Transforming industrial markets

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Abstract

BC Hydro's Power Smart Partner Industrial program was launched in April 2002. The basic concept was that BC Hydro's largest business customers have the most to gain from implementing long-term energy savings strategies. BC Hydro partners with these companies, and it contributes matching funding and other resources to help them overcome barriers to realizing energy savings opportunities. The purpose of this paper is to summarize the findings of a market and impact evaluation of the Power Smart Partners Industrial program. There are four key findings. First, program participants installed energy efficient technologies at higher rates than non-participants, and in most cases the differences in installation rates were significant at the 90% level or better. Second, sector demand equations for purchased electricity were estimated for metal mining, wood products, pulp and paper, chemical, and coal mining, and these demand equations had reasonable and well determined activity and price elasticities. Third, evaluated energy savings over four years were 469.3 GWh per year compared to program estimated energy savings of 497.3 GWh per year and evaluated peak savings were 64.5 MW compared to program estimated demand savings of 68.1 MW. Fourth, the program offering and program cost effectiveness compared well with other exemplary programs, with first year program costs for energy of $0.14 per kWh and first year program costs for peak of $724 per kW.

Introduction

The industrial sector uses about forty percent of the energy consumed domestically in Canada, a level similar to that of other resource-rich industrialized countries such as the United States or Australia. The main sources of information on energy use in the industrial sector in Canada include Natural Resources Canada [1] and Statistics Canada [2]. 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. Some recent published studies on energy use in industrial facilities include BC Hydro [3, 4, 5, and 6] which review and examine overall energy use as well as key technologies including fans, pumps and motors. Friedman [7] provides similar information for California industrial energy use. Industry Canada [8], Jaccard et al [9] and Natural Resources Canada [10] examine opportunities for energy efficiency in Canadian industry. These studies have found that the industrial sector has a number of cost-effective technologies which can reduce energy use and greenhouse gas emissions.

The Power Smart Partner Industrial program was launched in April 2002. The basic concept was that BC Hydro's largest business customers have the most to gain from implementing long-term energy savings strategies. BC Hydro partners with these companies, and it contributes matching funding and other resources to help them overcome barriers to realizing energy savings opportunities. Requirements of the Power Smart Partners included: (1) commitment to improve overall energy efficiency; (2) signing a Power Smart Partner agreement outlining their energy efficiency target and the Energy Champion responsible for carrying out the plan; and (3) commitment to provide matching funds to identify and implement energy savings opportunities. BC Hydro in turn provided: (1) matching funds for businesses to identify energy savings opportunities; (2) education and training for business partner staff, including provision of energy managers; and (3) funding for energy savings opportunities including a fixed incentive program and a large project program. Under the Fixed Incentive Fund, project incentives of 1.5 cents per kWh saved were offered. Under the Large Project Incentive Program, customers bid projects requiring an incentive of $1 million or more through a competitive process.

The purpose of this paper is to summarize the findings of a market and impact evaluation of the Power Smart Partners Industrial program. Specifically, this paper does the following. (1) Analyzes differences in market penetration rates between program participants and program non-participants for key energy efficient technologies. This analysis is undertaken at the end use level and then aggregated across all end uses. (2) Estimates demand equations for purchased electricity by transmission voltage customers by major sector. The sectors included are metal mining, wood products, pulp and paper, chemicals, and coal mining. (3) Evaluates net and gross energy and peak savings by end use. The evaluated net energy and peak savings are then compared to savings reported by the program. (4) Compares program cost effectiveness and program offerings with other comprehensive commercial and industrial programs of North American utilities. Both the present program and the comparison programs are viewed as exhibiting best practices in recent surveys.

Data and Method

This study evaluates the Power Smart Partners Industrial program for the four fiscal years from April 2002 through March 2006. Further details on the underlying research are included in ADM Associates [11] and Innovolgie [12]. For this period, there were 151 facilities that participated in the Power Smart Partners Industrial program, with 233 projects and expected savings of 497 GWh per year. Data for the evaluation were collected through interviews with program staff, review of program materials and processes, telephone interviews with customers, on-site inspections, and end-use metering. Based on program data, stratified sample designs were developed for a telephone survey to collect information for the market and impact analysis. Sample sizes were determined which would provide savings estimates for the program with ±10% precision at the 90% confidence level.

