating system. Each archetype, which is a set of physical measurements for components such as floor space, window area, insulation levels, and rate of air exchange, represents a group of households. Modellers use archetype descriptions to calculate the heatload and cost of the typical building as well as the cost and energy savings of retrofitting. For each shell archetype, CIMS includes a choice of four or five different heating systems. These systems include oil furnaces, natural gas furnaces (typically three efficiency levels with 78% to 90% efficiency), high efficiency space heat/hot water systems, wood stoves, electric baseboard heating, and electric air source heat pumps.

A.1.4 Non-Appliance Hot Water Use

This service meets the hot water required for baths, showers, hand washing, and cleaning. The competing technologies, shower heads and faucets with varying flow (litres/minute) levels, consume hot water rather than energy. The water demand determined by this node contributes to the hot water demand that drives the hot water heating service.

A.1.5 Lighting and Major Appliances

Each of the following appliances is modelled as a separate service:

- Refrigerators
- Dryers
- Dish Washers
- Air Conditioners
- Freezers
- Ranges
- Clothes Washers
- Lighting

The stock is measured in number of appliance units (i.e., number of refrigerators) and the ratio between the service and the driving variable (number of households) is the market penetration of the appliance. Generally, there is a range of efficiency levels for new stock in each major appliance service.

Clothes washers demand both electricity and hot water. Dish washers are disaggregated into two categories: machine, which demand electricity and hot water, and non-machine, which only consume hot water. Due to varying demand for air conditioning not all the residential sub-models incorporate them as a separate end-use and they are often combined with the *minor appliances*.

A.1.6 Minor Appliances

This service contains many diverse technologies including televisions, car block heaters, lawn mowers, and computers. Although, these appliances collectively consume a significant portion of household energy, individually either their consumption or their market penetration is low. As a group, this end-use is growing considerably. Efficiency improvements are outweighed by increase in number of goods.

A.1.7 Renewable Energy Sources and other Distributed Energy

A number of renewable technologies (in addition to wood stoves) can be applied at the household level to provide both passive and active energy. These include photovoltaic panels, geothermal, solar hot water heating and passive solar design. Options are also increasingly becoming available to generate electricity using combined heat and power generations at the household level, for instance through fuel cells and through micro-CHP (for instance the stirling engine). Some of these options are modelled at the end-use in which they meet thermal demand, rather than as a unique ‘supply’ node in the flow model.

A.1.8 Water Heating

The water heating demand depends on the technologies used to supply services of non-appliance hot water, dish washing, and clothes washing. For most purposes, hot water must be at 60^{o}C and, unheated water generally enters the household at 15^{o}C. Both storage tank and non-storage tank water heaters are modelled. Fuel cell and stirling engines are modelled at this end-use to meet water heat loads (while generating electricity for household use).

A.1.9 Energy Flow Model, Residential Sector

Although each province in Canada has a number of unique characteristics in terms of climate, the availability of fuel and the structure of the residential sector, all households require the same basic set of energy services. The following section describes the basic structure and the end-uses common to all regional residential models. Major differences between regional models are described later in this section.

Figure A1.1 presents CIMS’s residential sector flow sub-model. The number of residences required in any year drives the model. The flow model demonstrates the linkages between the driving variable and the energy end-uses in the residential sector. The number of residences are determined exogenously, based on future growth estimates of population and economic activity. The end-uses are linked to the driving variable through engineering ratios based on historic relationships between a residence and each end-use.

A.1.10 Energy End-Uses (Non-Space Heating)

Due to similarities in service demand and technology choices, the lighting and major appliance services modelled in the residential sector have been aggregated for all housing types. Air conditioning, a large energy consumer in some regions (e.g., Ontario), consists of room or window units and central units. Disaggregating apartment and non-apartment water heating captures the level of use and technology differences between these two categories.

A.1.11 Space Heating

In contrast to the other energy services in the residential sector, the amount of space heating demanded by a residential unit can vary considerably depending on the building type. As a result, the space heating service node of the model is divided into three basic housing types: apartment, attached (row), and single family detached dwellings. The apartment category includes both high and low rise apartments while the attached category consists of duplexes, triplexes, and townhouses. As described above each of these housing types have been divided up into different archetypes to describe the differences in building heatloads and the fuels and efficiencies of the heating systems.

A.1.12 Apartments

In the apartment node, two basic technology archetypes are available, standard and 'improved shell'. The standard archetype generally represents the existing or a baseline shell design that demands a relatively high heat load while the improved apartment shell design represents better insulation, windows, etc., demanding a lower heat load. Each of these archetypes is divided into several different heating system types based on the type of fuel and efficiency of the heating system, e.g., oil heating, several efficiency levels of natural gas heat (62%, 78%, 90%) and electric heat. During each model run new apartments can be purchased either from the options available from existing stock or from a selection of new buildings with an improved shell design and better heating systems. There are no retrofit options currently available for existing apartment stock.

A.1.13 Attached Housing (Row)

The attached housing category is modelled in the same manner as the apartments.

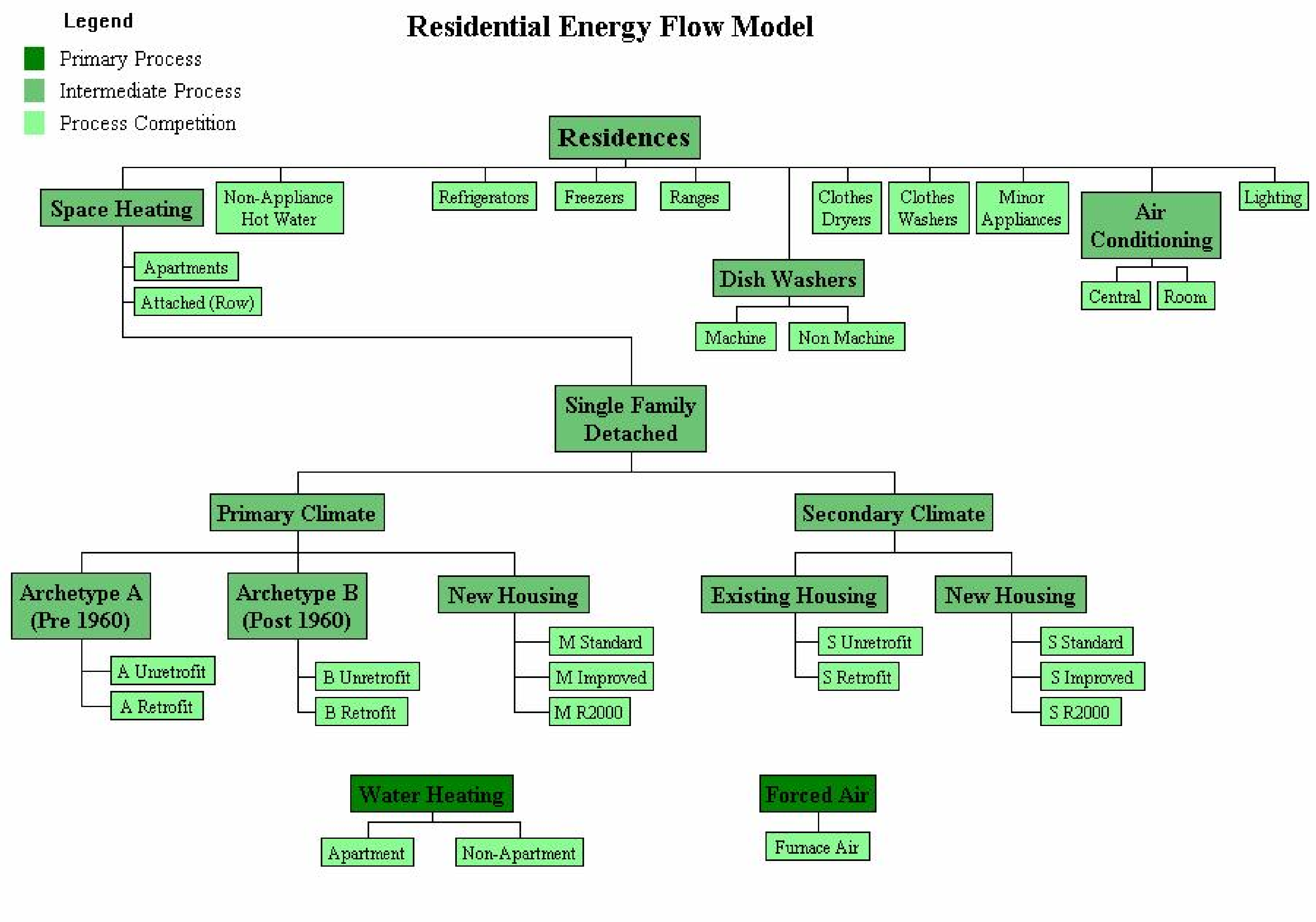
A.1.14 Single Family Dwellings

The greatest level of technological variety in the residential sector exists in the types of systems for heating single family dwellings (SFDs). These technologies also show the greatest differences between the regions. In the basic CIMS residential sub model, SFDs are divided up into two categories, existing and new housing.

Two archetypes are used to model all existing houses. Archetype A houses have very little insulation and, therefore, higher heatloads than Archetype B houses. Where wood consumption is present, wood stoves meet part of heat load demand. CIMS allows houses in either of these archetypes to retrofit to improve insulation levels. The six possible heating systems for the current housing stock are oil furnace, electric baseboard heating, air-source heatpump, standard natural gas furnace (78% efficient), high-efficiency natural gas furnace (78% efficient), and high efficiency space heat/hot water systems.

In each region, three types of houses compete for new stock: standard, improved and R-2000 archetypes. R-2000 houses meet the current heating budget specified by R-2000 standards for the region. The improved archetype is based on the ratio between standard and improved archetypes. Houses can be upgraded to better insulated categories through retrofits. Heating systems are the same as those modelled for existing homes. In some regions wood stoves may be chosen to heat standard and improved archetypes.

Figure A1.1
Energy Flow Model for the Residential



A.1.15 Regional Differences in CIMS Residential Sub-models

A.1.15.1 British Columbia

The BC residential sub-model has some differences compared to the other provinces in Canada. It is the only model to make use of the primary/secondary climate distinction available for single family detached homes -- coastal SFD (Lower Mainland and Vancouver Island) and interior SFD are represented. The same has not been done for apartment and attached housing since over 80% of these buildings are in the coastal area and this trend is assumed to continue over the modeling period.

The coastal SFD (Primary Climate) housing portion of the model is as described above. The interior region (Secondary Climate), with only half as many houses as the coastal region, uses only a single archetype to represent existing stock. The archetype heatload is the average of all current housing stock heatloads. These houses, like the others, can be retrofitted to improve insulation levels. Since wood provides primary heat for approximately 20% of interior houses, CIMS includes wood stove heating systems for these archetypes. The other heating systems in the interior are identical to the coastal systems described above.

A.1.15.2 Natural Gas Fireplaces

Natural gas fireplaces are the third biggest gas user in the residential sector behind space heating and DHW, however their penetration varies dramatically regionally with the West having the largest penetration of them and the East having the least.

Natural Gas Fireplace Gas Use
as a percentage of Total Natural Gas Use[1]

Region	% of Total NG Use
B.C.	13%
Alberta	~13%
Saskatchewan	~10%
Manitoba	~8%
Ontario	6%
Quebec	~4%
Atlantic	~0%

All vented gas fireplaces sold in Canada must now be tested for their energy efficiency using the Canadian Standards Association CSA-P.4.1-02 standard. The energy efficiency rating of the fireplace is printed on the EnerGuide label. Fireplaces range in efficiency from about 20 to 77 percent. The price of natural gas fireplaces has more to do with "add-ons" (e.g. mantles, etched glass, etc.) so this measure can be initiated at no incremental cost. *For the Economic Potential we assume that more efficient Natural Gas Fireplaces can reduce the fuel use due to fireplaces by 30% at no incremental cost.* Natural gas fireplaces are assumed to have a life of 15 years.

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[1] BC value is from the Terrasen DSM study, ON value is from Enbridge DSM study, all other regional values estimated based on knowledge of provincial NG use.

A.1.15.3 Pool Heaters

Pool heaters use a large amount of energy, comparable to the space heating needs of an average sized house. However, due to their low penetration the total fuel use due to pool heaters is quite small, approximately 1% of total gas energy use. Gas heating is still the most popular method for heating pools, and new technology can greatly reduce the costs associated with pool heating. Standard pool heaters are in the range of 80-85% efficient. If a pool heater is 5-10 years old, it is likely only 65-75% efficient. Pool heaters have an estimated life of 15 years. There are two likely technology upgrades that are more efficient than standard pool heaters, high-efficiency pool heaters and solar pool heaters.

- ***High-Efficiency Pool Heaters***

  High efficiency pool heaters include advanced heat exchangers, forced draft combustion systems, pilot-less ignitions and innovations in hydraulics. High efficiency pool heaters are now available that are 89-95% efficient. *For the Economic Potential analysis it is estimated that a 95% efficient pool heater can be purchased at a $2,900 incremental cost over a standard unit that is 82% efficient, reducing pool heating energy use by 14%*[2].

