Voluntary Energy Savings in Industry

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ABSTRACT

The Canadian Industry Program for Energy Conservation (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. CIPEC is delivered through the combined efforts of Natural Resources Canada 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 purpose of the present study is to build on previous work to: (1) estimate sector energy consumption by end use for thirteen end uses; (2) develop net measure savings rates by end use; (3) determine impact of the CIPEC program impact on energy savings; and (4) determine impact of the CIPEC program impact on carbon dioxide emissions. The study is based on survey data, econometric modeling and engineering analysis. 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 industrial sector uses about forty percent of the electricity, natural gas and residual fuel oil consumed in Canada, and it is thus a major contributor to Canadian emissions of greenhouse gases. 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 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, it 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 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 objective is to reduce energy consumption and GHG emissions. The purpose of the present study is to: (1) estimate sector energy consumption by end use for thirteen end uses; (2) develop net measure savings rates by end use; (3) determine impact of the CIPEC program impact on energy savings; and (4) determine impact of the CIPEC program impact on carbon dioxide emissions. The study is based on survey data, econometric modeling and engineer analysis.

Method

Focus groups were held in Montreal and Toronto 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, briefly described below, and interviews with program managers and staff, five main substantive issues were identified for study. The issues were:

- Estimate industrial sector energy consumption by facility, by end use and by fuel;
- Develop gross measure savings rates for the most important energy saving technologies;
- Estimate the attribution rate or share of the market impacts on installation of energy saving technologies due to the program;
- Determine program impact on energy savings due to installation of energy savings technologies; and
- Determine program impact on greenhouse gas emissions in terms of kilotonnes of carbon dioxide equivalent.

Table1. Study Issues, Data Sources and Methods

Study Issue	Data Sources	Methodologies
End use consumption	Customer survey Natural Resources Canada data US DOE data	Engineering algorithms
Gross measure savings rates	File review Documents review	Engineering algorithms
Attribution rates	Customer survey NRCan data	Logit regressions
Energy savings	Customer survey NRCan data	Engineering algorithms
Emissions savings	Customer survey NRCan data	Engineering algorithms

We conducted a brief review of the literature on industrial DSM, with a focus on those industries which are important in Canada (please see references). Some key findings of this review included the following:

- Industry uses perhaps 40% of the non-transportation energy produced in North America, and in many industries cost-effective technologies exist to reduce consumption by 10% or more.
- Existing capital typically has a long remaining life, and in the absence of an external intervention such as a utility DSM program or electric rates which encourage conservation, equipment may not be upgraded for many years.
- Plant experience varies with respect to the availability of on-site energy expertise. At some plants, there may not be an engineer or energy manager directly responsible for energy efficiency; and decision-makers may be located far from regional plant sites. At other plants, there are on-site energy managers who know their facilities well.

- Modifications to industrial manufacturing processes are complex, can affect product quality, may require extended shutdowns, and may affect output and productivity, at least in the short term.
- In some cases, energy efficiency expenditures have a lower risk-adjusted rate of return than product improvement expenditures. For companies where energy is a small part of overall costs, energy cost savings may be dismissed as not significant enough to warrant the attention of busy management and technical staff.
- Customer access to accurate and dispassionate technical information, particularly for new and emerging technologies, is sometimes difficult.

Discrete Choice 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

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

where, 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 techology, 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, and estimated using maximum likelihood.

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

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 2.

Table 2. 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:

(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 3.

Table 3. 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 $0.95 W/m^2/C^{\circ}$	Upgraded $0.48 W/m^2/C^{\circ}$	0.038
Wall Insulation	Space Heating	Standard $0.70 W/m^2/C^{\circ}$	Upgraded $0.35 W/m^2/C^{\circ}$	0.176

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 4, 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 4. 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 5.

Table 5. 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 6.