Telephone surveys were conducted with decision makers at 42 of the 151 participating facilities. The telephone-based survey was undertaken with decision makers at 42 of the 151 facilities which participated in the program. The survey provided information to estimate free ridership and spill over as well as provide information on customer satisfaction, customers experience with the program, and decision making pertaining to energy-related investments.

On-site visits were conducted at 59 participant and 65 non-participant sites. The on-site visits were used to collect information for the market and impact analyses. The on-site visits were used to verify installation of rebated measures, determine any changes in operating procedures since the measures were installed, undertake metering of energy use for selected measures, and collect information on saturation of energy efficient measures. Using this data, estimates of saturation rates for energy efficient measures were developed for the main types of end uses in industrial facilities including lighting, pumps, fans and blowers, compressors, and process equipment. The saturations are reported separately for participant and non-participant facilities in order to better define the market potential. T-tests were used to identify differences in saturation rates that were statistically significant between participants and non-participants.

The data collected through the on site surveys were used to estimate gross energy and demand savings. Analysis began with a review of the program's calculated savings to determine whether the methodology used appeared to be appropriate, whether assumptions made were reasonable, and whether the calculations were correct. To verify that measures were correcting installed, the field staff examined the following. (1) For lighting measures, the installation of lamps, ballasts, reflectors and controls was checked and verified. Data was collected on types and numbers of lighting fixtures, bulbs and ballasts. (2) For fans and blowers, compressors, and pumps, information on efficiency was obtained from name plates. Motors with ASDs are connected to a controller box which varies the speed according to the load's requirements, and clamp on voltage meters were used to measure the variation in the voltage as appropriate. (3) For process measures, the installation of any process equipment, any removal of process equipment and any process-related data were checked. In many cases, comparative pre-post load monitoring had been undertaken and this information was used. These procedures were used to estimate gross realization rates for the sampled projects, and the gross realization ratio by segment was used to expand the sample results to the population of projects in the program.

The data collected though the telephone surveys were used to estimate net energy and demand savings. Several criteria were sued to determine what proportion of a given project should be attributed to free ridership. The criteria included: (1) customers' pre-program installation of the technology; (2) customers' plans to install the technology without the program; and (3) customers' views of the importance of the program in making the install decision. With three binary variables there were eight possible combinations for assigning a free ridership score to each customer. Several criteria were also used to determine spill over. The criteria included: (1) installation of similar measures without an incentive; and (2) likelihood of undertaking another energy efficiency project at the site without an incentive. The net effect of the free rider and spill over analysis was used to determine a net to gross ratio for each segment.

Electricity Demand Equations

As an initial step in understanding the market, we estimated demand equations for purchased electricity for the five main industrial sectors, which make up about 95% of the industrial load, using annual data for the twenty fiscal years ending in March 2007. The log of the demand for purchased electricity for each sector i at time t was modelled as a linear function of a constant term, the log of real or constant dollar sector GDP, a trend term, the log of the marginal price of electricity and an error term as follows:

Table 1. Electricity demand equations by industrial sector (GWh per year)

	Metal mining	Wood products	Pulp and paper	Chemicals	Coal mining
Constant	5.10*** (0.34)	2.37*** (0.62)	2.49*** (0.75)	2.86*** (0.63)	0.54 (1.62)
Log sector GDP	0.39*** (0.052)	0.50*** (0.081)	0.89*** (0.10)	0.67*** (0.093)	0.87*** (0.23)
Trend	-0.0067*** (0.0025)	0.026*** (0.0057)	0.0057*** (0.0018)	-0.0056** (0.0029)	-0.025*** (0.0032)
Log marginal electricity price	-0.086** (0.041)	-0.10*** (0.048)	-0.10*** (0.031)	-0.082* (0.050)	-0.065* (0.040)
Adjusted R^2	0.65	0.98	0.88	0.79	0.81
F test	12.6 (0.00)	377.5 (0.00)	39.3 (0.00)	24.6 (0.00)	27.7 (0.00)

Note. One, two, or three asterisks means that the regression coefficient is significant at the 10%, 5% or 1% level.

