Impacts of an Energy Star® Promotion

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ABSTRACT

BC Hydro's Power Smart group has been encouraging the use of energy efficient appliances since the late 1980's. Starting in October 2001, Power Smart again emphasized appliances with the promotion of ENERGY STAR® compliant refrigerators, clothes washers and dishwashers through advertising and point of purchase materials and a salesperson incentive for the first two products. The promotion lasted until the end of March 2002.

The purpose of this project was to determine the impact of the promotion and to provide a baseline against which the impact of future activities could be measured. The evaluation was based on a time series of data collected as part of a Residential End Use Survey, and adjusted to match industry data (Canadian Appliance Manufacturers Association) on total shipments and ENERGY STAR® shares. The evaluation methodology was to use a regression discontinuity model, where sales were modeled as a linear trend and program activity was represented as a dummy variable during program promotion periods. Engineering algorithms were used to estimate energy savings.

Based on the evaluation analysis, it was estimated that the promotion had resulted in an increase in sales of 542 refrigerators and 550 clothes washers. It was also determined that there was no significant change in the sales of dishwashers, which was likely attributed to the lack of a salesperson incentive for this product. However, due to the small data time series (16 quarters), the statistical quality was not as high as might be desired, but this would be expected to improve as more data is collected over time.

The evaluation also projected the changing market share for ENERGY STAR® appliances. It determined that the ES share of refrigerators was expected to grow from about 40% in 2004 to over 70% by 2006. Over the same period, ES clothes washers should increase from about 34% of sales to about 50% of sales and dishwashers should increase from about 50% to about 74% of sales.

Introduction

In British Columbia, BC Hydro's Power Smart group has been encouraging the use of energy efficient appliances since the late 1980s. One of the vehicles for improving energy efficiency, reducing energy consumption and reducing greenhouse gas emissions is the ENERGY STAR® labeling program, operated jointly by the US Environmental Protection Agency (EPA) and the US Department of Energy (DOE). The purpose of the program is to increase consumer awareness, interest and desire for energy efficient products.

ENERGY STAR® appliances have had a major impact on energy use and attitudes towards energy use in the United States and a number of papers have examined various aspects of the ENERGY STAR® program and its impacts in the United States. The ENERGY STAR® program is also being promoted in jurisdictions outside of the United States, but there are relatively few studies examining the impacts of these programs.

In Canada, ENERGY STAR® appliances have only been promoted at the national level since 2002 and are relatively new. Starting in September 2001, Power Smart emphasized these products with the promotion of ENERGY STAR® compliant refrigerators and clothes washers through salesperson incentives, with this promotion lasting until the end of March 2002. The program consisted of advertising, in-store training and a $ 20 salesperson incentive for refrigerators and clothes washers (although two retail chains negotiated to change this incentive to providing additional points for their customer loyalty programs).

The purpose of this paper is to estimate the impact of BC Hydro's ENERGY STAR® promotional activities on sales of ENERGY STAR® compliant products and on energy savings due to increased sales of ENERGY STAR® compliant products and to provide a forecast of ENERGY STAR® shares for the relevant appliances.

Study Approach

Following the initial project team meeting and a review of previous research, five main issues emerged for this study:

- Issue 1. Review trends in electricity consumption for refrigerators, clothes washers and dishwashers.
- Issue 2. Estimate recent historical sales of refrigerators, clothes washers and dishwashers.
- Issue 3. Estimate market share of ENERGY STAR compliant refrigerators, clothes washers and dishwashers.
- Issue 4. Forecast future sales and shares of total and ENERGY STAR compliant refrigerators, clothes washers and dishwashers.
- Issue 5. Evaluate the impact of BC Hydro's promotional program on sales of ENERGY STAR compliant appliances and electricity and natural gas consumption.