- ***Solar Pool Heating***

  Solar pool heaters typically use unglazed, plastic solar collectors. No tank is required because the pool acts as a storage unit. Often the existing pool pump can be used to circulate pool water directly through the collectors. For an outdoor pool, the combination of a pool cover and a solar pool heater may provide a long enough swimming season to completely eliminate the need for a conventional pool heater. A Solar pool heating system costs between $2,500-$4,500 and is assumed to save approximately 50% of the energy used to heat the pool. The life of a solar pool heating system is roughly 10 years, though some maintenance will likely be necessary during that time[3]. *For the Economic Potential analysis it is estimated that a solar pool heater can be purchased at a $3,500 incremental cost, reducing pool heating energy use by 50%*[4].

A.1.15.4 Justification for Maintaining the Same Archetype Heating Loads

The archetype heating loads used for the base year (2000) in CIMS were calculated from the disaggregated source data that was used to develop the *Energy Use Data Handbook, 1990 to 2000.*

Our first task was to compare the net space heating loads (tertiary heating loads) used in CIMs with the heating loads developed from our past DSM experience with BC Hydro, Terrasen Gas (BC), Enbridge Gas Distribution (ON), Manitoba Hydro (MB), and New Brunswick Power (NB). Exhibit A below shows the comparison in net space heating loads between the CIMs database and our past projects. It is important to note that for the existing detached dwellings every project uses a different cut-off year for the split between Archetype A and Archetype B,

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[2] Personal Communications with Jandy pool heater manufacturers.

[3] Sources: 1) “Tuning Up Multi-Unit Residential Buildings”, 2003, submitted by Marbek for CMHC, 2) CANSIA website, 3) www. CANRen.gc.ca.

[4] Personal Communications with Jandy pool heater manufacturers.

making accurate quantitative comparisons of the existing archetypes ineffective, except to notice dramatic departures from expected trends.

Exhibit A: Comparison of CIMs Net Space Heating Loads with Marbek Past Projects

Dwelling Type	CIMs AT	NB Power	% Diff.	CIMs BC	Terrasen	% Diff.	CIMs MB	MB Hydro	% Diff.	CIMs ON	Enbridge	% Diff
Existing												
Single Detached												
Primary Climate		Pre 1966			Pre 1976			Pre 1986			Pre 1980	
Archetype A (pre 1960)	63.95	133.00	108%	109.34	79.70	-27%	55.08	65.57	19%	77.83	88.23	13%
Archetype B (post 1960)	48.40			50.15	66.40	32%	41.76	61.36	47%	55.65	56.38	1%
Secondary Climate	0.00			61.19			0.00	69.53	14%	0.00		
Single Attached	48.08			33.79	44.71	32%	41.43	48.76	18%	54.78	53.02	-3%
Apartments	21.74			15.19	18.65	23%	15.76	26.51	68%	27.49		
New												
Single Detached												
Primary Climate	48.65	60.00	23%	44.18			48.04	54.28	13%	63.97	52.27	-18%
Secondary Climate	0.00			61.19			0.00	61.51	1%	0.00		

Exhibit A shows the comparison data is within the same order of magnitude as the CIMs data (i.e. all with 100% percent difference, with one exception), however, there are no general trends that can be used to develop a scale to improve the CIMs data. There are many possible explanations for this discrepancy, for example, it could be partly due to differences in the archetype definitions, to changes in weather patterns from 2000 to the Marbek project years, or any other methodology differences from the CIMs source data to our past project data.

Without a strong basis for changing the CIMs data, we decided to dig further to see where the source data from the *Energy Use Data Handbook* actually came from and whether it is reliable or not. Personal communications with Nathalie Trudeau, one of the senior economists charged with developing the handbook revealed that the energy data in the handbook is primarily from the *Energy Balance: Report on Energy Supply-Demand in Canada.* This report is developed by Statistics Canada from 14 feeder surveys of the producers and large distributors of petroleum products, major electric utilities, industrial electricity producers, coalmines and the natural gas utility industry. The feeder surveys are extremely robust, for example, the survey for the industrial consumption of energy has over 4,000 respondents. Information for the residential sector is based off the survey entitled "*The Annual Electricity Supply and Disposition Survey*", that reaches over 370 respondents from gas and electric utilities across Canada[5].

Based on the above findings, we feel that the data is used to determine the net space heating loads for the archetypes is from a robust and reliable source. After our necessary due diligence, we are comfortable moving ahead using this data.

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[5] Personal communications, Justin Lacroix, Statistics Canada

A. 1.16 Technology life

The following table shows assumptions about technology life for key technologies in the residential sector.

Technology	**Tech. Life**
Clothes Washers	13
Clothes Dryers	16
Ovens/Stoves	20
Freezers	20
Refrigerators	16
Dishwashers	13
Lighting	1-8
Space Heating*	20-30
Water Heating (standard tank)	9

*Space heating is 20 years in existing single family dwellings and 30 years in new homes.

A1.17 Discount Rates

The main criterion used by CIMS for choosing technologies is the life-cycle cost of competing technologies. Annualized costs in the residential sector are derived using the revealed discount rates described in the table below.

Technology	Lit. Range	Source*	Rate Used
Space heat / Shell	26 - 79	Hartman and Doane 1986	35%
Refrigeration	61 - 108	Cole and Fuller 1980	65%
Other appliances	30 - 70	Reported in Train 1985	35%

Full references:

Cole, H., and R. Fuller. *Residential Energy Decision-making: An Overview with Emphasis on Individual Discount Rates and Responsiveness to Household Income and Prices.* Columbia, MD: Hittman Associates Report, 1980.

Hartman, R. S., and M. J. Doane. "Household Discount Rates Revisited." *The Energy Journal* 7, no. 1 (1986): 139-148.

Train, K. “Discount Rates in Consumers’ Energy-Related Decisions: A Review of the Literature.” *Energy* 10, no. 12 (1985): 1243-1254.

A.2. The Commercial Sector

This chapter presents the framework from which CIMS's sub-model of Canada's commercial sector was developed. It provides a general description of the sector and the salient features of the model. For more information about the development of the commercial sector sub-model please see *ISTUM-C: Canadian commercial Building Sector Energy End-Use Model* (Strickland, 1996). The model was adjusted during a 1999 project which represented greenhouse gas emissions abatement actions from the Buildings Issue Table in the National Climate Change Process.

In CIMS, the definition of the commercial sector excludes light industrial facilities, which are included in the other manufacturing sub-model, and high-rise residential apartments which are included in the residential sub-model.

The commercial building sector accounts for roughly 20% of all energy consumed in Canada. For the most part, energy in the commercial sector is consumed to provide energy services such as lighting, heating, ventilation and air-conditioning (HVAC); cooking, refrigeration, hot water, and plug load (i.e. power for computers and other office equipment). Lighting and HVAC account for roughly 60% of the energy consumed in this sector. However, the distribution of energy use in any particular commercial building depends on its architectural characteristics, building type and size, efficiency of installed equipment and activities of the occupants.

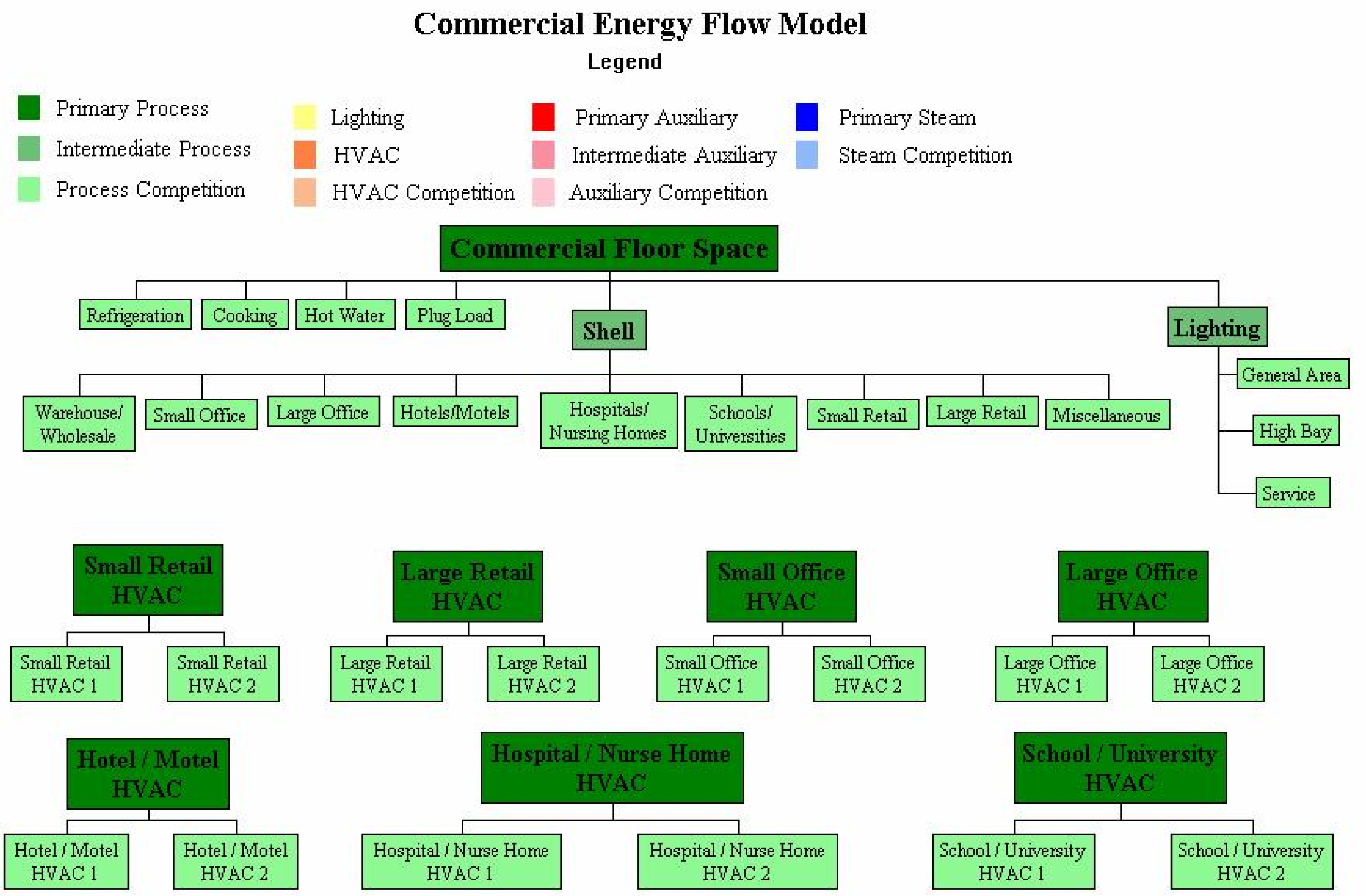
The most common fuels used in the commercial building sector are, in order of importance, electricity, natural gas and light fuel oil. Electricity is the only energy source used for lighting, refrigeration, plug load, cooling, fan and pumping. Electricity and natural gas are used for cooking. All three energy sources are used for space and hot water heating.

A.2.1 Energy Flow Model, Commercial Sector

Figure A2.1 shows CIMS's commercial sector energy flow model. CIMS considers commercial floor space as being the driving variable (primary node) of the commercial sector. The flow model demonstrates the linkages between the driving variable (commercial floor space) and the energy end-uses in the commercial building sector. The amount of commercial floor space is determined exogenously, based on future growth estimates of population and economic activity. The end-uses are linked to the driving variable through engineering ratios based on historic relationships between commercial floor space and each end-use. Not all energy end-uses found in the commercial sector are included in the model. Only space heating, lighting, refrigeration, cooking, hot water and plug load are considered significant enough, in terms of their total energy consumption, for inclusion.

End uses are described in more detail in the next sections.

Figure A2.1


Commercial Energy Flow Model
Legend
Primary Process
Intermediate Process
Process Competition
Lighting
HVAC
HVAC Competition
Primary Auxiliary
Intermediate Auxiliary
Auxiliary Competition
Primary Steam
Steam Competition
Commercial Floor Space
Refrigeration
Cooking
Hot Water
Plug Load
Shell
Lighting
Warehouse/ Wholesale
Small Office
Large Office
Hotels/Motels
Hospitals/ Nursing Homes
Schools/ Universities
Small Retail
Large Retail
Miscellaneous
General Area
High Bay
Service
Small Retail HVAC
Small Retail HVAC 1
Small Retail HVAC 2
Large Retail HVAC
Large Retail HVAC 1
Large Retail HVAC 2
Small Office HVAC
Small Office HVAC 1
Small Office HVAC 2
Large Office HVAC
Large Office HVAC 1
Large Office HVAC 2
Hotel / Motel HVAC
Hotel / Motel HVAC 1
Hotel / Motel HVAC 2
Hospital / Nurse Home HVAC
Hospital / Nurse Home HVAC 1
Hospital / Nurse Home HVAC 2
School / University HVAC
School / University HVAC 1
School / University HVAC 2

A.2.2 Lighting

In the commercial building sector, lighting consumes more electricity than any other end-use, accounting for 30 to 40 percent of total consumption. Lighting is measured in terms of the number of square meters of commercial floor space that it serves. Therefore, the lighting service has a one to one ratio with commercial floor space.