Table 2. Lighting systems penetration rates

	Participant	Non-participant	Difference	t-test
Dimming controls	8.6	3.0	5.6	1.32
EMS	12.1	1.5	10.6	1.82
T8 lamps	65.5	30.8	34.7	4.12
CFLs	32.8	12.3	20.5	2.79
HPS	72.4	61.5	10.9	1.30
Metal halide	72.4	72.3	1.2	0.01
LEDs	29.3	10.8	18.5	2.62
Electronic ballasts	70.7	43.1	27.6	3.23

Table 3. Lighting systems savings

	Expected savings	Gross evaluated savings	Net evaluated savings
Energy (GWh per year)	21.4	22.1	20.2
Peak (MW)	2.9	3.0	2.8

$$\ln GWh_{it} = \alpha_i + \beta_i GDP_{it} + \gamma_i t + \delta_i eprice_{it} + \varepsilon_{it} \quad (1)$$

Additional specifications included the log of the price of natural gas and the log of lagged purchased electricity, but these were not statistically significant and were dropped from the final specifications. The equations were estimated using White's heteroscedasticity adjusted least squares. Since the equations are estimated in double log form, the regression coefficients are estimates of the relevant elasticities.

Table 1 presents the results of the regression modelling. The coefficients for each model are shown in the relevant row, with the t-statistics for the coefficient shown in parentheses. The adjusted R-squared statistic shows the share of the variance in purchased energy explained by the model. The F statistic measures the statistical significance of the linear regression with the significance level shown in parentheses. All five models perform well, as each model is significant at better than the 1% level, the explanatory power of the regression is impressive, and the coefficients are all significant at the 10% level or better. The estimated activity elasticities are 0.39 for metal mining, 0.50 for wood products, 0.89 for pulp and paper, 0.67 for industrial chemicals, and 0.87 for coal mining. The estimated price elasticities are -0.086 for metal mining, -0.10 for wood products, -0.10 for pulp and paper, -0.082 for industrial chemicals, and -0.065 for coal mining.

Lighting Systems

Lighting systems typically include lighting fixtures, lamps, ballasts and controls. Many lighting systems have efficiencies of twenty-five percent or less, with the electrical energy which is not converted to lighting converted instead to waste heat. Key methods of reducing lighting consumption include using more efficient lighting sources and installing appropriate lighting controls to reduce annual hours of use for a given light source.

Table 2 shows the penetration rates for program participants and program non-participants for six energy efficient lighting technologies: dimming controls, EMS, T8 fluorescent lamps; compact fluorescent lamps; high pressure sodium lamps; metal halide lamps; LED lamps; and electronic ballasts. Differences between penetration rates for participants and non-participants and associated t-tests are also shown, with a t-value of 1.96 or greater being significant at the 95% level and a t-value of 1.67 or greater being significant at the 90% level. The differences are significant at the 95% level for T8 lamps, CFLs, LEDs and electronic ballasts and at the 10% level for EMS.

Table 3 summarizes energy and peak savings for lighting systems. Expected savings or program reported savings were 21.4 GWh per year for energy and 2.9 MW for demand. Gross evaluated savings based on the engineering analysis were 22.1 GWh per year for energy and 3.0 MW for demand. Net

Table 4. Fan and blower systems penetration rates

Component	Participant	Non-participant	Difference	t-test
ASD	27.1	6.2	20.9	3.21
Cog belts	35.6	6.2	29.4	4.25
Motor sizing	8.5	1.5	7.0	1.78
HEM	67.8	40.0	27.8	3.23

Table 5. Fan and blower systems savings

	Expected savings	Gross evaluated savings	Net evaluated savings
Energy (GWh per year)	50.7	52.4	47.9
Peak (MW)	6.9	7.2	6.6

Table 6. Pump systems penetration rates

Component	Participant	Non-participant	Difference	t-test
Efficient pumps	55.9	27.7	28.2	3.31
Pump sizing	69.5	38.5	31.0	3.64
Pipe sizing	69.5	40.0	29.5	3.46
ASD	32.2	13.9	18.4	2.47
Motor sizing	8.5	1.5	7.0	1.78
HEM	67.8	40.0	27.8	3.23

Table 7. Pump systems savings

	Expected savings	Gross evaluated savings	Net evaluated savings
Energy (GWh per year)	61.2	63.1	57.7
Peak (MW)	8.4	8.6	7.9

evaluated savings based on the free rider and spillover analysis were 20.2 GWh per year and 2.8 MW.