Issue 1 was addressed mainly using Natural Resources Canada data on average appliance energy consumption levels. Issues 2, 3 and 4 were addressed mainly through information collected by the Residential End Use Survey (REUS). This data was augmented by (1) appliance shipment data from the Canadian Appliance Manufacturers Association (CAMA) [1], (2) a retailer survey completed in early 2003 to determine ENERGY STAR® appliance shares for 2002, and (3) recently available quarterly ENERGY STAR® shipment data for 2003, also from CAMA. Issue 5 was addressed mainly by information collected through program interviews with utility and retail staff and a document and literature review.

The REUS survey was conducted in March 2003 and included a mail survey of some 5,685 randomly selected BC Hydro residential customers[2]. In addition to a wide range of additional questions on household energy use, respondents were asked if they had various major

[1] The Canadian Appliance Manufacturers Association (CAMA) is the industry association representing Canada's major and portable appliance manufacturers and marketers on issues such as trade, standards development, the environment and energy efficiency. In addition, CAMA collects and disseminates comprehensive market data on behalf of its member companies. They publish an annual "Major Appliance – Industry trends & Forecast" book that includes annual and quarterly data on appliance shipments to regions in Canada, and starting in 2004, will also publish Energy Star share data.

[2] This sample size provides a confidence level of ± 1.5%, 19 times out of 20.

household appliances, when they had purchased these appliances, and whether or not the appliances were ENERGY STAR® qualified.

The program evaluation was conducted by using a regression discontinuity model analysis of the quarterly ENERGY STAR® sales information to determine if there was a change in shares during the period of the promotion.

When the REUS appliance purchase data was compared with the CAMA data, it showed significant differences in overall sales to BC. Further the REUS ENERGY STAR® shares were also much higher than the retailer survey data for 2002. While the REUS survey was well constructed and included a copy of the ENERGY STAR® seal accompanying the questions regarding ENERGY STAR®, it was concluded that some customers confused the ENERGY STAR® brand with EnerGuide, the Canadian appliance labeling program. However, it was also thought that this bias was systematic (i.e., would occur equally in the REUS responses for all quarterly data), and therefore the REUS data could be adjusted to correspond with CAMA sales, the ENERGY STAR® shares from the 2002 retailer surveys, and the quarterly ENERGY STAR® data for 2003. Then the regression discontinuity model could be run on the adjusted data to determine the impact from the promotion.

For each appliance, the estimated number of sales by quarter in BC Hydro's service territory was estimated by expanding the REUS results to the population of residential customers, adjusted for apparent over-reporting in the survey using Canadian Appliance Manufacturers Association (CAMA) data. The CAMA shipment data for BC was adjusted to reflect the BC Hydro service territory. The algorithm used is given in Equation (1).

$$(1)\quad \text{Sales}_{ijk} = \text{Purchases by respondents}_{ijk} * (1{,}442{,}597/5{,}685) * \text{Adjustment}_{ij}$$

Sales refers to estimated sales of appliance i (refrigerator = 1, clothes washer = 2, dishwasher = 3), for appliance type j (total = T, ENERGY STAR compliant = ES) for quarter k (2001:Q2 = 1, . . . , 2003:Q1 = 8); purchases by respondents refers to reported purchases of appliance i during quarter j by survey respondents; 1,442,597 is the number of residential accounts at the end of March 2003, 5,685 is the number of surveyed residential customers reporting appliance use and the adjustment factor for appliance i of type j is the ratio of CAMA-data based estimated sales for BC Hydro's service territory to REUS-based estimated sales for BC Hydro's service territory. Estimates were made separately for total sales and sales of ENERGY STAR® compliant product.