Lighting is not modelled separately by building segment. CIMS simulates lighting at different energy efficiency levels. The base technology represents the average efficiency of stock in 2000. The 'new' technology represents the marginal energy efficiency of new stock built in 2000. Other options represent actions to adopt more efficient lighting equipment (super T8, advanced HID, compact fluorescent lighting) and improving lighting design.

The lighting end-use category is modelled as three sub-categories: general area lighting, high bay lighting and service lighting. General area lighting is the dominant category of lighting and refers to the lighting found throughout general office areas and uses predominately fluorescent tube lights. Service area lighting refers to lighting systems used in corridors, lobbies, vestibules, washrooms, and any non-critical areas adjacent to areas illuminated by general area lighting. Lastly, service lighting refers to the lighting systems used in high bay areas of a building - large atria and lobbies, gymnasiums etc. The energy intensity of any sub-category depends on the efficiency of the lighting equipment and the use rate.

CIMS does not currently account for the energy consumed for exterior lighting such as street lighting, architectural lighting or parking lot lighting.

A.2.3 Shell/HVAC

The Shell/HVAC category is disaggregated into nine representative building segments (sub-categories). These segments, listed below, combine two or three different building types to group buildings with similar HVAC system types and usage. For example, the schools category includes elementary schools, colleges and universities.

A. Warehouses and Wholesale Outlets
B. Hotels and Motels
C. Schools and Universities
D. Small Office Buildings
E. Large Office Buildings
F. Small Retail
G. Large Retail
H. Hospitals and Nursing Homes
I. Miscellaneous buildings (not including residential or light industrial).

The mix of buildings in the segments is derived from data for the base year. The eight segments each have different occupancy and use rates, system types, and shell types. The relative shares of the building types within each segment can vary over the study period.

Each building segment encompasses a variety of shell and building HVAC technology options. Each is represented by a 'shell' node which competes alternative shell options. This represents a demand for heat load which is met by a corresponding HVAC service node for each building segment (see flow model). The link between the shell and HVAC competitions attempts to capture the relationship between decisions about building shell characteristics and the amount of energy demanded of the heating and air conditioning services. HVAC systems are modelled as 'single' technologies to represent the interdependence of choices about heating, cooling and ventilation systems.

A.2.4 Refrigeration, Cooking, Hot Water, Plug Load

The end-uses in the commercial sub-model are linked to the driving variable based on historic ratios of use per unit floor space and the weighted average of all the various commercial sub-sectors (e.g., a hospital will use more hot water than a warehouse per unit area). The weighted ratios can change over time, depending on changes in the proportion of the different kinds of floor space assumed over that period.

As shown on the flow model, refrigeration, cooking, hot water and plug load are each represented by a competition node. At these nodes, technologies compete based on life-cycle cost to provide the increased energy end-use services demanded due to change or growth in floorspace. The number of technologies available for each of these end-uses varies. In general, however, the database lists the first of each end-use technology group as an aggregate technology representing all the existing stock necessary to provide that particular energy service. The next technologies represent the retrofit and new stock options available to replace the retired stock and to meet new growth.

The model treats the six end-use categories (space heating, lighting, refrigeration, cooking, hot water and plug load) independently, meaning that the demand for energy in one category does not depend on the demand in another. This assumption is valid for all categories except shell/HVAC. The energy intensity of the shell/HVAC category depends directly on the lighting levels and the plug load within the building and indirectly on the refrigeration and cooking equipment. The effects of lighting and plug load services on the HVAC energy consumption and the ramifications of assuming their independence, are discussed in the caveats below. More efficient lighting and plug load technologies will affect the shell/HVAC energy consumption. The effects of refrigeration and cooking on the shell/HVAC category are considered negligible.

A.2.4.1 Plug Load

The plug load is related to the primary node by the installed outlet wattage per square meter of commercial building floor space. This category represents the energy use of electric office equipment such as photocopiers, computers and microwave ovens. It does not include refrigerators, freezers or hot water heaters which are represented separately in the model. The ratio of plug load to commercial floorspace averages 5 watts per square meter and varies by building type.

The energy intensity of this category depends on both the efficiency of office equipment and the use rate. The high efficiency choice for this category includes super energy-efficient equipment and technologies that switch to low energy "sleep mode" when not in use.

A.2.4.2 Domestic Hot Water

Domestic hot water (DHW) end-use represents the hot water used for all building services except space heating and is measured in cubic meters of hot water demand for the whole commercial building sector. It is related to the primary node by the ratio of cubic meters demand to commercial building floor space. Hot water is used for showering, washing, cleaning and food preparation.

A.2.4.3 Refrigeration

The refrigeration end-use includes all commercial refrigeration except for cooling required for air conditioning and is measured in gigajoules of refrigeration demand per square meter of commercial building floor space. This end-use is represented by two types of technologies; stand-alone plug-in refrigerators and large built-up refrigeration systems. These two types have different efficiency improvement opportunities. The refrigeration category in the model combines these two technologies and its energy intensity is the weighted average of the two system types. The ratio of the two system types is assumed to remain constant over time in a typical simulation.

A.2.4.4 Cooking

The cooking end-use is served by either electric or gas ovens, stoves and fryers and is measured in gigajoules of cooking demand per square meter of commercial floor space. This end-use also consists of different system types and the energy intensity of this end-use is the average for all types of commercial cooking equipment. As in the other end-use services, the shares of the various equipment types are assumed to remain constant over the simulation period.

A.2.5 Commercial Sector: Assumptions and Caveats

Any model is a simplification of reality. The results from CIMS are limited by data availability and the complexity of modelling all energy relationships in the commercial sector. The major assumptions and caveats made in the process of developing this CIMS sub-model are described below.

A.2.5.1 Energy Prices

As with the other CIMS sub-models, energy prices used in the commercial sector sub-model for both natural gas and electricity are based on the average charge per unit of energy consumed. Each unit of energy is assumed to cost the same regardless of the consumption rate of the customer. In reality both natural gas and electric utilities have rate structures that charge different prices depending on a customer’s total consumption. Therefore energy cost savings predicted by CIMS may be different from actual savings.

Many utilities also have demand charges or fixed fees charged per kW of demand. Since many energy efficiency measures reduce the demand of a facility, they also reduce the demand charges. These cost savings have not been included in the savings predicted by CIMS.

A.2.5.2 Discount Rates

The main criterion used by CIMS for choosing technologies is the life-cycle cost of competing technologies. To reflect the constraints imposed on investments due to rapid payback requirements, risk aversion, capital availability and other investment criteria, annualized costs in the commercial sector are generally derived using a 40% discount rate. In addition, the hospital and school sectors' shell/HVAC technologies are discounted at a rate of 30%, instead of 40%, consistent with evidence of their longer planning / cost horizons and the fact that they are owner-operated. [1] These rates reflect *ex post* measures of discount rates and are meant to encompass many more factors than simple rate-of-return criterion.

A.2.5.3 Retrofit Technologies

Some technologies are also set up as retrofits in the commercial sector. After existing stock is retired, CIMS compares the costs of the parent or lead technology and the attachable retrofit technologies. Although it remembers how much of the original parent stock there was, at this point CIMS assumes that there is no existing stock and sets up a competition between the lead technology and the retrofit technology(ies) to determine how much of that "remembered" original stock will remain as is (no retrofit) and how much will be retrofitted. The cost of the parent technology is simply the operating and maintenance (O&M) cost including fuel costs. The cost of each retrofit technology is O&M, fuel plus the annualized retrofit capital cost less any tax or other credit.

A.2.5.4 Interactive Effects Between Various Energy End-uses

The commercial building sector is different from both the industrial and the residential sectors in that there are significant interactive effects between energy end-uses and energy efficiency measures. As a result of these interactive effects, an energy efficiency measure that is undertaken for one end-use may have an impact on the energy consumption of another end-use. For instance, an energy-efficient lighting retrofit in a commercial building will reduce the cooling load but will increase the heating load because the waste heat from the lighting system is reduced. However, because there are so many factors that influence the consumption of energy by the HVAC system, these interactive effects are very difficult to quantify. Models exist that calculate these interactions for a specific building type but this type of analysis is beyond the scope of this current CIMS sub-model. The focus in the model is on capturing the main interactive effects between shell choice and HVAC demand.

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[1] The rates used in the commercial model are based on: B. N. Lohani, and A.M. Azini. "Barriers to Energy End-Use Efficiency." Energy Policy 20, no. 6, 1992.

A.2.5.5 Cogeneration

Cogeneration of heat and electricity has been limited exogenously in CIMS to between 30 and 50 percent of the demand in schools, large office, hospital, miscellaneous and hotel shell/HVAC categories. This is because cogeneration is only practical in large facilities that have a demand for both electricity and hot water or steam. The range of 30 to 50 percent is due to the different mix of buildings that make up each sub-category.

Cogeneration systems are sized to provide 100% of the facility's heating load. In certain instances this results in a surplus of electricity beyond that required by the shell/HVAC system. This surplus is assumed to be sold back to the electric utility for the same price that the facility is charged for electricity.

A.2.5.6 Oil Heating

CIMS assumes that no oil-fired heating is installed after 1990 in the commercial building sector of all regions except the Atlantic region, where natural gas is less available. This was done to simplify the model since oil heating is a small and declining portion of the market. The Atlantic region is the only region in Canada where the proportion of oil-fired heating is significant in the commercial building sector.

A.2.5.7 Lighting

CIMS does not account for the energy consumed for exterior lighting such as street lighting, architectural lighting or parking lot lighting. Data for these end-uses are not available.

2.6 Technology life

The following table shows assumptions about technology life for key technologies in the commercial sector.

Technology	**Tech. Life**
➢ Building Shells*	25-63
➢ HVAC Systems**	25
➢ Hot Water Equipment	10
➢ General Area/Service Area Lighting	12
➢ High Bay Lighting	10
➢ Cooking Equipment	15
➢ Plug Load	15

*Shell life is longest for large offices, large retail, schools/universities.

**heating, ventilation and air conditioning are modelled as a package.

A.3. INDUSTRIAL SECTOR

This document describes how the industrial sector is modelled in CIMS. We provide a general description of the sector, its energy end-use processes, and the salient features of the model. The prototype for this CIMS module was the ISTUM-I model developed at Simon Fraser University.[2]

A.3.1 Background

Unlike the commercial and residential sectors, the industrial sector is too diverse to simulate in a single module. CIMS therefore includes the following industrial sector sub-models, each reflecting the activity of one major industrial branch: chemical manufacturing, industrial minerals, iron and steel, mining, metal smelting and refining, petroleum refining, pulp and paper, and other manufacturing.[3] Coal mining and oil and gas extraction are covered in the CIMS energy supply component. In some cases, a branch may include more than one industry (e.g., chemicals includes many unrelated chemical-producing industries, non-metallic minerals includes cement, and in some regions, lime, glass and brick production) while for some branches, the model is industry specific (e.g., petroleum refining, pulp and paper).

In 2003, the industrial sector consumed 2,733.5 PJ of secondary energy, or 32% of the energy used in Canada.[4] Figure A3.1 provides the breakdown of total industrial energy use to the sub-branches represented in CIMS. Pulp and paper consumes more than any other industrial branch, at 30% of the total. Other manufacturing and petroleum refining follow, at 20% and 14% respectively. Metal smelting and refining and iron and steel each account for about 10% of industrial energy consumption. The remaining 10% is attributed to mining, industrial minerals, forestry and construction (the last two categories are referred to as “other” in the figure).

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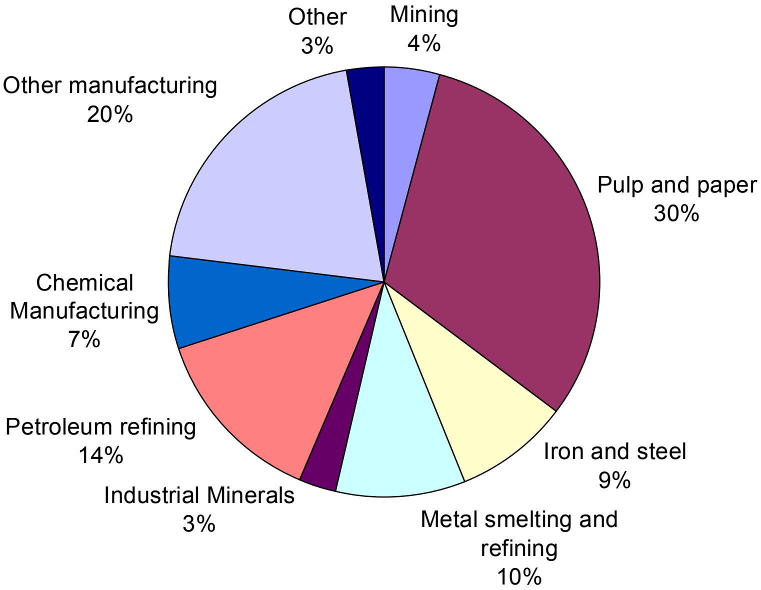
[2] Nyboer, J. 1997. Simulating evolution of technology: An aid to energy policy analysis. Ph.D. diss, School of Resource and Environmental Management, Simon Fraser University, Vancouver, Canada.