Fan and Blower Systems

Fans and blowers provide the motive force to move air or another gas against the resistance of the air conveyance system. These systems typically include a motor, a fan or blower, a speed control, a control vane or damper and a duct system. Up to one-half of the potential energy savings in a fan or blower system can be captured though the appropriate sizing of motors, reducing unnecessary loads and minimizing motor idling.

A number of energy efficient fan and blower technologies were examined. Table 4 shows the penetration rates for program participants and program non-participants for four energy efficient fan and blower technologies: adjustable speed drives; cog belts; appropriate motor sizing; and high efficiency motors. The differences between participants and non-participants are significant at the 95% level for adjustable speed drives, cog belts and high efficiency motors and at the 90% level for appropriate motor sizing.

Table 5 summarizes energy and peak savings for fan and blower systems. Expected savings or program reported savings were 50.7 GWh per year for energy and 6.9 MW for demand. Gross evaluated savings based on the engineering analysis were 52.4 GWh per year for energy and 7.2 MW for demand. Net evaluated savings based on the free rider and spillover analysis were 47.9 GWh per year and 6.6 MW.

Pump Systems

Pumps move liquids against the resistance of a piping system and uphill against gravity. Pumping systems typically include a motor, a pump or impellor, a speed control device, throttle or valve, and piping. Up to one-half the potential energy savings in a pumping system can be captured though appropriate sizing of the motor and its load, reducing unnecessary loads, and minimizing motor idling.

A number of energy efficient pump technologies were examined. Table 6 shows the penetration rates for program participants and program non-participants for six energy efficient pump technologies: high efficiency pumps; appropriate pump sizing; correct pipe sizing; adjustable speed drives; appropriate motor sizing; and high efficiency motors. The differences between participants and non-participants are significant at the 95% level for high efficiency pumps; appropriate pump sizing; correct pipe sizing; adjustable speed drives; and high efficiency motors and at the 90% level for appropriate motor sizing.

Table 7 summarizes energy and peak savings for pump systems. Expected savings or program reported savings were 61.2 GWh per year for energy and 8.4 MW for demand. Gross evaluated savings based on the engineering analysis were 63.1 GWh per year for energy and 8.6 MW for demand. Net evaluated savings based on the free rider and spillover analysis were 57.7 GWh per year and 7.9 MW.

Table 8. Compressor systems penetration rates

Component	Participant	Non-participant	Difference	t-test
Air inlet temperature	11.9	4.6	7.3	1.47
System controls	64.2	27.9	36.3	4.34
Heat recovery	10.2	3.1	7.1	1.58
ASD	27.1	6.2	20.9	3.21
Motor sizing	8.5	1.5	7.0	1.78
HEM	67.8	40.0	27.8	3.23

Table 9. Compressor systems savings

	Expected savings	Gross evaluated savings	Net evaluated savings
Energy (GWh per year)	104.4	107.8	98.6
Peak (MW)	14.3	14.8	13.5

Table 10. Other motor systems

Component	Participant	Non-participant	Difference	t-test
Motor sizing	8.5	1.5	7.0	1.78
HEM	84.8	61.5	27.8	3.23
Power factor	57.6	20.0	37.6	4.63
ASD	67.8	56.0	10.9	1.26

Table 11. Process systems savings

	Expected savings	Gross evaluated savings	Net evaluated savings
Energy (GWh per year)	259.6	268.0	245.0
Peak (MW)	35.5	36.7	33.7

Compressor Systems

Compressors increase the pressure of a gas to the point where it can do useful work, typically by increasing the pressure from 15 pounds per square inch (or atmospheric pressure) to 100 pounds per square inch. Compressed air systems typically include a motor, a speed control device, compressor, dryer/filter unit, throttle or vane or damper, and a piping system. Key methods of saving energy in compressor systems include using as little compression as possible, minimizing air leaks, and maintaining compressor efficiency through periodic maintenance.