Market share of ENERGY STAR® compliant product is defined as the share of sales for each appliance i in each quarter k that was ENERGY STAR® compliant and was calculated using Equation (2). The REUS ENERGY STAR® share data was also adjusted to line up with the 2002 BC ENERGY STAR® retailer survey data and the 2003 CAMA ENERGY STAR® data for BC.

$$(2)\quad \text{Market share}_{ik} = (\text{Sales}_{iESk} / \text{Sales}_{iTk})$$

Using the sales estimate in Equation (1), total future sales of appliance type i in quarter k were estimated based on the regression model given in Equation (3), where α and β are parameters and ε is the error term.

$$(3)\quad \text{Sales}_{iTk} = \alpha + \beta\ \text{Quarter}_{iTk} + \varepsilon_{iTk}$$

The regressions were estimated using both ordinary least squares assuming no autocorrelation and by maximum likelihood assuming first-order autocorrelation in the residuals. In the ordinary least squares regressions, it is assumed that the error terms ε are uncorrelated from period to period, that is, that there is no correlation between the error terms over time.

In the maximum likelihood regressions, it is assumed that the error terms follow a first-order autoregressive scheme as given by Equation (4), where the absolute value of the autocorrelation coefficient ρ is less than one and the new error terms η are uncorrelated over time. This means that an error or innovation in sales at time t affects future sales, but that the effect of this error or innovation decays over time.

$$(4)\ \varepsilon_{iTk} = \rho\varepsilon_{iTk-1} + \eta_{iTk}$$

ENERGY STAR® compliant sales of appliance type *i* in quarter *k* were based on the regression model given in Equation (5), where α, β and γ are parameters, ε is the error term and Program is a dummy variable that takes on the value one during the program quarter and zero otherwise. The coefficient γ provides an estimate of the impact of the program on sales of the specific ENERGY STAR® appliance. This model is often referred to as the regression discontinuity model because it posits a discontinuity for the period the program is in effect.

$$(5)\ \text{Sales}_{iESk} = \alpha + \beta\ \text{Quarter}_{iESk} + \gamma\ \text{Program}_i + \varepsilon_{iESk}$$

Again, the regressions were estimated using both ordinary least squares assuming no autocorrelation and by maximum likelihood assuming first order autocorrelation in the residuals.

Energy savings due to incremental sales of ENERGY STAR® appliance *i* are estimated using Equation (6) where Consumption is the appliance consumption from Natural Resources Canada (2003), Incremental Savings is the share by which energy consumption is reduced for ENERGY STAR® appliances from Webber, Brown and Koomey (2000) and Program is the program impact on sales from the regression modeling.

$$(6)\ \text{Energy Savings}_i = \text{Consumption}_i * \text{Incremental Savings}_i * \text{Program}_i.$$

A separate set of regression models were used to forecast total appliance sales as well as ENERGY STAR® appliance sales into the future. These regressions were based on the 2002 retail survey of ENERGY STAR shares and the 2003 CAMA quarterly ENERGY STAR® data rather than the REUS data as this was thought to provide the best baseline information upon which to base the forecasts. The regressions were estimated using both ordinary least squares assuming no autocorrelation and by maximum likelihood assuming first order autocorrelation in the residuals.

Refrigerators

Trends in Energy Consumption

In Canada, average annual refrigerator energy consumption fell from 956 kWh per year in 1990 to 640 kWh per year in 2000. This is a percentage reduction of 33.1% in unit energy consumption over ten years. Key factors leading to this decrease include:

- Improvements in motors and compressors.
- Improvements in gaskets and seals.
- Development of thinner, high efficiency insulation.
- Improved controls that reduce consumption for self-defrosting loads.

Historical Sales

Based on the adjusted REUS data, we estimated sales of refrigerators to BC Hydro customers by quarter for the period 2001:Q2 to 2003:Q1. For the eight quarters shown two features stand out: first, total refrigerator sales appear to be growing over time; second, comparing quarter-over-quarter changes (i.e. 2002: Q4 versus 2001: Q4); in the ENERGY STAR® share of total refrigerator sales, the ENERGY STAR® share appears to have grown.

