Energy Savings in Industry: Canadian Industry Program for Energy Conservation

Penny Cochrane, Willis Energy Services
Ken Tiedemann, BC Hydro

ABSTRACT

The Canadian Industry Program for Energy Conservation (CIPEC) was established in 1975 and is the oldest voluntary industry and government energy efficiency partnership in the world. CIPEC is a sector-level outreach and advocacy program that: (1) promotes the establishment, implementation, tracking and reporting of energy efficiency improvement targets at an aggregate and sub-sector level, and (2) develops tools and services to overcome barriers to the implementation of energy efficiency programs and projects at the sector and company levels. CIPEC is delivered through the combined efforts of Natural Resources Canada and trade associations from the manufacturing, mining and electricity generation sectors representing over 8,000 companies and approximately 90% of secondary industrial energy use in Canada. This study reports on a process, market and impact evaluation of CIPEC. Key findings are as follows. (1) Estimates of net measure savings rates are based on a pre-post comparison of energy consumption using a control group. Savings by end use varied from a low of 1.7% of base consumption for facility lighting to a high of 5.6% of base consumption for process and water heating. About two-thirds of energy savings are attributable to electricity end uses while the remaining one-third of energy savings is due to fuel oil and natural gas. (2) Energy savings were estimated as the product of the use rate, the net savings rate, and the number of participants. Total savings over five years for CIPEC were some 28,178 TJ. (3) Carbon dioxide emission reductions were estimated as the product of energy savings by measure and a fuel specific emissions factor. Total emissions reductions for CIPEC were some 2,427 kilotonnes of carbon dioxide equivalent per year.

Introduction

The main purchased energy sources in the Canadian industrial sector are electricity, natural gas and residual fuel oil. The industrial sector uses about forty percent of the purchased energy consumed in Canada, and it is thus a major contributor to Canada's emissions of greenhouse gases (GHG). Major uses of electricity, natural gas and residual fuel oil in Canadian industry include water and process heat, space conditioning, process cooling and refrigeration, fans, pumps, compression, conveyance, electro-chemical processes, lighting and a wide variety of motor systems. The Canadian Industry Program for Energy Conservation (CIPEC) was established in 1975, and it is the oldest voluntary industry and government energy efficiency partnership in the world. CIPEC is a sector-level outreach and advocacy program that promotes the establishment, implementation, tracking and reporting of energy efficiency improvement targets at an aggregate and sub-sector level. As well, CIPEC is involved in the development of tools and services to overcome barriers to the implementation of energy efficiency programs and projects at the sector and company levels. CIPEC is delivered through the combined efforts of Natural Resources Canada (NRCan) and trade associations from the manufacturing, mining and electricity generation sectors. These associations represent over 8,000 companies and approximately 90% of secondary industrial energy use in Canada. The main CIPEC objective is to reduce industrial energy consumption and GHG emissions. The study is based on survey data, econometric modeling and engineer analysis. The purpose of the present study is to conduct a comprehensive evaluation of the impacts of CIPEC.

Background

Key sources of information on energy use in the industrial sector in Canada include Natural Resources Canada (1996) and Statistics Canada (2005). These studies document overall consumption levels as well as changes in consumption over time, with estimates of the impact of changes in activity levels, output mixes and energy efficiency on overall energy consumption. Recent published studies on energy use in industrial facilities include BC Hydro (1991a, 1991b, 199c, 2002) which examine overall energy use as well as key technologies including fans, pumps and motors. Friedman (2001) provides similar information for California industrial energy use. Industry Canada (1998) and Jaccard et al. (1993) examine opportunities for energy efficiency in Canadian industry. Taken as a group, these studies have found that the industrial sector has a number of cost-effective technologies which can reduce energy use and greenhouse gas emissions.

Focus groups were held in Montreal and Toronto with plant-level industry officials to better understand how energy use decisions are made, the factors affecting these decisions, and the key technologies installed as a result of program participation. The focus groups were also used to help define the researchable issues for the study. Following a detailed literature review, and interviews with program managers and staff, six substantive issues were identified for study. The issues were: (1) examine trends in industrial energy use; (2) estimate sector energy consumption by end use for thirteen end uses; (3) develop net measure savings rates by end use; (4) estimate attribution rates measuring program effectiveness; (5) determine impact of the CIPEC program impact on energy savings; and (6) determine impact of the CIPEC program impact on carbon dioxide emissions. The study is based on customer focus groups, customer survey, logit modelling and engineering algorithms.