Table 8 shows the penetration rates for program participants and program non-participants for six energy efficient compressor system technologies: reduce air inlet temperatures; compressor system controls; heat recovery for hot water; adjustable speed drives; appropriate motor sizing; and high efficiency motors. The differences are significant at the 95% level for compressor system controls; adjustable speed drives; appropriate motor sizing; and high efficiency motors and at the 90% level for appropriate motor sizing.

Table 9 summarizes energy and peak savings for compressor systems. Expected savings or program reported savings were 104.4 GWh per year for energy and 14.3 MW for demand. Gross evaluated savings based on the engineering analysis were 107.8 GWh per year for energy and 14.8 MW for demand. Net evaluated savings based on the free rider and spillover analysis were 98.6 GWh per year and 13.5 MW.

Other Motor Systems

Other motor systems include conveyance systems, hydraulic systems, cutting, grinding and milling equipment, material shaping equipment, electro-chemical equipment and a wide variety of other specialized equipment. Many process systems include a motor, a controller, a drive and relevant end use equipment. Main opportunities for energy efficiency include proper equipment sizing, use of high efficiency motors, and sue of adjustable speed drives.

Table 10 shows the penetration rates for program participants and program non-participants for four process system technologies: appropriate motor sizing; high efficiency motors; power factor correction; and adjustable speed drives. The differences are significant at the 95% level for high efficiency motors and power factor correction and at the 90% level for appropriate motor sizing.

Table 11 summarizes energy and peak savings for process systems. Expected savings or program reported savings were 259.6 GWh per year for energy and 35.5 MW for demand. Gross evaluated savings based on the engineering analysis were 268.0 GWh per year for energy and 36.7 MW for demand. Net evaluated savings based on the free rider and spillover analysis were 245.0 GWh per year and 33.7 MW.

Table 12. Program savings

	Expected savings	Gross evaluated savings	Net evaluated savings
Energy (GWh per year)	497.3	513.4	469.3
Peak (MW)	68.1	70.3	64.5

Table 13. Commercial and Industrial Comparative Analysis (first year costs)

Utility (year)	Program	Description	$ per kWh	$ per kW
CA[1] (PGE, SCE, SDGE) (2002)	Standard Performance Contract	Targeted at customer efficiency projects and offers fixed-price incentives by end-use for measured kW savings achieved through installation of energy-efficiency measures	0.14	809
NYSERA[1] (2001-02)	Energy Smart™ C/I Performance	Executed standard performance contract with ESCOs and contractors who receive performance based incentives for projects that reduce energy consumption and summer peak	0.17	635
BC Hydro[1] (2004)	Industrial Power Smart Partners	Provide energy audits, co-funding and bonus rewards to large industrial customers who undertake major energy efficiency investments	0.14	724
BC Hydro[1] (2004)	Commercial Power Smart Partners	Provide energy audits, co-funding and bonus rewards to large commercial, government and institutional customers who undertake major energy efficiency investments	0.24	1,187
Xcel (Colorado)[1] (2002-05)	Custom Efficiency (Colorado)	Offered demand-side bidding programs where customers bid a fixed price per kW for demand side reductions in energy consumption	0.16	304
Northeast Utilities[1] (2003)	Custom Services	Offered subsides for energy audits, prescriptive incentives, custom incentives and upgrade incentives though a vendor-driven umbrella program	0.35	1,730
National Grid[1] (2002)	Energy Initiative	Provided prescriptive and custom rebates, technical assistance, training, and commissioning services to large commercial and industrial customers	0.32	1,600
Wisconsin Power & Light[1] (2002)	Shared Savings	Identified and implemented energy efficiency projects for commercial, industrial and agricultural customers with below market-rate financing paid through savings on energy bills	0.21	1,460
Pacific Gas & Electric[2] (2001)	Standard Performance Contracting	Paid financial incentives for custom-designed energy retrofits including lighting, refrigeration, HVAC, motors, variable speed drives and waste heat recovery	0.18	1,245
Connecticut Light & Power[2] (2002)	Request for Proposal program	Allowed customers on either on their own or in cooperation with third party consultants to bid for funds to design and implement custom-tailored energy savings projects	0.20	1,135

Sources. 1. Quantum Consulting [13]. 2. York and Kushler [14].