Table 1. Recent Refrigerator Sales

	Total (units)	ENERGY STAR® (units)	ENERGY STAR® share (%)
2001: Q2	16800	1797	10.7
2001: Q3	17430	1668	9.6
2001: Q4	20160	2139	10.6
2002: Q1	19741	2096	10.6
2002: Q2	18900	2182	11.5
2002: Q3	15541	1754	11.3
2002: Q4	22051	2353	10.7
2003: Q1	19320	2053	10.6

Regression Models

We model refrigerator sales with several regression models as shown in Table 2. For each model, the regression coefficients are shown in a column with the standard error of the regression coefficient shown in parenthesis below the coefficient. OLS means that the model was estimated using ordinary least squares and ML means that the model was estimated using maximum likelihood. R-squared is a measure of goodness of fit for least squares regressions. The Durbin-Watson statistic is used to detect the presence of autocorrelation in the residuals, with a value of 2.0 indicating no autocorrelation.

Given the limited data available, the statistical results are good. Model 1 indicates that total sales are growing by about 310 units per quarter. Model 2 indicates that total sales are growing slightly less rapidly at about 299 units per quarter, with this estimate perhaps preferred to Model 1 since autocorrelation is slightly reduced. Model 3 suggests that ENERGY STAR® sales are increasing by about 60 units per quarter, with the incentive program increasing sales by some 460 units over the 2 quarters of program activity. Model 4 suggests that ENERGY STAR® sales are increasing by about 73 units per quarter, with the incentive program increasing sales by some 542 units, again with this estimate perhaps preferred to Model 3 since autocorrelation is reduced.

Table 2. Refrigerator Regression Models

	Model 1 Total Sales OLS	Model 2 Total Sales ML	Model 3 ES Sales OLS	Model 4 ES Sales ML
Constant	17348 (1623)	17440 (1245)	1676 (184)	1609 (61)
Quarter	310 (321)	299 (250)	60 (34)	73 (11)
Program	-	-	230 (178)	271 (61)
R-squared	0.134	-	0.442	-
Durbin-Watson	2.65	2.36	3.59	2.17

Figure 1 shows the results of the regression discontinuity model, and shows the impact on ES sales during the period of the promotion.

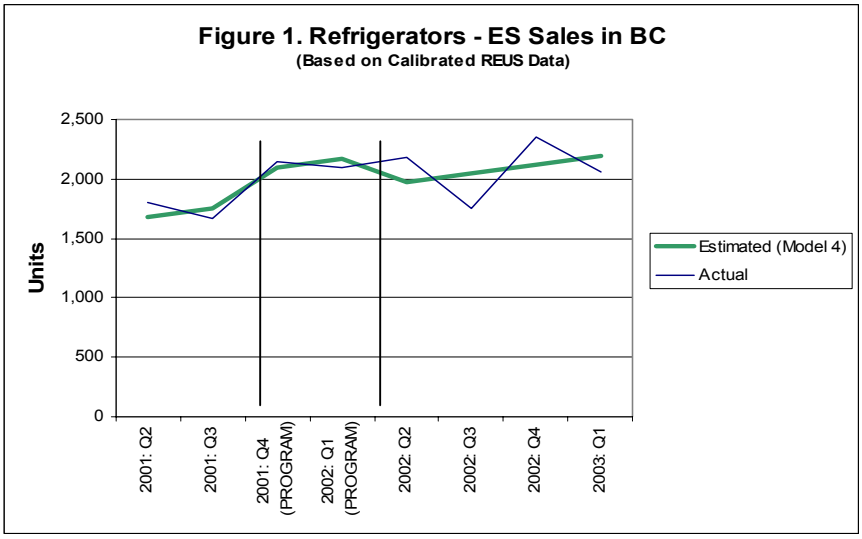


Figure 2 shows the forecast sales of refrigerators in BC, based on the regression analysis. Two total sales lines are shown. It has been assumed that at the time of the ENERGY STAR® promotion, essentially all the ENERGY STAR® appliances were sold in the retail sector as opposed to the builder sector. However as the builder sector represents a potential market, it has been included in the forecast.