Model

Discrete choice models are used in situations where the customer chooses from a set of discrete options. These options might include, for example: (1) install an adjustable speed drive or a standard drive for an industrial fan system (a zero or one choice); (2) install a standard efficiency furnace, a medium-efficiency furnace or a high-efficiency condensing furnace (choose one of three separate alternatives); (3) replace incandescent lamps with CFLs (choose zero, two, three, or more CFLs). What these situations have in common is that we wish to estimate the probability that a given choice will be made conditional on a set of exogenous variables. Since a probability is bounded below by zero and above by one, ordinary least squares models are not appropriate because the estimated probabilities can be less than zero and greater than one for some set of values for the exogenous variables using OLS estimators.

Choice modelling is a quantitative statistical method for analysing decisions or choices made by individuals between distinct alternatives. The determinants of choice behaviour are estimated by fitting a mathematical model to real or experimental data describing the choices made by individuals and other important variables thought to influence the decision process. Choice models have a number of useful applications in evaluation research since they can be used to explore the voluntary decisions made by customers to participate in energy efficiency programs and to implement energy efficiency measures. Information about participation and implementation decisions can be used to better design and market energy efficiency programs. In addition, statistical methods have been developed that use participation and implementation models to estimate free ridership rates and control for self-selection in consumption models designed to estimate net energy savings.

The decision to install the efficient version of the technology can be modelled by fitting a logit or probit model to the following discrete choice (yes/no) equation where

$$(1) \qquad \text{Install} = f(\beta x + \varepsilon)$$

Install is a dummy variable indicating whether or not the customer installed the efficient technology, x is list of variables thought to influence the customer's decision to install the efficient technology, β is the regression coefficient for each decision variable, and ε is an error term associated with the unobserved factors that influence the install decision.

If a logit model is used as the functional form, the model reduces to a simple closed form equation as follows, in which probability that a customer will participate in the initiative is calculated as a function of the variables found to predict participation.

$$(2) \qquad \text{Logit}(P) = \log(P/1 - P) = \beta x + \varepsilon$$

This equation can be estimated using maximum likelihood. Some standard references on choice modelling include Greene (2003) and McFadden (1974).

Trends in Energy Use in Canadian Industry

As a preliminary step, it is useful to understand trends in energy use in Canadian industry. Table 1 shows overall trends in energy use and output for the period 1990 through 2008. For this period, gross domestic product (GDP) measured in constant 2002 dollars rose by 40.0% and gross output measured in constant 2002 dollars rose by 44.3%, while energy use in PJ rose at 19.5%, or about one-half the rate of the two output measures. The result was that energy intensity measured in units of GDP fell by 14.7% and energy intensity measured in units of out put fell by 17.1%. It is worth noting that energy intensity using either measure fell substantially for the period 1990 through 2000, but energy intensity then showed little overall improvement for the period from 2000 through 2008.

The reasons for the apparent plateauing in overall industrial energy intensity are not clear, but the following factors may be relevant. First, the pulp and paper industry, which is the largest industrial user of energy in Canada, has substituted use of domestically-generated wood waste and spent pulping liquor for purchased fuels, with the former making up 54% of total energy use in paper manufacturing by 2005. Although substituting wood waste and spent pulping liquor for purchased fossil fuel-based energy reduces GHG emissions, the lower thermal efficiency of wood waste and spent pulping liquor results in increased energy intensity. Second, as the ore deposits with the highest mineral content tend to be exploited first, increased exploitation of mineral resources requires additional energy per ton of concentrate produced. Third, much of the energy used in industry is for various motor systems. Although there are considerable remaining opportunities to make these systems more efficient, particularly for drives and end use equipment, the potential for efficient motors may have been substantially exploited by the late 1990s.