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

[4] Natural Resources Canada. 2005. Energy use data handbook, 1990 and 1997 to 2003. Ottawa: Office of Energy Efficiency, Natural Resources Canada. Upstream mining was removed from the industrial total to more closely match the CIMS representation of this sector.

Figure A3.1
Energy Use by Industrial Branch in Canada in 2003



Source: Natural Resources Canada. 2005. Energy use data handbook, 1990 and 1997 to 2003. Ottawa: Office of Energy Efficiency, Natural Resources Canada.

Some industries are found in very few regions (e.g., aluminum smelting occurs only in BC and Québec) while others occur in most regions (pulp and paper occurs in all regions except Saskatchewan). Table 3.1 shows the disaggregation of industry sub-sectors in CIMS by region.

Table A3.1
Disaggregation of Industry Sub-sectors in CIMS

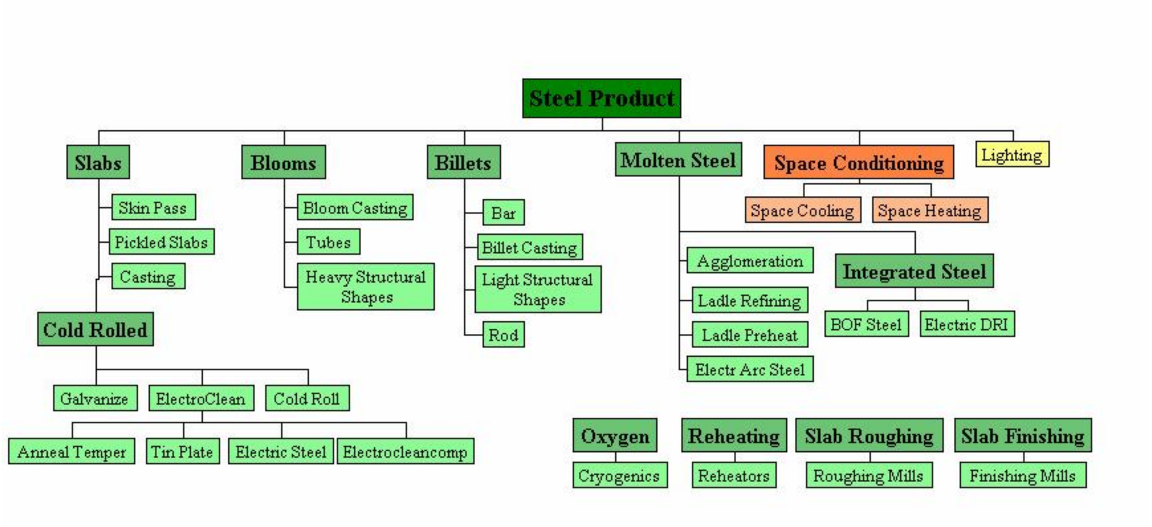
	British Columbia	Alberta	Sask.	Manitoba	Ontario	Quebec	Atlantic Region
Chemical Products	■	■			■	■	
Industrial Minerals	■	■			■	■	■
Iron and Steel					■	■	
Metal Smelting	■			■	■	■	■
Mining (metals, uranium, potash)	■		■	■	■	■	■
Other Manufacturing	■	■	■	■	■	■	■
Pulp and Paper	■	■		■	■	■	■
Petroleum Refining	■	■	■		■	■	■

Each industrial sub-model in CIMS has its own driving variable, usually the total amount of final product produced or the amount of raw input processed (e.g., tonnes of steel, tonnes of mineral ore throughput, m^3 refined petroleum products). The driving variables are determined exogenously, often based on official forecasts used by Natural Resources Canada to develop

Canada's Emissions Outlook: An Update, although in several cases sector specific sources are used.[5]

In CIMS, the product and energy service demands in a sub-sector are linked in a flow model that describes the sequence of activities required to generate that product. The energy flow model for the iron and steel industrial branch is shown in Figure A3.2 below as an example. A CIMS flow model is geared towards representing technology evolution and energy consumption rather than economic criteria (as in an econometric model where units are typically in monetary terms) or actual mechanical processes (as in the blueprints or process flow diagrams used by engineers). Because the emphasis is on energy consumption and not material flow, the nodes in the flow model represent process stages in which energy consumption can be distinctly estimated. The flow model describes hierarchical nodes, linked by engineering ratios. Technology competitions take place at the lowest level nodes in the hierarchy.

Figure A3.2
Energy Flow Model of the Steel Products Industry



Nodes shaded in green represent unique industry processes, while nodes shaded in other colors represent auxiliary systems. These are generic energy services that are supplied to the major process technologies and are shared by all CIMS industry sub-models. The auxiliary systems fall into four general categories: steam generation (boilers and cogenerators), lighting, heating, ventilation and air conditioning (HVAC), and electric motor systems including pumps, fans, compressors and conveyors. Figure A3.3 shows the energy flow diagrams for auxiliary systems not included in Figure A3.2. In some cases, the energy service meets the direct need for steam, pumping or compression, while in other cases, it serves only to provide suitable conditions for production to continue, as in the case of lighting and HVAC systems.

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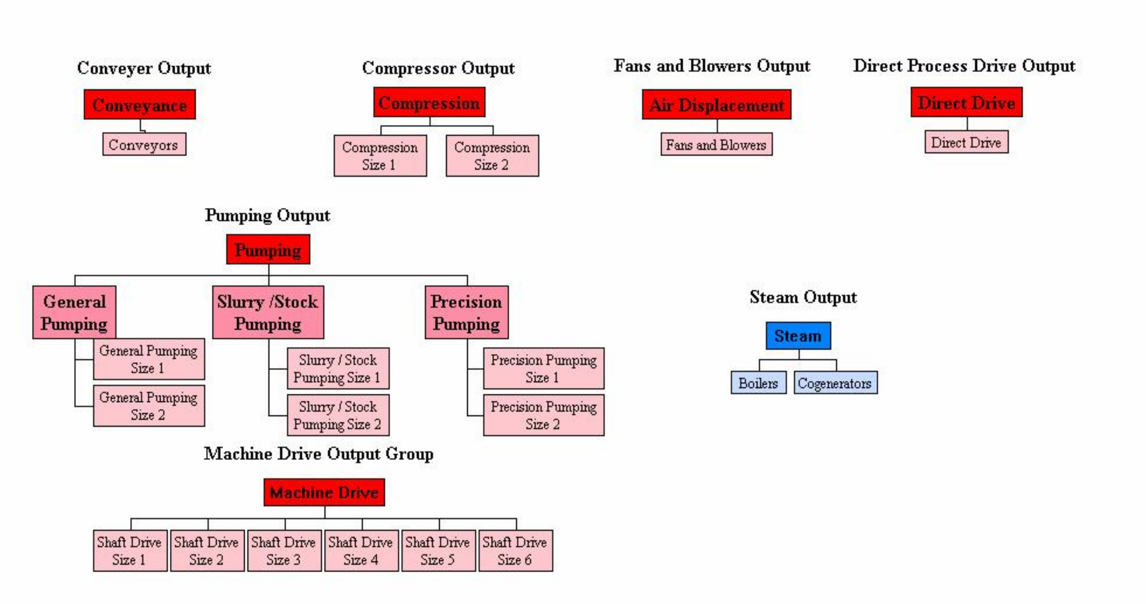
[5] Analysis and Modelling Group. 1999. Canada's emissions outlook: An update. Ottawa: Analysis and Modelling Group, National Climate Change Process.

Figure A3.3
Auxiliary Flow Model Diagram



The sections that follow describe how key auxiliary systems and process specific components are captured by the CIMS industrial model. The section on auxiliary systems covers steam generation and electric auxiliary services. Lighting and HVAC are not described in detail because the energy demanded by these services is small. The section on process specific systems covers each of the CIMS industrial sub-models.

A.3.2 Auxiliary Systems

A.3.2.1Steam Generation

A number of industry process technologies generate steam as a by-product. CIMS accounts for steam generated by these technologies in the overall steam demand in each industry. Any shortage of steam must be met by boilers and cogenerators.

Boiler efficiency can vary greatly depending on boiler design, age, and fuel used. For modern oil and gas boilers, thermal (first law) efficiencies may be 85% or higher. Boiler efficiencies can be increased by introducing non-condensing and condensing heat recovery systems and by installing regenerative burners with computerized fuel/air mixtures to maximize fuel efficiency.

Cogeneration is the sequential production of electricity and useful thermal energy, usually as steam or shaft drive power. In cogeneration a boiler is used in conjunction with a turbine system to generate electricity, with the "waste" steam going to meet process steam requirements. In comparison to conventional electricity generation, cogeneration facilities are capable of conversion efficiencies of up to 85% (including both the steam and electricity produced) as compared to utility condensing turbine systems which have an efficiency in the 30% to 40% range.

A.3.2.2 Electric Auxiliary Systems

The vast majority of electricity consumed by industry is used by motor systems. A motor is the core component of a much broader system of electrical and mechanical equipment that provides services, including hydraulic power, compressed air, motive power and air flow. Opportunities for efficiency improvement exist in both the motor itself, and in the latter systems – pumping, air displacement, compression, conveyance as well as other types of machine drive that are unique to a given production process (direct drive).

Figure A3.3 above is a generic energy flow model representing motor and steam auxiliary systems as they appear in the various CIMS industrial sub-models. As the figure indicates, CIMS simulates six auxiliary groups related to process drive (in red). The first five demand shaft or mechanical drive provided by the sixth group, motors (machine drive). Each group simulates technology evolution of a specific system.

Increased disaggregation in some of the groups reflects differing end-uses and levels of efficiency. For example, compressor systems vary in electrical efficiency by size. Therefore, competition between different technologies must be separated by size. The energy flow model reflects this by displaying two sizes of compressors which are available for use by the model.

Pumping, air displacement, compressing and conveyance systems have been represented as packages within CIMS. The components of each of these systems are associated with the key end-use. For example, a pipe, throttle and speed control device is attached to a pump, and the entire package is called a pump system. In the model, there are at least two types of systems:

1) The least efficient system, comprised of the least efficient components.
2) The most efficient system, comprised of the most efficient components.

The system efficiency is then a function of the efficiency of all the components within that system. In some cases intermediate efficiencies have also been listed. New technologies may be added to reflect the intermediate range.

Electronic variable speed drives (VSDs) provide speed control by varying the rotating speed of the induction motor to match variable speed requirements of driven equipment. Pumps and fans, for example, are often required to deliver varying qualities of fluid flow. When this control procedure is used the energy consumption of the fan or pump is dramatically reduced during part load operation, as compared to the conventional practice of using a valve or damper to reduce flow.

A.3.3 Process Specific Systems

A.3.3.1 Chemical Manufacturing

Unlike some of the other industrial sectors modelled in CIMS, the chemical products sector is not dominated by a single energy intensive product to which all others can be associated. As a result, several products and processes must be modeled to accurately reflect the energy flow within the industry. The dominant chemical products, from an energy consumption perspective, are: chlorine, caustic soda (sodium hydroxide), sodium chlorate, hydrogen peroxide, ammonia, methanol, ethylene, propylene and polymers. Sub-nodes in the model represent different process stages in which energy consumption can be distinctly represented.

Ethylene, methanol, toluene and xylene are the primary petrochemicals produced. Crude oil and natural gas feedstocks provide the raw material from which these are produced. Ammonia, chlorine (often produced in complement with caustic soda) and sulphuric acid are the major inorganic chemicals produced. Like petrochemicals, natural gas provides the principal raw material used in the manufacture of ammonia. Ammonia, in turn, forms the primary feedstock for urea, ammonium phosphate, ammonium nitrate, ammonium sulfate and nitrogen solutions commonly sold as fertilizers.

A.3.3.2 Industrial Minerals

The industrial minerals sub-model of CIMS generally includes all industry involved in the production of all non-metallic mineral products. It encompasses the cement, lime, glass and brick industries, with cement and lime as the major energy consumers. These key products both require significant quantities of thermal energy per unit production during the calcining process. Other energy-demanding processes involved in cement or lime production typically include raw materials preparation (this excludes extraction of the raw materials from their *in situ* locations, even though these may be within the plant gate), and finishing or finished materials preparation. Calcining remains the most energy intensive part of the processes, consuming large quantities of combustible fuel (85% or more of the total energy consumed). Initial and final preparation of the materials requires electricity to drive motors that are attached to various auxiliary and grinding devices.

A.3.3.3 Iron and Steel

The CIMS iron and steel model represents this industrial branch as a process whole, including the production of coke from coal, the incorporation of iron ore (including any agglomeration that occurs on site) and ending with the set of end products. End products include the three basic forms (slabs, blooms and billets) and, in many cases, their sub-forms. The iron and steel industrial branch has a high energy intensity per tonne of product.