CAMA also provides a forecast of appliance sales for Canada, which is likely preferable to this forecast. However a regression forecast of the total market is required so that a forecast can be made for ENERGY STAR® market shares in the future. The rapid increase in ENERGY STAR® sales starting in 2003 is also noteworthy. This is attributed to a number of new ENERGY STAR® models in the 17 – 19 cubic foot size, which is the most common size in BC, coming into the market.

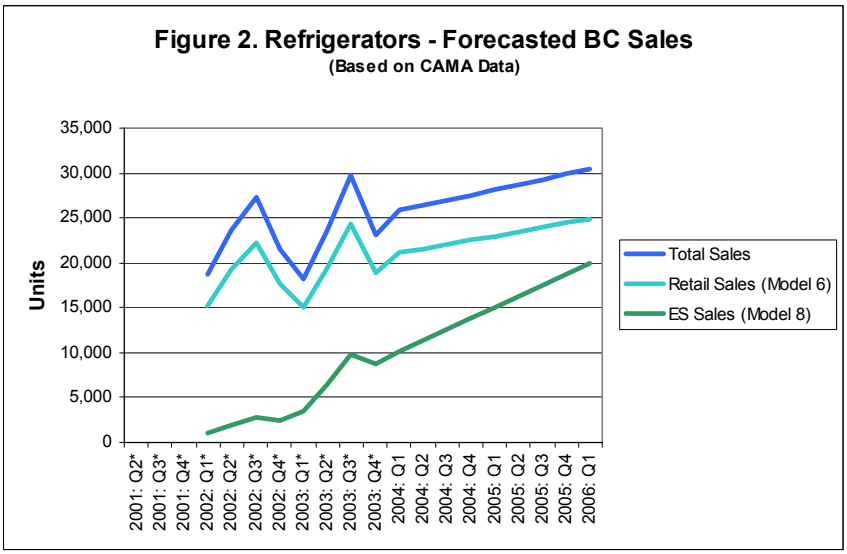
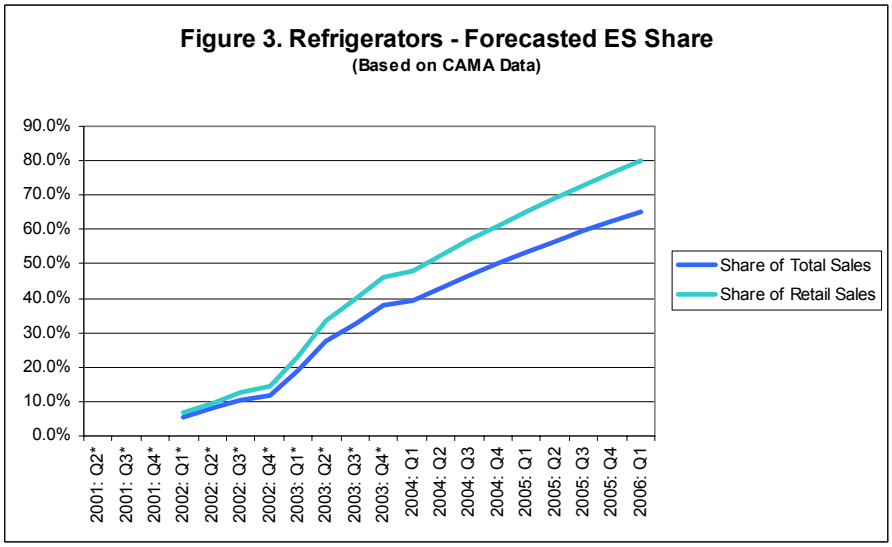


Figure 3 shows the forecast share of ENERGY STAR® refrigerators over the next three years and shows that they may be expected to grow to about 80% of the retail market, and to about 65% of the overall market.



Clothes Washers

Trends in Energy Consumption

In Canada, average annual clothes washer electricity consumption fell from 1,218 kWh per year in 1990 to 838 kWh per year in 2000. This is a percentage reduction of 31.2% in unit energy consumption over ten years. Key factors leading to this decrease include:

- Increased penetration of horizontal axis washers that use less hot water.
- Improvements in motors and drive systems.
- More flexible controls that allow better matching of the load size and load content to washing requirements.