Table 1. Trends in Total Industrial Energy Use and Output, 1990-2008

Year	Energy Use (PJ)	GDP (billion 2002 dollars)	Gross Output (billion 2002 dollars)	Intensity (MJ/GDP)	Intensity (MJ/GO)
1990	2,710.0	221.1	572.6	12.3	4.7
1991	2,675.1	209.2	537.0	12.8	5.0
1992	2,685.7	209.6	538.7	12.8	5.0
1993	2,704.2	217.8	561.1	12.4	4.8
1994	2,855.2	231.1	600.0	12.4	4.8
1995	2,919.8	238.2	622.9	12.3	4.7
1996	2,984.4	240.5	627.6	12.4	4.8
1997	2,979.3	253.4	663.6	11.8	4.5
1998	2,942.5	264.1	685.9	11.1	4.3
1999	3,032.8	278.9	747.2	10.9	4.1
2000	3,124.5	297.8	794.4	10.5	3.9
2001	3,010.9	295.0	793.6	10.2	3.8
2002	3,168.1	301.1	817.8	10.5	3.9
2003	3,257.8	305.1	817.1	10.7	4.0
2004	3,311.6	315.5	844.8	10.5	3.9
2005	3,244.2	322.1	863.4	10.1	3.8
2006	3,155.5	322.8	872.3	9.8	3.6
2007	3,417.6	322.5	881.4	10.6	3.9
2008	3,237.8	309.5	826.3	10.5	3.9
Growth (1990-2008)	19.5%	40.0%	44.3%	-14.7%	-17.1%

The aggregate information in Table 1 shows the overall trends in energy use and energy efficiency in Canadian industry, but the aggregate numbers hide important details on industry-level variations in energy use. Table 2 shows trends in total energy consumption for the twenty industries which were the largest energy users in 1990, for the period 1990 through 2005. Of these twenty high energy using industries, eleven of the industries used more energy in 2005 than in 1990, while nine of the industries used less energy in 2005 than in 1990. Industrial energy use is quite concentrated, with seven industries using at least 100 PJ per year in 2005. These industries were upstream mining (564 PJ), pulp mills (332 PJ), paper mills except newsprint (114 PJ), newsprint mills (206 PJ), petroleum refining (302 PJ), iron and steel (237 PJ) and primary alumina and aluminium (196 PJ).

Table 2. Energy Use for Selected Industries, 1990-2005 (PJ)

Industry	1990	1995	2000	2005
Copper, nickel, lead, zinc mines	36.6	29.2	23.2	24.4
Iron mines	39.8	37.4	35.5	32.2
Upstream mining	210.9	323.1	404.4	564.2
Wood products	44.3	46.8	62.0	50.4
Pulp mills	297.9	353.3	369.7	332.3
Paper mills (except newsprint)	99.3	104.4	113.3	114.2
Newsprint mills	244.8	257.2	264.5	206.4
Paperboard mills	62.0	64.4	70.3	63.8
Petroleum refining	323.1	302.1	295.1	302.0
Petrochemicals	32.1	34.1	42.4	61.9
Alkali and chlorine	30.4	30.1	29.9	16.2
Chemical fertilizer (not potash)	31.9	55.9	63.5	53.2
Other chemical	94.2	96.4	52.7	30.4
Resin and synthetic rubber	48.1	30.6	39.7	24.8
Cement	59.3	61.2	63.6	63.0
Iron and steel	219.4	247.8	257.6	236.9
Primary alumina and aluminium	109.8	140.7	155.5	195.5
Other non-ferrous smelt/refining	73.5	79.5	79.2	72.0
Fabricated metals	37.3	36.4	32.8	40.7
Construction	66.9	49.0	49.9	60.5
All industries	2,710.0	2,919.8	3,124.5	3,244.2

Source. Natural Resources Canada, Energy Use Data Handbook, 1990-2008.