Presently, two different processes generate Canadian steel. In the first process, coke, a coal derivative, reduces iron oxides in ore to pig iron in a blast furnace. Basic oxygen furnaces (BOFs) then purify this liquid iron along with some scrap by injecting high purity oxygen, which is itself an energy-intense product. In the second process, electric arc furnaces (EAFs) recycle 100% scrap metal. In both cases, the molten steel (with carbon content less than 2%) may be cast, inspected, reheated and finished. Each of a wide variety of finished products requires varying inputs of heat and mechanical energy to its manufacture.

The steel industry is rapidly modernizing. Most of these technologies concentrate on energy-saving measures and reuse of what had historically been waste heat. Direct reduced iron and direct smelted iron processes, presently in pilot scale plants, may eventually make the coke-dominated process redundant. More advanced finishing processes such as direct rolling and thin slab and thin strip casting will eliminate reheating of steel (typically done after initial inspection).

A.3.3.4 Mining

The CIMS mining model represents metal mines as well as potash mining. Other non-metal mines are not modelled in CIMS, as they currently consume a relatively small percentage of total mining energy. Activities related to coal mining and oil and gas extraction are covered elsewhere in CIMS.

Metal mines are typically categorized as either open-pit or underground. While the general production processes that occur in both categories are about the same, specific aspects of the mining technologies can differ significantly. For example, underground mining operations must address air quality issues in the mine shaft, which may require: cooling, heating and ventilation.

The basic processes for metal mining include most of the following generic steps (although not always in this order): initial breaking, transport (hoisting, trucking, conveying), crushing, grinding, concentration (mineral separation) and waste disposal (rock and tailings). Energy consumption in the final smelting and refining stage is not included in this sub-model but has been included in the CIMS metal smelting model.

A.3.3.5 Metal Smelting and Refining

The metal smelting and refining model of CIMS includes establishments that are primarily engaged in manufacturing finished metal products excluding iron and steel. These processes consume very high amounts of energy per unit of product. The CIMS sub-model explicitly includes processes related to aluminium, nickel, copper, zinc, lead, magnesium and titanium. Though economically important, minor elements such as gold, silver, platinum and cadmium are not represented explicitly because they are often processed in conjunction with the metals listed or are processed in too small a quantity to require direct representation.

In metal smelting, metal is typically extracted from the concentrate by leaching (hydrometallurgical recovery) or through heat (pyrometallurgical recovery). In Ontario, for example, all zinc smelters use hydrometallurgical techniques while copper and nickel smelters use pyrometallurgy. Smelting processes generate products that contain between 95% and 99% pure metal. Refining, if it occurs, depends on the type of smelting technique used. Products prepared through hydrometallurgy tend to use electrowinning for refining while products prepared through pyrometallurgy tend to use electrolysis or fire refining. Refined products are at least 99.99% pure metal.

Purification of the aluminum is accomplished utilizing the Hall-Heroult process, which requires large quantities of electrical energy. Although Canada has no aluminum ore body of sufficient concentration to warrant extraction, readily available, inexpensive electrical energy attracts companies who wish to refine the metal from alumina (concentrated ore). Recycled aluminium requires only 5% of the energy of original production. Increasing demand for conservation and recycling may have a significant effect on the production of virgin metal.

A.3.3.6 Petroleum Refining

This industrial sector includes establishments primarily engaged in manufacturing petroleum products. Activities such as the manufacture of lubricating oil and grease or asphalt and coal/coke products are included in CIMS where they are carried out in these plants. Establishments that are primarily engaged in these activities are not included; however, because of their comparatively small size.

The basic process involves refining crude oil into a number of products including: ethane, propane, butane, motor gasoline (typically 40% of total product), naphthas, jet fuel, petrochemical feedstocks, distillate fuel oil, diesel fuel, residual fuel oils, lubricants, coke and asphalt. All crude includes these products in varying concentrations. However, it is possible to increase output of more desirable products per unit crude input by using cracking and reforming processes.

The type and quality of crude and the processing requirements to generate the end products determine the refinery's complexity and have significant impact on energy consumption in the plant. In spite of this, however, the basic processing procedures are common to all refineries. The major process steps include: atmospheric distillation, vacuum distillation, cracking, desulphurization, alkylation, isomerization, reforming, sulphur recovery and hydrogen production. The last two processes should not be considered part of the actual refining process; they act as utility functions to clean out sulphurous compounds or provide hydrogen for specific in-plant operations.

A.3.3.7 Pulp and Paper

The pulp and paper industry includes establishments primarily engaged in manufacturing pulp, paper, paperboard and building and insulation board. These establishments are included in the CIMS pulp and paper sub-model because they are large in size and their products are highly energy intensive when compared to other industry products. Paper products which do not form part of the sub-model include: asphalt roofing, paper box and bag, and other converted paper product industries. These are included in the other manufacturing model of CIMS. The pulp and paper industrial branch has a high energy intensity per tonne of product.

Pulping processes can be broken down into three basic types: chemical, mechanical, and recycled. Mechanical pulping, which tends to be very electricity intensive, uses wood fibre much more efficiently than does chemical pulping. Recycled pulp consumes considerably less energy than either of the other two major processes but input supply is limited and the collection and transportation of this supply can significantly increase the energy intensity of the product. The products generated from each of these processes are distinct enough that they generally do not compete on the open market.

Each pulp product serves as the stock for many types of paper products. Newsprint, the largest category in terms of production (> 60%), can use feedstock from each of the pulping processes. Other paper products incorporated into this sub-model includes tissue paper, uncoated and coated paper (or wood-free paper), and linerboard, each of which may have varying degrees of stock inputs.

The following steps in the production of pulp and paper are common to both chemical and mechanical mills where raw logs serve as feedstock: wood debarking, wood chipping, pulp making, pulp washing, pulp bleaching, pulp drying, paper stock preparation, paper sheet formation, paper pressing and paper drying. Mills that use chips or recycled paper as feedstock may exclude some of these steps.

A.3.3.8 Other Manufacturing

The CIMS industrial sub-model for other manufacturing industries has been created to capture those industries within a region which, on their own, do not consume enough energy to merit the development of a separate model. When considered as a group, however, they may consume a significant (if not the dominant) portion of the energy within any one region. The industries considered part of the other manufacturing sector are: food, beverage, tobacco, rubber products, plastic products, leather and allied, primary textiles, textile products, clothing, wood, furniture and fixture, printing and publishing, fabricated metal products, machinery, transportation equipment, electrical and electronic, and other manufacturing.

The other manufacturing group of industries typically includes a large variety of technologies and processes. Usually, a simplified flow model of generic energy services represents adequately the energy consumption of these industries as a whole. Steam boilers, process heat, space heat, and electricity for lights and electric motors and their attached auxiliary devices (pumps, conveyors, fans and the like) constitute the bulk of energy-using services.

Unlike other "major" industries the other manufacturing industry as a group does not have any single product which dominates the production processes and to which the production of all other products may be linked. As a proxy for the physical output measures used in the sub-models major industries (i.e., tonnes of steel or cubic metres of gasoline) the output of the other manufacturing industry is represented in monetary terms such as the RDP (real domestic product) of the industry.

A. 3.4 Discount rates

The main criterion used by CIMS for choosing technologies is the life-cycle cost of competing technologies. To reflect the constraints imposed on investments due to rapid payback requirements, risk aversion, capital availability and other investment criteria, annualized costs in the industrial sector are derived using a 35% discount rate for process technologies, and 50% for auxiliary technologies.[6]

A.3.5 Technology life

The following table shows assumptions about technology life for key technologies in the industrial sector.

Technology	Tech. Life
➢ Motors Shaft Drive Size 1	5
➢ Motors Shaft Drive Size 2	10
➢ Motors Shaft Drive Size 3	15
➢ Motors Shaft Drive Size 4, 5 and 6	25
➢ Direct Drive	10
➢ Fans	30
➢ Conveyor	15
➢ Compression	10
➢ Pumps	10
➢ Boilers / Cogenerators	30

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[6] These rates are based on: DeCanio, S. J. "Barriers Within Firms to Energy-Efficient Investments." *Energy Policy* 21, no. 9 (1993): 906-914; Hassett, K. A., and G. E. Metcalf. "Energy Conservation Investment: Do Consumers Discount the Future Correctly?" *Energy Policy* 21, no. 6 (1993): 710-716.

SUB-APPENDIX A2

Fuel Prices in CIMS

Fuel Prices in CIMS
Source: NEB Techno-Vert Prices

Atlantic	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
Residential ($1995/GJ)						
Electricity	26.02	25.20	24.88	24.53	24.20	23.88
Natural Gas	-	12.13	12.57	12.30	12.01	11.68
Light Fuel Oil	13.32	12.41	14.14	14.13	14.08	13.95
Commercial ($1995/GJ)						
Electricity	19.87	22.51	21.70	21.32	20.98	20.64
Natural Gas	-	10.62	11.06	10.79	10.50	10.17
Light Fuel Oil	13.73	11.68	12.19	12.29	12.36	12.35
Heavy Fuel Oil	6.39	4.74	4.68	4.47	4.24	3.98
Industrial ($1995/GJ)						
Electricity	13.54	14.55	14.36	14.01	13.70	13.38
Natural Gas	-	7.78	8.22	7.95	7.66	7.33
Heavy Fuel Oil	5.28	5.15	5.08	4.85	4.61	4.32
Quebec						
Residential ($1995/GJ)						
Electricity	17.96	16.58	16.42	16.38	16.34	16.26
Natural Gas	12.41	11.61	12.06	11.80	11.52	11.19
Light Fuel Oil	12.20	11.71	13.37	13.52	13.62	13.62
Commercial ($1995/GJ)						
Electricity	16.11	14.72	14.58	14.54	14.51	14.44
Natural Gas	9.22	9.99	10.44	10.18	9.90	9.58
Light Fuel Oil	12.76	11.02	11.74	11.71	11.64	11.51
Heavy Fuel Oil	5.94	4.41	4.35	4.16	3.95	3.70
Industrial ($1995/GJ)						
Electricity	9.56	9.13	9.16	9.13	9.10	9.03
Natural Gas	5.90	7.02	7.47	7.21	6.93	6.60
Heavy Fuel Oil	5.62	5.15	5.08	4.85	4.61	4.32
Ontario						
Residential ($1995/GJ)						
Electricity	25.35	26.62	31.53	30.32	28.89	26.88
Natural Gas	7.60	9.69	10.11	9.86	9.60	9.30
Light Fuel Oil	12.92	10.88	11.35	11.29	11.20	11.07
Commercial ($1995/GJ)						
Electricity	20.28	23.61	26.23	25.13	23.88	22.19
Natural Gas	5.46	7.96	8.38	8.14	7.88	7.57
Light Fuel Oil	12.64	10.59	10.53	10.30	10.06	9.78
Heavy Fuel Oil	6.36	4.62	4.56	4.37	4.16	3.92
Industrial ($1995/GJ)						
Electricity	18.80	22.07	24.41	23.22	21.96	20.36
Natural Gas	4.81	6.69	7.11	6.87	6.61	6.31
Heavy Fuel Oil	5.26	5.05	4.99	4.78	4.55	4.29

Manitoba	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
Residential ($1995/GJ)						
Electricity	17.39	16.03	15.38	14.90	14.46	14.06
Natural Gas	8.45	9.75	10.20	9.99	9.77	9.51
Light Fuel Oil	13.35	11.30	11.80	11.75	11.67	11.54
Commercial ($1995/GJ)						
Electricity	11.86	11.03	10.62	10.19	9.81	9.45
Natural Gas	6.27	7.37	7.86	7.63	7.40	7.12
Light Fuel Oil	10.37	8.29	8.66	8.74	8.79	8.76
Heavy Fuel Oil	12.02	8.62	8.51	8.13	7.73	7.26
Industrial ($1995/GJ)						
Electricity	9.38	8.85	8.46	7.99	7.57	7.18
Natural Gas	5.20	5.81	6.29	6.06	5.83	5.55
Heavy Fuel Oil	4.58	4.83	4.77	4.56	4.34	4.07
Saskatchewan						
Residential ($1995/GJ)						
Electricity	24.75	26.56	26.05	25.65	25.28	24.91
Natural Gas	6.48	7.57	8.03	7.83	7.62	7.37
Light Fuel Oil	12.68	10.64	10.57	10.35	10.10	9.82
Commercial ($1995/GJ)						
Electricity	20.25	20.50	20.19	19.82	19.47	19.13
Natural Gas	4.91	6.05	6.51	6.31	6.10	5.85
Light Fuel Oil	10.32	8.28	8.21	7.99	7.74	7.46
Heavy Fuel Oil	11.58	8.30	8.20	7.83	7.45	6.99
Industrial ($1995/GJ)						
Electricity	12.75	13.89	13.76	13.40	13.07	12.74
Natural Gas	3.93	4.78	5.24	5.03	4.83	4.58
Heavy Fuel Oil	5.84	4.83	4.77	4.56	4.34	4.07