Historical Sales

For clothes washers, we estimated sales to BC Hydro customers by quarter for the period 2001:Q2 to 2003:Q1. For the eight quarters shown in Table 3, total clothes washer sales appear to be growing over time. Sales of ENERGY STAR® clothes washers have followed a more erratic pattern than for all clothes washers, with steady growth in ENERGY STAR® sales. Comparing quarter-over-quarter changes in the ENERGY STAR® share of total clothes washer sales, the ENERGY STAR® share appears to have grown rapidly.

Table 3. Recent Clothes Washer Sales

	Total (units)	ENERGY STAR® (units)	ENERGY STAR® share (%)
2001: Q2	12928	2207	17.1
2001: Q3	16160	3269	20.2
2001: Q4	14140	2942	20.8
2002: Q1	16968	3923	23.1
2002: Q2	12120	2288	18.9
2002: Q3	15554	3596	23.1
2002: Q4	19190	5230	27.3
2003: Q1	19796	4740	23.9

Regression Models

We model clothes washer sales with several regression models as shown in Table 4. Again, for each model, the regression coefficients are shown in a column with the standard error of the regression coefficient shown in parenthesis below the coefficient. In most respects, the statistical results are good, although the standard error for program impact is large. Model 1 indicates that total sales are growing by about 746 units per quarter. Model 2 indicates that total sales are growing slightly less rapidly at about 732 units per quarter, with this estimate perhaps preferred to Model 1 since autocorrelation is slightly reduced. Model 3 suggests that ENERGY STAR® sales are increasing by about 348 units per quarter, with the incentive program increasing sales by 684 units. Model 4 suggests that ENERGY STAR® sales are increasing by about 343 units per quarter, with the incentive program increasing sales by some 550 units, again with this estimate perhaps preferred to Model 3 since autocorrelation is reduced.

Figure 4 shows the results of the regression discontinuity model, and shows the impact of the program on ENERGY STAR® sales during the period of the promotion.

Table 4. Clothes Washer Regression Models

	Model 1 Total Sales OLS	Model 2 Total Sales ML	Model 3 ES Sales OLS	Model 4 ES Sales ML
Constant	12502 (1748)	12552 (1652)	1873 (723)	1912 (662)
Quarter	746 (346)	732 (328)	348 (132)	343 (120)
Program	-	-	342 (699)	275 (660)
R-squared	0.436	-	0.582	-
Durbin-Watson	2.16	2.06	2.31	2.08

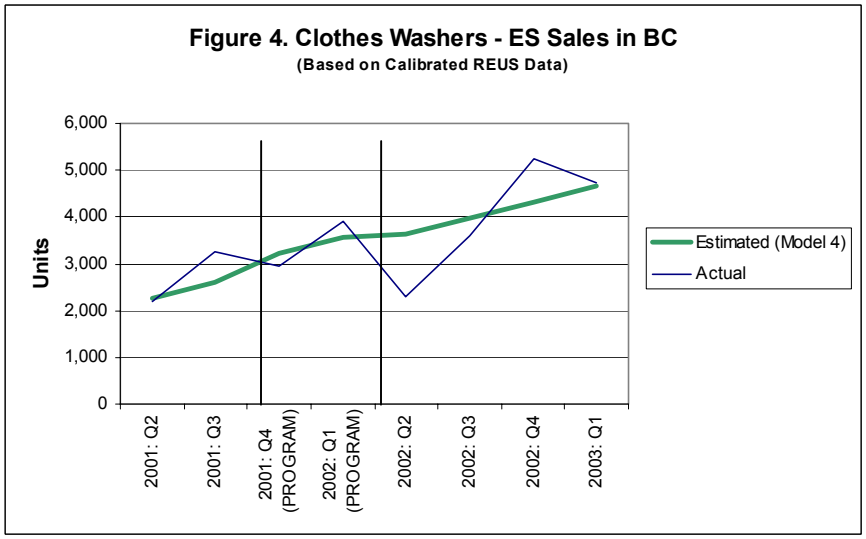


Figure 5 shows the forecast sales of clothes washers in BC, based on the regression analysis. The growth rate for clothes washers is lower than refrigerators.