Results

End use estimates. Industry Canada provided information on energy consumption by facility type, facility size, information on energy shares by major end use, and total energy consumption per square meter. Since the end use information was more aggregated than desired for this analysis, detailed spreadsheets from United States Department of Energy were used to develop energy consumption shares for thirteen end uses. The end uses included water and process heat, cooking, process cooling and refrigeration, pumps, fans and blowers, compressed air, conveyance, other machine drives, electro-chemical processes, space heating, space cooling, facility lighting and other uses. The resulting estimated end use shares were then checked with experts for the Office of Energy Efficiency to ensure that they were reasonable. Annual consumption per end use per industrial facility was estimated using the following equation:

(3) $GJ_i = share_i * \text{consumption per facility}$.

In equation (3), GJ_i is average energy consumption per facility for end use i, $share_i$ is the share of end use i in total energy consumption, and consumption per facility is a weighted average across all fuels and across all facility types. Estimated energy consumption for a typical industrial establishment by end use for 2002 is shown in Table 3.

Table 3. Estimated Industrial Energy Consumption by End Use

End Use	Consumption (GJ/establishment)	Share
Water and process heat	12,510	0.107
Cooking	1,173	0.010
Process cooling and refrigeration	7,204	0.062
Pumps	14,714	0.126
Fans and blowers	6,067	0.052
Compressed air	8,058	0.069
Conveyance	6,185	0.053
Other machine drives	29,800	0.254
Electro-chemical processes	12,206	0.104
Space heating	9,171	0.078
Space cooling	797	0.007
Facility lighting	7,825	0.067
Other uses	1,404	0.012
Total	117,137	1.000

Gross measure savings ratios. These ratios are estimates of the share of energy for that end use that will be saved on average through the installation of the efficient as opposed to the standard version of the technology. A wide variety of sources including Natural Resources Canada publications, technical reports on utility commission and program evaluation web sites, journal and conference literature and utility reports were reviewed to determine estimates of energy savings for key technologies. The gross measure savings ratio was estimated for each measure using the following equation and reviewed with technical experts:

(4) $\text{Savings ratio}_i = (1 - \text{efficiency}_{st}/\text{efficiency}_{ef})$.

Here, the savings ratio is the ratio applied to the end use consumption for a given measure and efficiency_{st} and efficiency_{ef} are the percentage efficiency levels of the standard and the efficient technologies for the relevant end use. The calculated savings ratios are shown in Table 5.

Attribution rate. The attribution rates for various technologies were estimated with the survey data for CIPEC participants and non-participants using the following logit models as shown in Table 4:

(5) $\text{Install}_i = F(\text{participant, industrial dummy, fuel rate})$.

Install_i takes the value 1 if measure i is installed, but it is 0 otherwise. Participant takes the value 1 for CIPEC participants, but it is 0 otherwise. Rate is the average rate paid by industrial customers by service territory in dollars per MWh equivalent. Industrial takes the value 1 if the customer is in the mining or manufacturing sectors but takes the value 0 otherwise.

Table 4. Gross Measure Savings Ratios

Measure	End Use	Standard Efficiency	Energy Efficient	Savings Ratio
Drive/Controls	Fans/Blowers	Vane 75%	ASD 95%	0.211
Fan Motor 1-5 HP	Fans/Blowers	Std efficiency 83.3%	Hi efficiency 87.5%	0.048
Drive/Controls	Pumps	Control valve 80%	ASD 95%	0.158
Pump Motor 6-25 HP	Pumps	Std efficiency 86.3%	Hi efficiency 90.1%	0.042
Drive/Controls	Compressed Air	Control throttle 83%	ASD 95%	0.126
Compressor Motor 1-5 HP	Compressed Air	Std efficiency 83.3%	Hi efficiency 87.5%	0.048
Reduce Air Leaks	Compressed Air	Average leaks 75%	Reduced leaks 85%	0.118
Coupling/ Drive	Conveyance	Worm gear/v belt/ helical 85%	ASD 95%	0.105
Convey Motor 6-25 HP	Conveyance	Std. efficiency 86.3%	Hi efficiency 90.1%	0.042
Coupling/Drive	Other Process	Worm gear/v belt/ helical 85%	ASD 95%	0.105
Process Motor 6-25 HP	Other Process	Standard efficiency 86.3%	Hi efficiency 90.1%	0.042
Ovens	Cooking	Standard	Microwave	0.100
Mid Efficiency Boiler	Space, Water, Process Heat	Standard efficiency 75%	Mid efficiency 85%	0.118
Hi Efficiency boiler	Space, Water, Process Heat	Standard efficiency 75%	Condensing 90%	0.167
Mid Efficiency furnace	Space Heating	Standard efficiency 65%	Mid efficiency 78%	0.167
Hi Efficiency furnace	Space Heating	Standard efficiency 65%	Condensing 90%	0.278
Economizer	Space Cooling	No economizer	Air side economizer	0.100
Drive/Controls	Refrigeration	Standard 85%	ASD 95%	0.105
CFL	Lighting	Type A 6%	CFL 24%	0.075
T8 Lamps	Lighting	T12 24%	T8 25.5%	0.047
HID Lamps	Lighting	Mercury vapor 15%	HID 30%	0.050
Roof Insulation	Space Heating	Standard $0.95W/m^2/C^{\circ}$	Upgraded $0.48W/m^2/C^{\circ}$	0.038
Wall Insulation	Space Heating	Standard $0.70W/m^2/C^{\circ}$	Upgraded $0.35W/m^2/C^{\circ}$	0.176