Alberta	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
Residential ($1995/GJ)						
Electricity	22.55	24.33	26.70	25.62	24.35	22.55
Natural Gas	6.23	6.53	6.99	6.79	6.59	6.35
Light Fuel Oil	11.74	9.70	9.63	9.41	9.16	8.88
Commercial ($1995/GJ)						
Electricity	12.59	15.58	17.29	16.51	15.63	14.45
Natural Gas	5.08	5.32	5.78	5.58	5.38	5.13
Light Fuel Oil	9.38	7.34	7.28	7.05	6.81	6.52
Heavy Fuel Oil	4.97	3.55	3.50	3.34	3.17	2.98
Industrial ($1995/GJ)						
Electricity	13.52	16.12	18.12	17.21	16.23	14.97
Natural Gas	2.34	4.08	4.54	4.34	4.14	3.90
Heavy Fuel Oil	4.97	4.76	4.70	4.49	4.26	3.99

BC and Territories						
Residential ($1995/GJ)						
Electricity	17.29	16.57	16.25	15.92	15.61	15.30
Natural Gas	9.04	9.78	10.23	10.02	9.80	9.54
Light Fuel Oil	13.58	11.54	11.52	11.36	11.12	10.83
Commercial ($1995/GJ)						
Electricity	12.77	15.88	15.58	15.26	14.96	14.66
Natural Gas	7.83	9.60	10.08	9.86	9.62	9.34
Light Fuel Oil	13.05	11.00	11.05	10.98	11.12	11.21
Heavy Fuel Oil	6.25	4.52	4.47	4.27	4.07	3.83
Industrial ($1995/GJ)						
Electricity	9.46	9.25	9.16	8.89	8.65	8.39
Natural Gas	5.39	5.22	5.70	5.47	5.24	4.96
Heavy Fuel Oil	5.16	5.00	4.94	4.73	4.50	4.24

SUB-APPENDIX A3

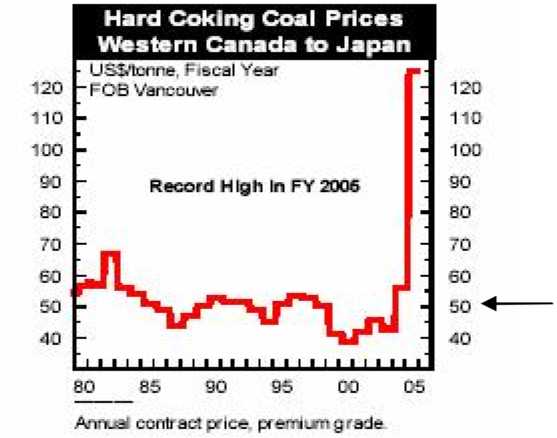
Coal Prices in CIMS

Upon examination, the coal prices for industry derived from the NEB forecasts (Table A3.1) appeared to be too low; these prices were much lower than the prices that had been used for all previous analysis.

Table A3.1
Coal prices for industry derived from NEB Techno-Vert forecast ($1995/GJ)

	2005	2010	2015	2020	2025	2030	2035
Alberta	0.51	0.48	0.46	0.46	0.46	0.46	0.46
Atlantic	1.78	1.69	1.61	1.61	1.61	1.61	1.61
British Columbia	0.51	0.48	0.46	0.46	0.46	0.46	0.46
Manitoba	1.35	1.29	1.22	1.22	1.22	1.22	1.22
Ontario	1.61	1.53	1.46	1.46	1.46	1.46	1.46
Quebec	1.61	1.53	1.46	1.46	1.46	1.46	1.46
Saskatchewan	0.74	0.71	0.67	0.67	0.67	0.67	0.67

MKJA conducted some research into the cost of extracting and marketing coal, and the North American long run delivered supply cost[1] is a minimum of about $1.75/GJ in $1995.[2] This price agrees with the long term market cost of high quality coking coal being about $50/tonne for the last 25 years – see figure below.



Long run average price

This translates to (($50 USD /tonne) *1.3(USD/CDN)) / 28 GJ/T = $2.32 / GJ. The price for sub-bituminous and bituminous, the most widely used grades, will be somewhat lower but not less than $1.75/GJ.

Upon investigation, the NEB prices were found to be an average of thermal coal prices for the electricity sector across Canada.[3] We chose not to adopt these coal prices across the board for all uses because industry pays more for coal because of smaller contract sizes and the need for higher quality coal (sub-bituminous at minimum), while delivered prices to electricity generators across Canada are known to differ widely. In Alberta and Saskatchewan electricity plants are sited right beside low quality sub-bituminous and lignite fields, and are designed to handle these

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[1] Long run costs include capital amortization and variable costs, such as labour and energy.

[2] Internal MKJA memo; "Coal prices in CIMS", by C. Bataille for R. Murphy and B. Sadownik for the DSM project, June 9th 2005. Included at the end of this memo.

[3] Rose spoke to Karen Morton, Market Analyst (403) 299-2755 on June 15, 2005.

poorer coals. These coals have no alternative use and the generators pay only for extraction costs, also known as "mine-mouth costs." This reduces the cost of the coal to $0.5/GJ, which stands in contrast to the market cost of industrial sub-bituminous at $2.00 GJ or more. Electricity generators in other areas pay less than industrial users because of larger contract sizes and transport efficiencies, but this price is much closer to the market cost of sub-bituminous coal.

Given that the NEB forecast could produce difficult to support results, MKJA reviewed the existing coal prices in CIMS for industry (which were approved by NRCan officials in 1997) but did not find the existing prices to be realistic either. This lead us to the US Department of Energy coal forecast documentation, which was found to much more reasonable. This forecast, which is split into a different price for electricity[4] and industrial[5] users, was converted to Canadian dollars and a 20% "small market" premium was added to reflect greater distances and smaller consumption in Canada. This resulted in the final market price (Table A3.2). We kept the Alberta and Saskatchewan electricity production coal prices because of direct knowledge of these "mine-mouth" values. Based on the same logic, coal mining in all provinces faces a $0.50/GJ "mine-mouth" opportunity cost for coal consumption.

Table A3.2
Coal prices ($1995/GJ) used in CIMS

Industry	**2005**	**2010**	**2015**	**2020**	**2025**
Alberta	2.36	2.30	2.25	2.25	2.25
Atlantic	2.36	2.30	2.25	2.25	2.25
British Columbia	2.36	2.30	2.25	2.25	2.25
Manitoba	2.36	2.30	2.25	2.25	2.25
Ontario	2.36	2.30	2.25	2.25	2.25
Quebec	2.36	2.30	2.25	2.25	2.25
Saskatchewan	2.36	2.30	2.25	2.25	2.25
Electricity Generation	**2005**	**2010**	**2015**	**2020**	**2025**
Alberta	0.50	0.50	0.50	0.50	0.50
Atlantic	2.06	2.01	1.96	1.96	1.96
British Columbia	2.06	2.01	1.96	1.96	1.96
Manitoba	2.06	2.01	1.96	1.96	1.96
Ontario	2.06	2.01	1.96	1.96	1.96
Quebec	2.06	2.01	1.96	1.96	1.96
Saskatchewan	0.50	0.50	0.50	0.50	0.50

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[4] http://www.eia.doe.gov/emeu/international/stmforelec.html

[5] http://www.eia.doe.gov/emeu/international/stmforind.html

SUB-APPENDIX A4

Annual Average Provincial Growth Rates in CIMS

INTRODUCTION

Growth rates are described by region for the sector sub-models included in CIMS for that region. Sub-models have been established regionally in CIMS where that sector is important to that region's energy picture and where there are statistical energy data to support a separate model. So, for instance, while there are pulp and paper producers in Manitoba and Saskatchewan energy data are confidential and are not released at that level by Statistics Canada.

GROWTH RATES BY REGION

British Columbia
Annual Average Provincial Growth Rates

Sector	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025
Residential	1.5%	1.6%	1.5%	1.7%	1.7%
Commercial	2.6%	2.7%	2.2%	1.5%	1.1%
Industry					
pulp and paper	0.2%	0.9%	0.8%	0.9%	0.9%
chemical man.	-0.2%	2.0%	2.1%	1.8%	1.9%
iron & steel					
metal smelting & refining	0.4%	4.9%	1.2%	1.1%	1.1%
metals and mineral mining	-3.7%	-0.9%	0.0%	0.0%	0.0%
other manufacturing	2.8%	1.9%	2.1%	1.7%	1.7%
industrial minerals	0.3%	0.9%	1.3%	2.0%	2.0%
petroleum refining	-3.0%	0.8%	1.1%	0.4%	0.4%

Alberta
Annual Average Provincial Growth Rates

Sector	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025
Residential	2.1%	1.4%	1.5%	1.4%	1.3%
Commercial	1.7%	1.7%	1.5%	1.5%	1.3%
Industry					
pulp and paper	0.2%	0.9%	1.0%	1.0%	1.1%
chemical man.	-0.1%	1.7%	1.8%	1.5%	1.6%
iron & steel					
metal smelting & refining					
metals and mineral mining					
other manufacturing	3.4%	1.7%	1.0%	1.0%	1.0%
industrial minerals	0.5%	1.6%	-0.8%	1.7%	1.7%
petroleum refining	2.1%	1.1%	1.3%	0.0%	0.0%

Saskatchewan
Annual Average Provincial Growth Rates

Sector	**2001-2005**	**2006-2010**	**2011-2015**	**2016-2020**	**2021-2025**
Residential	1.1%	1.1%	1.0%	1.0%	0.9%
Commercial	2.0%	1.7%	1.5%	1.5%	1.5%
Industry					
pulp and paper					
chemical man.					
iron & steel					
metal smelting & refining					
metals and mineral mining	6.5%	1.9%	0.1%	0.1%	0.1%
other manufacturing	4.5%	1.2%	1.2%	0.9%	0.9%
industrial minerals					
petroleum refining	0.4%	0.9%	1.6%	1.9%	1.9%

Manitoba
Annual Average Provincial Growth Rates

Sector	**2001-2005**	**2006-2010**	**2011-2015**	**2016-2020**	**2021-2025**
Residential	1.0%	1.0%	1.0%	0.9%	0.9%
Commercial	1.4%	1.3%	0.9%	0.6%	0.7%
Industry					
pulp and paper					
chemical man.					
iron & steel					
metal smelting & refining	0.4%	1.0%	0.7%	0.6%	0.8%
metals and mineral mining	-0.6%	1.5%	1.7%	2.0%	1.2%
other manufacturing	5.0%	2.2%	2.0%	1.8%	1.5%
industrial minerals					
petroleum refining					

Ontario
Annual Average Provincial Growth Rates

Sector	**2001-2005**	**2006-2010**	**2011-2015**	**2016-2020**	**2021-2025**
Residential	1.7%	1.3%	1.5%	1.4%	1.3%
Commercial	1.9%	2.2%	2.3%	2.1%	2.0%
Industry					
pulp and paper	0.5%	2.2%	2.2%	2.3%	2.3%
chemical man.	-0.2%	1.9%	2.0%	1.7%	1.7%
iron & steel	0.0%	1.3%	1.2%	1.2%	1.2%
metal smelting & refining	-1.0%	0.9%	0.8%	0.8%	0.8%
metals and mineral mining	-0.5%	-0.3%	0.4%	0.4%	0.4%
other manufacturing	1.2%	0.6%	0.6%	0.6%	0.6%
industrial minerals	0.3%	1.4%	1.5%	2.2%	2.2%
petroleum refining	4.4%	1.5%	1.9%	1.0%	1.0%

Quebec
Annual Average Provincial Growth Rates

Sector	**2001-2005**	**2006-2010**	**2011-2015**	**2016-2020**	**2021-2025**
Residential	1.1%	1.2%	1.3%	1.2%	1.2%
Commercial	1.7%	1.2%	1.0%	0.9%	0.7%
Industry					
pulp and paper	0.2%	0.9%	0.9%	0.9%	0.9%
chemical man.	-0.1%	1.7%	1.8%	1.6%	1.7%
iron & steel	0.0%	1.3%	1.2%	1.3%	1.3%
metal smelting & refining	2.7%	3.8%	0.7%	0.3%	0.3%
metals and mineral mining	0.3%	0.7%	0.8%	0.8%	0.8%
other manufacturing	2.1%	1.2%	1.1%	1.1%	1.1%
industrial minerals	0.0%	0.0%	0.8%	1.7%	1.7%
petroleum refining	3.8%	1.0%	1.3%	1.4%	1.4%

Atlantic
Annual Average Provincial Growth Rates

Sector	**2001-2005**	**2006-2010**	**2011-2015**	**2016-2020**	**2021-2025**
Residential	0.7%	0.4%	0.7%	0.7%	0.7%
Commercial	1.9%	1.5%	1.3%	1.1%	1.0%
Industry					
pulp and paper	0.3%	1.6%	1.7%	1.8%	1.9%
chemical man.					
iron & steel					
metal smelting & refining	0.0%	2.5%	0.9%	0.0%	0.0%
metals and mineral mining	0.5%	0.8%	0.8%	0.8%	0.8%
other manufacturing	1.2%	0.8%	1.0%	0.7%	0.7%
industrial minerals	-0.5%	2.4%	0.0%	0.0%	0.0%
petroleum refining	1.5%	0.9%	0.5%	1.3%	1.3%