Table 6. 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

Discussion

A number of recent studies have examined energy efficiency policies for industry in European countries jurisdictions. The purpose of this section is to compare the results of selected European studies with the analysis presented in this paper for Canada. Table 7 provides a summary of five European programs as well as CIPEC. For each program, the table provides a summary description, the year of program launch, the net impact of the program on energy consumption, government costs, and cost effectiveness, measured in millions of Euros per petajoule of energy saved. Key points are that annual energy savings for CIPEC are about five to ten times larger than for the five European programs and that CIPEC is very cost effective from the perspective of government costs per unit of energy saved.

Key Learnings

1. Organization and Management. Clearly define program roles and responsibilities, and ensure that participants clearly understand who is responsible for what. Adjust the program to reflect new opportunities and challenges in the market, but ensure that the revised program definition and strategy is clearly communicated to all stakeholders.

2. Program Planning. Conduct adequate market research to understand market barriers and drivers, identify and build contacts with key market players and align the goals and interests of market players and the program. Develop a program plan with a clearly articulated program logic that clearly states the program objectives, operational outputs and resources required, and ensure that program schedules are clear and realistic and that suitable allowance is made for possible slippage in program implementation. Ensure that program objectives are clear, well defined, measurable and achievable and collect base line data to the extent feasible and practical to allow for cogent analysis of the extent to which a program is meeting its objectives and achieving efficiency and effectiveness in delivery.

3. Program Delivery. Leverage scarce dollars for marketing and implementation through partnerships and cooperation with other market players. Develop open and respectful relationships with consultants and contractors, and leverage relationships with partners in one industry to build program support in other industries. Keep program procedures, including applications, modeling and verification, as simple and transparent as possible to maximize participation and energy savings.

4. Program Monitoring and Evaluation. Conduct baseline research on technology saturation and use before a program is in the field, and replicate this research as required to understand and document changes in the market as well as market effects that can be ascribed to the program. Establish systems to key metrics as well as changes in the metrics. Report program progress against program objectives, and make suitable corrections if key objectives are not being met. Establish appropriate algorithms to estimate energy and demand savings and collect suitable data through surveys, site visits and metering to ensure that the algorithms can be applied.

Table 7. Industrial Energy Efficiency Program Comparisons

Program and jurisdiction	Description	Starting year	Net impact	Government costs (MEUR)	Effectiveness (MEUR per PJ)
Energy Efficiency Deduction Scheme (Netherlands)	Tax relief to firms that invest in energy efficiency; renewable energy technologies, and the establishment of a list of approved technologies	1997	11.5 PJ or 1.4 PJ per year	160 (1997-2004) or 17.8 per year	12.7
Voluntary Agreements on Energy Efficiency in Trade and Industry (Denmark)	Tax relief for firms that sign agreement to implement energy efficiency measures; energy audits and energy management systems; subsides for investment in energy savings measures	1996	9.6 PJ or 1.2 PJ per year	250 (1996-2005) or 25 per year	20.8
Energy Audit Program and Voluntary Agreements (Finland)	Voluntary agreements to implement energy efficiency measures; subsidies for firms to carry our energy audits; subsidies for investments in energy savings measures	1992	24-29 PJ or about 2 PJ per year	36 (1992-2004) or 2.8 per year	1.4
Industrial Energy Efficiency Program (Norway)	Subsides for firms to carry out energy management and energy audits	1996	6 PJ or 0.6 PJ per year	13.5 (1996 - 2004) or 2.8 per year	4.7
Program for Improving Energy Efficiency (Sweden)	Five–year voluntary agreements which require participants to do energy audits, implement energy management systems and undertake investments which are profitable	1975	2.6 GWh PJ or 0.5 PJ per year	4.0 (2004-2009) or 0.7 per year	1.4
Canadian Industry Program for Energy Conservation (Canada)	Voluntary agreements to establish, implement, track and report energy efficiency improvement targets at an aggregate and sub-sector level; development of tools and services to overcome implementation barriers	1975	28.2 PJ or 5.6 PJ per year	5.0 (2000-2004) or 1.0 per year	0.2

Source. Khan and Nordqvist (2007), Stenqvist and Nilsson (2009) and this study. Note that annual net impacts and annual government costs do not necessarily refer to the same program periods.

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