Note. For commercial ovens and economizers it was possible to get only estimates of the savings ratio rather than the detailed information on efficiency available for the other measures.

Choice models. It was noted above that choice modelling is a quantitative statistical method for analysing decisions or choices made by individuals between distinct alternatives, where the determinants of choice behaviour are estimated by fitting a mathematical model to real or experimental data describing the choices made by individuals or firms and other important variables thought to influence the decision process. Based on the focus groups, the key factors for the modelling were: (1) customer was a CIPEC participant; (2) customer was a mining or manufacturing establishment; and (3) average fuel price in the Province. Results of the modelling are shown in Table 5, where the standard errors and significance of the chi-squared statistic are in parentheses, where the chi-squared statistics are measure of the goodness of fit of the equations. The logit model results are generally good, with most models statistically significant at the 5% level or better. The key take-away from these logit regressions is that participation in CIPEC has a statistically significant impact on saturation of energy efficient measures, except for cooking, economizers, and roof insulation, where the effects still have the correct signs.

Table 5. Logit Model Results

	Constant	**Participant**	**Mining/ manufacturing**	**Fuel Rate**	**Chi^2**
Fans	0.358 (0.873)	0.742 (0.268)	-1.155 (0.427)	-0.034 (0.014)	16.31 (0.001)
Pumps	-0.838 (0.706)	0.773 (0.257)	0.450 (0.388)	-0.015 (0.012)	10.91 (0.012)
Compressed Air	-2.383 (0.997)	1.053 (0.335)	0.364 (0.456)	-0.001 (0.015)	13.13 (0.004)
Conveyance	-4.719 (1.631)	1.105 (0.544)	1.912 (0.730)	0.003 (0.025)	19.24 (0.000)
Other Process	-2.335 (1.058)	0.789 (0.346)	0.393 (0.486)	-0.007 (0.106)	8.05 (0.045)
Cooking	-3.467 (1.515)	0.012 (0.510)	-0.026 (0.782)	0.001 (0.022)	0.11 (0.991)
Mid Efficiency Boiler	-0.847 (0.880)	1.067 (0.294)	-1.949 (0.531)	-0.017 (0.014)	32.89 (0.000)
Hi Efficiency Boiler	0.215 (1.063)	0.542 (0.334)	-2.869 (0.816)	-0.030 (0.017)	23.79 (0.000)
Mid Efficiency Furnace	-0.544 (1.038)	0.956 (0.330)	-1.232 (0.519)	-0.030 (0.016)	15.08 (0.002)
Hi Efficiency Furnace	-0.400 (1.437)	0.822 (0.448)	1.265 (1.138)	-0.039 (0.023)	23.60 (0.000)
Economizer	-0.773 (0.851)	0.308 (0.272)	-0.634 (0.428)	-0.015 (0.013)	3.58 (0.311)
Refrigeration	-2.206 (0.892)	1.221 (0.312)	0.585 (0.428)	-0.002 (0.014)	19.66 (0.000)
CFL	-0.449 (0.659)	1.614 (0.221)	-0.925 (0.334)	-0.001 (0.010)	67.02 (0.000)
T8 Lamps	0.464 (0.681)	1.606 (0.228)	-1.643 (0.353)	-0.021 (0.011)	76.86 (0.000)
HID Lamps	-0.957 (0.692)	0.914 (0.226)	0.004 (0.336)	-0.001 (0.011)	17.69 (0.001)
Roof Insulation	-1.876 (0.860)	0.490 (0.285)	-0.290 (0.435)	-0.001 (0.013)	3.68 (0.298)
Wall Insulation	-2.765 (0.957)	0.759 (0.326)	-0.012 (0.473)	0.005 (0.014)	5.95 (0.114)