SUB-APPENDIX A5

Provincial Results

British Columbia

British Columbia, Residential							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	154,410,033	158,606,703	164,043,806	172,166,669	185,214,881	200,354,338	1.05%
Electricity (GJ)	60,186,646	61,592,377	65,317,702	70,979,843	77,956,546	84,048,513	1.34%
Natural Gas (GJ)	80,563,597	84,092,552	86,187,280	88,729,785	94,740,703	103,076,257	0.99%
Refined petroleum products (GJ)	7,137,081	6,665,164	6,489,950	6,597,356	6,833,873	7,489,152	0.19%
Wood (GJ)	6,522,708	6,256,610	6,048,874	5,859,685	5,683,759	5,740,416	-0.51%
households	1,707,000	1,841,504	1,989,131	2,144,412	2,335,780	2,544,225	1.61%
GJ / hsld	90.4570	86.1289	82.4701	80.2862	79.2947	78.7487	-0.55%

British Columbia, Commercial							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	118,316,079	128,200,155	140,192,032	155,163,138	166,076,034	174,735,309	1.57%
Electricity (GJ)	50,565,368	55,628,747	62,361,324	68,555,426	72,365,996	75,002,863	1.59%
Natural Gas (GJ)	62,879,794	66,324,603	69,852,093	77,699,111	84,357,722	90,267,921	1.46%
Refined petroleum products (GJ)	4,870,918	6,246,805	7,978,615	8,908,601	9,352,316	9,464,525	2.69%
m2 floorspace	74,900,000	85,359,265	97,522,064	108,731,997	117,135,241	123,567,768	2.02%
GJ / m2	1.5797	1.5019	1.4375	1.4270	1.4178	1.4141	-0.44%

British Columbia, Industry							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	455,944,327	451,093,320	471,879,406	488,048,357	503,832,425	527,696,724	0.59%
Electricity (GJ)	89,493,152	83,142,515	89,059,269	90,830,433	92,310,724	94,961,008	0.24%
Natural Gas (GJ)	135,946,885	134,509,866	135,489,131	139,929,682	145,056,981	156,448,214	0.56%
Refined petroleum products (GJ)	14,908,684	14,040,753	14,561,923	15,668,646	16,950,064	18,663,821	0.90%
Coal, Petroleum Coke, Waste Fuels, Off gases (GJ)	13,598,459	18,281,642	22,879,680	24,252,590	25,895,595	27,271,781	2.82%
Wood Waste/ SPL (GJ)	201,997,147	201,118,544	209,889,403	217,367,006	223,619,061	230,351,900	0.53%

Alberta

Alberta, Residential							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	189,109,249	195,748,337	197,177,164	202,682,354	209,674,710	221,231,226	0.63%
Electricity (GJ)	26,321,518	29,093,240	30,616,550	32,959,440	35,934,983	38,683,924	1.55%
Natural Gas (GJ)	161,817,496	165,805,056	165,632,116	168,404,335	172,059,799	180,685,432	0.44%
Refined petroleum products (GJ)	970,235	850,041	928,498	1,318,579	1,679,928	1,861,870	2.64%
Wood (GJ)	-	-	-	-	-	-	
households	1,245,100	1,380,212	1,479,161	1,593,580	1,708,000	1,822,419	1.54%
GJ / hsld	151.8828	141.8248	133.3034	127.1868	122.7604	121.3943	-0.89%

Alberta, Commercial

	2000	2005	2010	2015	2020	2025	Average Annual Change
Total Energy (GJ)	153,385,264	161,764,133	171,325,096	181,842,081	193,481,109	204,722,958	1.16%
Electricity (GJ)	49,872,645	52,031,818	53,939,204	56,031,913	58,240,439	60,738,069	0.79%
Natural Gas (GJ)	102,151,756	107,702,019	114,490,669	122,466,057	131,417,198	139,758,875	1.26%
Refined petroleum products (GJ)	1,360,863	2,030,296	2,895,223	3,344,111	3,823,472	4,226,014	4.64%
m2 floorspace	86,000,000	93,703,818	102,097,739	109,723,216	118,173,968	126,244,336	1.55%
GJ / m2	1.7835	1.7263	1.6780	1.6573	1.6373	1.6216	-0.38%

Alberta, Industry

	2000	2005	2010	2015	2020	2025	Average Annual Change
Total Energy (GJ)	422,831,138	426,338,440	450,886,263	478,750,645	494,556,358	516,329,554	0.80%
Electricity (GJ)	37,342,992	32,656,495	30,799,717	31,447,728	33,316,093	36,966,001	-0.04%
Natural Gas (GJ)	235,249,333	238,261,589	247,444,800	257,916,503	261,984,308	271,622,433	0.58%
Refined petroleum products (GJ)	263,835	1,027,584	2,485,569	4,088,772	5,583,068	7,375,237	14.25%
Coal, Petroleum Coke, Waste Fuels, Off gases (GJ)	96,771,110	96,936,781	106,065,641	115,679,756	122,608,117	128,188,863	1.13%
Wood Waste/ SPL (GJ)	53,203,868	57,455,991	64,090,536	69,617,886	71,064,772	72,177,020	1.23%

Saskatchewan

Saskatchewan, Residential							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	48,629,990	48,447,858	48,294,445	48,437,491	48,946,810	50,560,573	0.16%
Electricity (GJ)	10,063,543	9,493,608	9,356,935	10,070,530	10,718,324	11,227,506	0.44%
Natural Gas (GJ)	37,546,554	38,223,468	38,404,989	37,768,328	37,564,711	38,645,376	0.12%
Refined petroleum products (GJ)	1,019,894	730,782	532,521	598,633	663,775	687,691	-1.56%
Wood (GJ)	-	-	-	-	-	-	
households	450,000	475,034	501,732	528,176	554,621	581,066	1.03%
GJ / hsld	108.0666	101.9882	96.2555	91.7071	88.2527	87.0135	-0.86%

Saskatchewan, Commercial							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	48,208,172	49,932,810	51,815,713	54,275,130	57,043,368	60,347,094	0.90%
Electricity (GJ)	15,621,735	16,314,418	17,079,623	18,009,779	18,854,256	19,854,939	0.96%
Natural Gas (GJ)	29,403,246	30,233,759	30,927,492	31,903,060	33,143,122	34,582,308	0.65%
Refined petroleum products (GJ)	3,183,191	3,384,633	3,808,598	4,362,291	5,045,990	5,909,847	2.51%
m2 floorspace	21,900,000	24,179,370	26,305,692	28,338,702	30,528,830	32,888,220	1.64%
GJ / m2	2.2013	2.0651	1.9698	1.9152	1.8685	1.8349	-0.73%

Saskatchewan, Industry							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	74,282,074	85,092,719	91,213,160	94,326,355	97,429,568	101,071,178	1.24%
Electricity (GJ)	18,536,501	19,583,607	19,714,361	19,459,670	19,113,057	19,463,339	0.20%
Natural Gas (GJ)	41,606,238	50,808,890	54,946,208	56,301,577	57,639,147	58,697,311	1.39%
Refined petroleum products (GJ)	3,597,327	4,349,084	5,265,573	5,943,099	6,631,808	7,263,421	2.85%
Coal, Petroleum Coke, Waste Fuels, Off gases (GJ)	6,998,170	6,583,352	7,210,782	8,256,217	9,578,804	11,093,567	1.86%
Wood Waste/ SPL (GJ)	3,543,838	3,767,786	4,076,236	4,365,792	4,466,752	4,553,540	1.01%

Manitoba

Manitoba, Residential							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	44,842,967	44,799,401	44,455,725	44,996,336	46,176,342	47,849,083	0.26%
Electricity (GJ)	19,207,144	19,918,313	21,061,524	21,902,804	22,968,481	23,807,008	0.86%
Natural Gas (GJ)	25,099,556	24,289,066	22,759,286	22,423,720	22,512,671	23,337,984	-0.29%
Refined petroleum products (GJ)	536,267	592,022	634,915	669,812	695,190	704,091	1.10%
Wood (GJ)	-	-	-	-	-	-	
households	439,000	460,816	483,589	507,989	532,388	556,788	0.96%
GJ / hsld	102.1480	97.2175	91.9287	88.5775	86.7344	85.9378	-0.69%

Manitoba, Commercial							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	47,505,640	46,056,613	47,378,503	48,812,392	49,574,736	50,947,299	0.28%
Electricity (GJ)	14,011,316	14,894,007	15,825,711	16,513,148	16,688,251	17,002,401	0.78%
Natural Gas (GJ)	32,370,635	29,984,461	30,304,959	31,100,103	31,787,378	32,966,310	0.07%
Refined petroleum products (GJ)	1,123,689	1,178,145	1,247,833	1,199,141	1,099,107	978,588	-0.55%
m2 floorspace	23,900,000	25,605,077	27,328,827	28,619,089	29,422,878	30,460,883	0.97%
GJ / m2	1.9877	1.7987	1.7336	1.7056	1.6849	1.6725	-0.69%

Manitoba, Industry							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	40,958,807	44,053,601	47,165,168	50,900,726	54,685,022	58,176,919	1.41%
Electricity (GJ)	20,677,428	22,294,988	24,674,398	27,085,752	29,677,912	32,018,881	1.76%
Natural Gas (GJ)	17,457,966	18,632,468	18,968,015	20,025,557	21,063,312	22,090,419	0.95%
Refined petroleum products (GJ)	892,279	996,344	1,158,330	1,306,569	1,448,501	1,510,733	2.13%
Coal, Petroleum Coke, Waste Fuels, Off gases (GJ)	364,653	497,385	674,714	831,567	968,521	1,084,944	4.46%
Wood Waste/ SPL (GJ)	1,566,482	1,632,416	1,689,711	1,651,281	1,526,776	1,471,942	-0.25%

Ontario

Ontario, Residential							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	525,874,714	544,924,777	556,386,151	584,337,598	618,218,668	653,412,539	0.87%
Electricity (GJ)	150,141,539	155,549,407	149,725,382	152,781,789	166,348,848	182,492,122	0.78%
Natural Gas (GJ)	323,763,655	334,713,785	349,997,116	372,355,217	390,946,473	408,855,544	0.94%
Refined petroleum products (GJ)	33,417,742	35,660,102	37,641,572	40,312,879	42,348,541	44,015,575	1.11%
Wood (GJ)	18,551,779	19,001,483	19,022,081	18,887,713	18,574,806	18,049,298	-0.11%
households	4,615,000	5,020,841	5,351,409	5,778,974	6,206,538	6,634,102	1.46%
GJ / hsld	113.9490	108.5326	103.9700	101.1144	99.6077	98.4930	-0.58%

Ontario, Commercial							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	431,487,643	452,465,685	483,222,383	527,031,038	570,368,656	618,535,768	1.45%
Electricity (GJ)	172,740,753	175,679,754	179,599,740	190,859,923	202,760,598	218,183,288	0.94%
Natural Gas (GJ)	237,923,806	256,676,676	283,250,537	315,026,029	345,680,963	377,571,422	1.86%
Refined petroleum products (GJ)	20,823,083	20,109,255	20,372,106	21,145,086	21,927,095	22,781,058	0.36%
m2 floorspace	219,600,000	241,407,813	268,854,677	300,495,524	332,621,289	367,348,620	2.08%
GJ / m2	1.9649	1.8743	1.7973	1.7539	1.7148	1.6838	-0.62%

Ontario, Industry

	2000	2005	2010	2015	2020	2025	Average Annual Change
Total Energy (GJ)	846,440,061	834,347,470	861,772,867	902,588,427	942,768,592	997,158,875	0.66%
Electricity (GJ)	141,261,072	135,051,067	135,370,836	139,168,137	143,868,657	151,019,751	0.27%
Natural Gas (GJ)	340,457,521	331,340,384	327,100,467	328,389,007	327,182,215	335,533,333	-0.06%
Refined petroleum products (GJ)	33,278,875	39,158,109	47,976,879	57,152,201	66,987,497	73,324,768	3.21%
Coal, Petroleum Coke, Waste Fuels, Off gases (GJ)	242,760,929	240,787,953	256,079,844	273,882,790	297,131,981	321,783,887	1.13%
Wood Waste/ SPL (GJ)	88,681,663	88,009,957	95,244,841	103,996,292	107,598,242	115,497,136	1.06%