Total Program Savings

Table 12 summarizes energy and peak savings for all technologies installed under the Power Smart Partners Industrial program. Expected savings or program reported savings were 469.7 GWh per year for energy and 68.1 MW for demand. Gross evaluated savings based on the engineering analysis were 513.4 GWh per year for energy and 70.3 MW for demand. Net evaluated savings based on the free rider and spillover analysis were 469.3 GWh per year and 64.5 MW.

Comparative Program Analysis

The cost effectiveness and program offering analysis focussed on two main issues: (1) nature and breadth of the program offering compared to programs of other utilities; and (2) first year program costs for energy and demand compared to other utilities. A literature review was undertaken to identify exemplary comprehensive industrial and commercial programs and to understand the best practices that make them exemplary programs. Both Power Smart Partners Commercial and Power Smart Partners Industrial were among the ten exemplary programs identified in the surveys consulted.

Key findings from the literature review include the following. (1) Program Offerings. Commercial and industrial demand-side management programs include three main types of programs: custom rebate programs; demand-side biding programs; and standard performance contracting programs. These are supplemented by prescriptive offerings at some utilities, but these are usually handled though separate programs at most utilities. (2) Best Practices. Some common features of exemplary programs include; focus on the implementation of the implementation of custom efficiency measures which supplement a prescriptive program or standard offer program; support for comprehensive projects which implement multiple measures at a given site; provision of technical engineering support during project scoping, design, implementation, commissioning and measurement and verification; and requirement for proof of installation of measures before a payment is made.

Table 13 summarizes ten comprehensive commercial and industrial programs offered by North American utilities. The programs are offered by the California investor owned utilities (Pacific Gas and Electric, Southern California Edison, San Diego Gas and Electric), NYSERDA, BC Hydro (industrial and commercial), Xcel, Northeast Utilities, National Grid, Wisconsin Power and Light, Pacific Gas and Electric (older program), and Connecticut Light and Power. The program period examined is shown in parentheses. BC Hydro's Power Smart Partners is among the more comprehensive programs in this set of exemplary programs. It covers all main technologies, all main types of assistance, and offers bonus rewards outside the main program.

In addition to summary descriptions, the table provides key financial metrics for the ten commercial and industrial programs. The metrics included are U.S. dollars per first year kWh saved and U.S. dollars per kW achieved. The Power Smart Partners Industrial program again performs well compared to its peers. First year program energy costs are $0.14, while first year program demand costs are $724 per kW.

Lessons Learned

Lesson 1. Program Definition and Strategy. Ensure that the initial program definition and program strategy are clear, well defined and accepted by program staff and key stakeholders. Adjust the program as needed to reflect new opportunities and challenges in the market, but ensure that the revised program definition and strategy are clearly communicated to program staff and stakeholders.

Lesson 2. Program Responsibility and Authority. Clearly define project management roles and responsibilities, and ensure that program staff, trade allies and customers clearly understand who is responsible for what. The program should appear to customers and trade allies to be a seamless and consistent whole and not a set of disparate and poorly coordinated parts.

Lesson 3. Staff and Contractor Qualifications and Training. Industrial projects are typically complex, multi-dimensional, and unique to a specific site. Use trained and experienced engineers to assess the validity of an industrial project concept, estimate or validate ex ante savings, and facilitate and manage industrial project planning, monitoring and implementation.

Lesson 4. Program Plan, Objectives and Metrics. Develop a program plan with clearly articulated program logic that states the program activities, operational outputs, objectives and resources required, ensure that program schedules are well defined and realistic, and that suitable allowance is allowed for slippage and contingencies. Program objectives should be clear, well defined, measurable and achievable, and base line and operational data should be collected which allows management to track progress against objectives and identify corrective actions as required.

Lesson 5. Marketing and Outreach. Leverage scarce marketing dollars through key account managers' relationships with customers and through partnerships and cooperation with other market players. Develop an open and respectful relationship with consultants and contractors and leverage relationships with partners in one area to build relationships in other areas.

Lesson 6. Program Procedures and Incentives. Keep program procedures (including applications, measurement and verification) as simple and transparent as feasible to maximize participation and energy savings. Ensure that financial incentives are an appropriate instrument for the market context, and if they are appropriate, set incentive levels high enough to buy down first costs to the point where the efficient technology is competitive with the standard technology on a life cycle cost basis.

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