Energy Savings. Energy savings were estimated for each measure using the following equation:

(6) $\text{Energy savings}_i = \text{Use}_i * \text{saving rate}_i * \text{part}_i$.

Here, energy savings for measure i is the product of the use rate, the savings rate, and the number of participants. Note that the savings ratio is the product of the attribution rate or partial effect of program participation on the install decision times the savings ratio. Note that the attribution rate is the partial derivative of the non-linear function F in equation (3). Because of the non-linearity of the function F, the partial effects cannot be read directly from the coefficients on the participation variable in the logit regressions, but it is a rescaling of the regression coefficients on the participation variable. Energy savings results are shown in Table 6.

Table 6. Energy Savings

	Consumption per facility (GJ)	**Savings rate**	**Number of participants**	**Electricity savings (GJ)**	**Oil and gas savings (GJ)**
Heating	12,510	0.056	8,200	-	5,744.6
Cooking	1,173	0.029	8,200	-	278.9
Refrigeration	7,204	0.019	8,200	1,122.4	-
Pumps	14,714	0.027	8,200	3257.7	-
Fans/blowers	6,067	0.027	8,200	1,343.2	-
Compressed air	8,058	0.027	8,200	1,784.0	-
Conveyance	6,185	0.025	8,200	1,267.9	-
Machine drives	29,800	0.025	8,200	6,109.0	-
Electro-chem	12,206	0.029	8,200	2,902.6	-
Space heating	9,171	0.036	8,200	-	2,707.3
Space cooling	797	0.036	8,200	235.3	-
Facility lighting	7,825	0.017	8,200	1,090.8	-
Other uses	1,404	0.029	8,200	333.9	-
Total energy	117,137			19,446.8	8.730.8

Emissions savings. Emissions savings were measured in terms of kilotonnes of carbon dioxide equivalent. This is a useful summary measure that aggregates the impacts of the various emissions produced through the use of a particular energy source or fuel. Carbon dioxide savings are given by the following expression, which is disaggregated by fuel:

(7) $\text{Carbon dioxide savings}_i = \text{Energy savings}_i * \text{emission factor}$.

Here, carbon dioxide savings for the ith measure are the product of energy savings for the measure multiplied by the fuel specific emission factor. The emission factors, which were supplied by Natural Resources Canada, are: (1) electricity – 64.23 tonnes of CO_2E per TJ; (2) natural gas – 50.45 tonnes of CO_2E per TJ; (3) fuel oil – 75.43 tonnes of CO_2E per TJ; and (4) fossil fuels – 56.79 tonnes of CO_2E per TJ. The latter estimate is based on a fuel split of 74.6% natural gas and 25.4 % fuel oil. Emissions savings results are shown in Table 7.

Table 7. Emissions Savings

Fuel	Energy savings (TJ)	Emissions factor (tonnes CO_2 E/TJ)	Emissions reductions (kilotonnes CO_2 E)
Electricity	19,446.8	99.30	1,931.1
Oil and gas	8,730.8	56.79	495.8
Total	28,177.6		2,426.9

Conclusions

CIPEC was established in 1975 and is the oldest voluntary industry and government energy efficiency partnership in the world. CIPEC is a sector-level outreach and advocacy program that promotes the establishment, implementation, tracking and reporting of energy efficiency improvement targets at an aggregate and sub-sector level. The purpose of the present study is to build on previous work to conduct a comprehensive evaluation of the program.