Quebec

Quebec, Residential

	2000	2005	2010	2015	2020	2025	Average Annual Change
Total Energy (GJ)	320,670,811	326,948,940	336,124,689	351,814,109	370,849,023	388,562,556	0.77%
Electricity (GJ)	186,840,755	195,654,366	207,268,446	220,304,905	235,874,803	250,984,893	1.19%
Natural Gas (GJ)	28,461,711	27,263,933	26,265,028	27,791,391	30,198,257	34,133,082	0.73%
Refined petroleum products (GJ)	49,217,159	49,293,909	48,893,985	50,896,761	52,797,981	53,285,438	0.32%
Wood (GJ)	56,151,186	54,736,732	53,697,230	52,821,052	51,977,982	50,159,143	-0.45%
households	3,244,000	3,421,308	3,634,593	3,878,902	4,123,211	4,367,519	1.20%
GJ / hsld	98.8504	95.5626	92.4793	90.6994	89.9418	88.9664	-0.42%

Quebec, Commercial							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	221,465,573	230,964,654	235,606,790	242,675,273	248,103,528	252,047,758	0.52%
Electricity (GJ)	115,450,052	116,909,929	117,692,081	118,572,705	118,211,422	116,666,417	0.04%
Natural Gas (GJ)	81,726,020	85,841,013	88,440,357	91,133,270	93,793,342	96,699,484	0.68%
Refined petroleum products (GJ)	24,289,502	28,213,712	29,474,352	32,969,298	36,098,764	38,681,857	1.88%
m2 floorspace	111,500,000	121,230,797	128,709,814	135,485,647	141,526,330	146,281,225	1.09%
GJ / m2	1.9862	1.9052	1.8305	1.7912	1.7531	1.7230	-0.57%

Quebec, Industry							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	678,810,998	752,528,707	810,237,065	832,182,389	846,962,006	869,467,990	1.00%
Electricity (GJ)	312,422,726	333,878,653	365,795,699	366,573,408	364,006,657	364,391,537	0.62%
Natural Gas (GJ)	138,770,914	131,768,768	125,765,637	126,590,235	129,624,419	136,356,114	-0.07%
Refined petroleum products (GJ)	59,091,098	61,139,486	64,204,300	67,103,935	70,411,322	72,866,196	0.84%
Coal, Petroleum Coke, Waste Fuels, Off gases (GJ)	67,949,310	117,057,740	135,078,849	141,568,919	148,684,040	156,265,404	3.39%
Wood Waste/ SPL (GJ)	100,576,951	108,684,060	119,392,580	130,345,892	134,235,568	139,588,739	1.32%

Atlantic

Atlantic, Residential							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	100,909,325	99,920,372	97,110,462	96,637,151	97,242,820	100,658,163	-0.01%
Electricity (GJ)	43,803,517	44,312,096	45,236,625	47,590,057	49,949,829	52,001,744	0.69%
Natural Gas (GJ)	1,731,096	1,986,333	2,955,935	4,097,785	5,265,117	6,283,666	5.29%
Refined petroleum products (GJ)	40,138,456	41,127,840	38,926,087	37,477,089	37,287,531	36,906,730	-0.34%
Wood (GJ)	15,236,256	12,494,103	9,991,815	7,472,220	4,740,343	5,466,023	-4.02%
households	966,000	1,000,287	1,018,671	1,055,502	1,092,333	1,129,164	0.63%
GJ / hsld	104.4610	99.8917	95.3305	91.5556	89.0231	89.1440	-0.63%

Atlantic, Commercial							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	57,380,974	60,666,792	61,960,033	64,831,687	67,144,262	69,285,839	0.76%
Electricity (GJ)	29,294,485	30,514,804	30,644,582	30,966,243	31,685,630	32,332,463	0.40%
Natural Gas (GJ)	4,386,268	6,758,764	8,849,523	10,703,784	11,942,569	13,376,726	4.56%
Refined petroleum products (GJ)	23,700,221	23,393,224	22,465,928	23,161,660	23,516,063	23,576,650	-0.02%
m2 floorspace	40,500,000	44,396,037	47,803,812	50,962,767	53,872,220	56,539,160	1.34%
GJ / m2	1.4168	1.3665	1.2961	1.2721	1.2464	1.2254	-0.58%

Atlantic, Industry							
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**Average Annual Change**
Total Energy (GJ)	194,878,653	191,812,686	198,344,095	206,216,579	213,875,314	225,778,182	0.59%
Electricity (GJ)	50,199,347	49,333,409	50,578,015	53,257,308	56,084,735	58,170,997	0.59%
Natural Gas (GJ)	12,428,879	14,211,482	15,157,420	15,999,446	17,499,422	18,680,408	1.64%
Refined petroleum products (GJ)	49,365,294	45,295,059	41,724,045	39,917,439	38,118,772	38,701,130	-0.97%
Coal, Petroleum Coke, Waste Fuels, Off gases (GJ)	34,514,024	34,260,555	38,910,380	42,756,439	48,225,231	54,522,056	1.85%
Wood Waste/ SPL (GJ)	48,371,109	48,712,181	51,974,235	54,285,947	53,947,154	55,703,591	0.57%

SUB-APPENDIX A6

CIMS Base Year Calibration with Statistics Canada Year 2000 Data

Provincial Calibration Data -- Natural Gas (GJ)

Natural Gas / NGLs

	British Columbia			Alberta			Saskatchewan			Manitoba		
	CIMS	**Source Data**		**CIMS**	**Source Data**		**CIMS**	**Source Data**		**CIMS**	**Source Data**	
Commercial	62,879,794	64,213,000	-2%	102,151,756	101,692,000	0%	29,403,246	29,190,000	1%	29,534,575	31,322,000	-6%
Residential	80,563,597	79,887,000	1%	161,817,496	161,959,000	0%	37,546,554	37,131,000	1%	25,099,556	25,823,000	-3%
Industrial	135,946,885	138,291,163	-2%	235,249,333	234,895,006	0%	41,606,238	41,008,829	1%	17,457,966	18,256,625	-4%
Total Manufacturing*	114,791,205	117,154,000	-2%	207,381,326	207,027,000	0%	20,132,657	20,079,000	0%	16,587,272	17,370,000	-5%
Total Manufacturing incl.cogen**	134,297,540	136,660,335	-2%	235,249,333	234,895,006	0%	20,132,657	20,079,000	0%	16,587,272	17,370,000	-5%
Mining***	1,649,345	1,630,829	1%				21,473,581	20,929,829	3%	870,694	886,625	-2%
Total	**279,390,276**	**282,391,163**	**-1%**	**499,218,584**	**498,546,006**	**0%**	**108,556,038**	**107,329,829**	**1%**	**72,092,097**	**75,401,625**	**-4%**

Natural Gas / NGLs (contd.)

	Ontario			Quebec			Atlantic			Canada		
	CIMS	**Source Data**		**CIMS**	**Source Data**		**CIMS**	**Source Data**		**CIMS**	**Source Data**	
Commercial	237,923,806	229,541,000	4%	81,726,020	78,777,000	4%	4,386,268	4,507,000	-3%	515,235,854	504,339,000	2%
Residential	323,763,655	320,355,000	1%	28,461,711	29,291,000	-3%	1,731,096	1,714,000	1%	658,983,664	644,977,000	2%
Industrial	340,457,521	345,546,494	-1%	139,408,182	140,464,885	-1%	12,428,879	11,909,606	4%	906,923,660	912,112,604	-1%
Total Manufacturing*	300,438,262	305,508,000	-2%	133,706,071	134,761,000	-1%	12,428,879	11,909,606	4%	792,340,836	798,080,000	-1%
Total Manufacturing incl.cogen**	338,281,062	343,350,800	-1%	138,186,175	139,241,105	-1%	12,428,879	11,909,606	4%	882,038,082	887,777,246	-1%
Mining***	2,176,458	2,195,695	-1%	1,222,007	1,223,780	0%				24,885,578	24,335,358	2%
Total	**902,144,982**	**895,442,494**	**1%**	**249,595,913**	**248,532,885**	**0%**	**18,546,243**	**18,130,606**	**2%**	**2,081,143,178**	**2,061,428,604**	**1%**

Source Data:

Residential, Commercial, Total Manufacturing: Statistics Canada, Supply and demand of primary and secondary energy in terajoule, quarterly, Table 128-00021,2, E-STAT Accessed September 1, 2005. <estat.statcan.ca/>

Total manufacturing NG/NGL use in Atlantic includes NGL consumptions described by CIEEDAC survey data. A *Review of Energy Consumption in Canadian Oil Refineries, 1990, 1994 to 2003* (Burnaby: Simon Fraser University, 2005)

Mining: Natural Resources Canada, Annual Census of Mines.

*includes Chemical Products, Industrial Minerals, Iron and Steel, Non-ferrous Metal Smelting, Pulp and Paper, Petroleum Refining and Other Manufacturing
** The CIMS industrial sector sub-models portray cogeneration within an industrial sector, while Statistics Canada allocates fuels consumed to produce electricity as part of Net Supply
Natural gas is calibrated to Statistics Canada's value for Total Manufacturing plus an estimate of the fuel used in cogeneration that would have been allocated to net supply.
Electricity is calibrated to Net Electricity Demand: This is Total Manufacturing (e-stat) minus an estimate of electricity produced by cogeneration
Estimates of fuel consumption and electricity production are based on cogeneration facility data described in:
Canadian Industry Energy End-use Data and Analysis Centre (CIEEDAC). 2003. Canadian Cogeneration Database: An Update. Burnaby, British Columbia. http://www.cieedac.sfu.ca
*** Mining includes metal mining, uranium and potash

NOTE: CIMS' natural gas demand in the commercial sector in the Manitoba was calibrated to be closer to MB Hydro's own 2000 figures for natural gas. (CIMS 26.74 PJ (natural gas only) vs. MB Hydro 26.76 PJ (natural gas only)

Provincial Calibration Data -- Electricity (GJ)

Electricity

	British Columbia			Alberta			Saskatchewan			Manitoba		
	CIMS	**Source Data**		**CIMS**	**Source Data**		**CIMS**	**Source Data**		**CIMS**	**Source Data**	
Commercial	50,565,368	52,667,000	-4%	49,872,645	47,879,000	4%	15,621,735	15,679,000	0%	14,062,553	14,358,000	-2%
Residential	60,186,646	59,819,000	1%	26,321,518	25,559,000	3%	10,063,543	9,800,000	3%	19,207,144	19,394,000	-1%
Industrial	89,493,152	91,336,575	-2%	37,342,992	35,721,772	5%	18,536,501	18,586,247	0%	20,677,428	20,536,498	1%
Total Manufacturing*	95,215,272	97,382,000	-2%	53,110,220	51,489,000	3%	12,191,033	12,150,000	0%	18,013,520	17,964,000	0%
Total Manufacturing including cogeneration adjustment**	82,199,148	84,365,876	-3%	37,342,992	35,721,772	5%	12,191,033	12,150,000	0%	18,013,520	17,964,000	0%
Mining***	7,294,004	6,970,698	5%	-	-		6,345,468	6,436,247	-1%	2,663,908	2,572,498	4%
Total	**200,245,165**	**203,822,575**	**-2%**	**113,537,155**	**109,159,772**	**4%**	**44,221,779**	**44,065,247**	**0%**	**53,947,125**	**54,288,498**	**-1%**

Electricity (contd.)

	Ontario			Quebec			Atlantic			Canada		
	CIMS	**Source Data**		**CIMS**	**Source Data**		**CIMS**	**Source Data**		**CIMS**	**Source Data**	
Commercial	172,740,753	174,998,000	-1%	115,450,052	118,159,000	-2%	29,294,485	30,098,000	-3%	447,556,354	453,838,000	-1%
Residential	150,141,539	153,705,000	-2%	186,840,755	186,452,000	0%	43,803,517	43,451,000	1%	496,564,662	498,180,000	0%
Industrial	141,261,072	140,362,690	1%	312,422,726	313,193,698	0%	50,199,347	51,587,104	-3%	669,933,217	671,324,583	0%
Total Manufacturing*	158,074,221	156,964,000	1%	306,507,608	307,458,000	0%	45,121,004	46,840,000	-4%	688,232,877	690,247,000	0%
Total Manufacturing including cogeneration adjustment**	134,952,634	133,842,412	1%	302,027,503	302,977,895	0%	42,108,734	43,827,730	-4%	628,835,563	630,849,686	0%
Mining***	6,308,438	6,520,277	-3%	10,395,223	10,215,803	2%	8,090,613	7,759,374	4%	41,097,654	40,474,897	2%
Total	**464,143,364**	**469,065,690**	**-1%**	**614,713,533**	**617,804,698**	**-1%**	**123,297,349**	**125,136,104**	**-1%**	**1,614,054,233**	**1,623,342,583**	**-1%**

Source Data:

Residential, Commercial, Total Manufacturing: Statistics Canada, Supply and demand of primary and secondary energy in terajoule, quarterly, Table 128-00021,2, E-STAT Accessed September 1, 2005. <estat.statcan.ca/>

Total manufacturing NG/NGL use in Atlantic includes NGL consumptions described by CIEEDAC survey data. A *Review of Energy Consumption in Canadian Oil Refineries, 1990, 1994 to 2003* (Burnaby: Simon Fraser University, 2005)

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*includes Chemical Products, Industrial Minerals, Iron and Steel, Non-ferrous Metal Smelting, Pulp and Paper, Petroleum Refining and Other Manufacturing
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