First, for the period 1990-2008, industrial gross domestic product (GDP) measured in constant 2002 dollars rose by 40.0% and industrial gross output measured in constant 2002 dollars rose by 44.3%, while energy use in PJ rose at 19.5%, or about one-half the rate of the two output measures. The result was that energy intensity measured in units of GDP fell by 14.7% and energy intensity measured in units of out put fell by 17.1%.

Second, detailed estimates of average end use consumption were made using official Canadian and American data sources. Average consumption shares across all purchased fuels were as follows: water and process heat – 0.107, cooking – 0.010, process cooling and refrigeration – 0.062, pumps – 0.126, fans and blowers – 0.052, compressed air – 0.069, conveyance – 0.053, other machine drives – 0.254, electro-chemical processes – 0.104, space heating – 0.078, space cooling – 0.007, facility lighting – 0.067, other uses – 0.012.

Third, savings estimates by technology and end use were estimated using a wide variety of sources including Natural Resources Canada publications, technical reports on utility commission and program evaluation web sites, journal and conference literature and utility reports. Savings ratios varied substantially from 0.038 for roof insulation for to 0.278 for high efficiency (condensing furnaces).

Fourth, the program attribution rate by technology was derived from discrete choice (logit) models using data collected from the very detailed customer survey. The key take-away from these logit regressions is that participation in CIPEC has a statistically significant impact on saturation of energy efficient measures, except for cooking, economizers and roof insulation, where the effect has the correct sign but it is not statistically significant.

Fifth, energy savings were estimated for each end use as the product of the use rate, the net savings rate, and the number of participants. Total savings over five years of program activity for CIPEC were 19,447 TJ for electricity and 8,731 TJ for natural gas and fuel oil for a total 28,178 TJ.

Sixth, carbon dioxide emission reductions were estimated as the product of energy savings by measure and a fuel specific emissions factor. Total emissions reductions for CIPEC members were some 2,427 kilotonnes of carbon dioxide equivalent per year.

References

BC Hydro. 1991a. *Efficient Compressed Air Systems.*

BC Hydro. 1991b. *High-Efficiency Motor Database.*

BC Hydro. 1991c. *Pumping Profits.*

BC Hydro.2002. *Electricity Conservation Potential Review.*

Friedman, R. 2001. "California Industry and Energy Efficiency." *Proceedings of the 2001 Energy Program Evaluation Conference.*

Greene, W. H. 2003. *Econometric Analysis – International Edition, New York University.*

Industry Canada and Natural Resources Canada. 1998. *Manufacturing Small to Medium-Sized Enterprises and Climate Change: A Review of Status, Barriers and Opportunities: Final Report.*

Jaccard, M., J. Nyboer and A. Fogwill, How Big is the Electricity Conservation Potential in Industry?, *Energy Journal, Vol. 14, No. 2, 1993.*

McFadden, D. 1974. "Conditional Logit Analysis of Qualitative Choice Behavior." *In Frontiers in Econometrics, edited by P. Zarembka, pp. 105-142, New York: Academic Press.*

Natural Resources Canada. Various. *Energy Use Data Handbook: 1990 and 1996 to 2003, 2005.*

Natural Resources Canada. 1996. *Industry Energy End-Use Analysis and Conservation Potential in Six Major Industries in Canada, 1996.*

Natural Resources Canada. 2002. *CIPEC: Energy Efficiency Planning and Management Guide.*

Natural Resources Canada. 2008. *Summary Report of Energy Use in the Canadian Manufacturing Sector 1995-2005.*

Office of Energy Efficiency. 2202, 2003, 2004, 2005Various. *Improving Energy Efficiency in Canada: Report to Parliament under the Energy Efficiency Act 2002, 2003, 2004, 2005.*

Office of Energy Efficiency.2002. *Commercial and Industry Building Use Survey, 2002.*

Statistics Canada. 2005. *Report on Energy Supply-Demand in Canada: 1990-2004, 2005.*

United States Department of Energy. 1988. *Industrial End-Uses of Fuel Consumption. Table N6.4, 1998.*