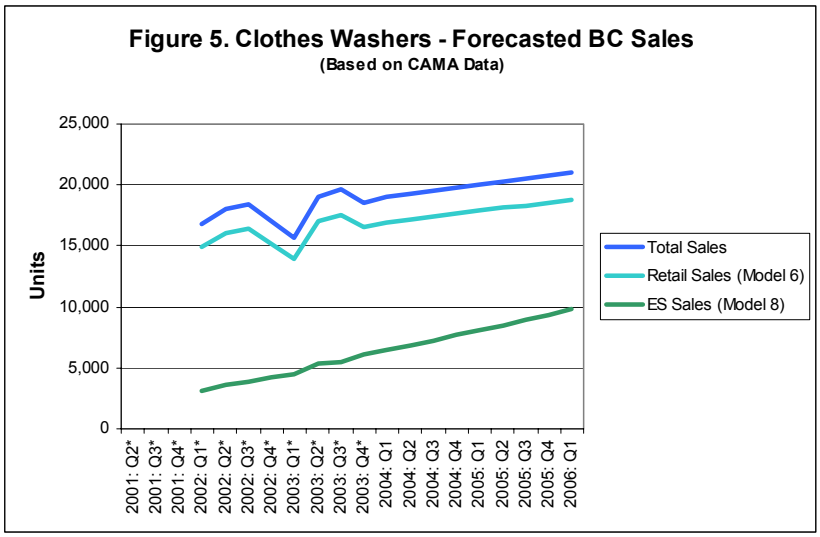
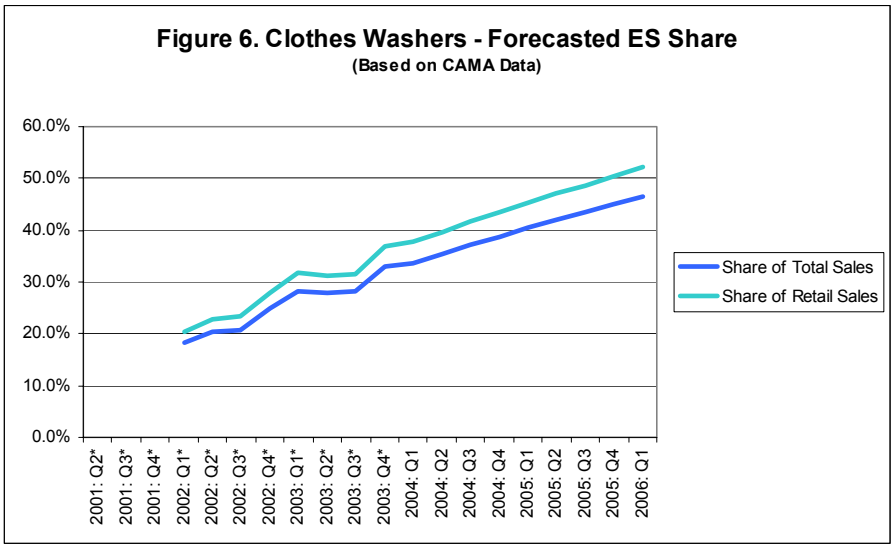


Figure 6 shows the forecast shares of ENERGY STAR® clothes washers. It shows a lower penetration than refrigerators and likely reflects the higher cost premium for the horizontal axis units. It may also indicate that the horizontal axis units will not saturate the market unless the cost premium decreases significantly.



Dishwashers

Dishwashers were also included in the evaluation, as they were included in the promotion program, but without the benefit of the salesperson incentive as the projected energy savings did not justify the incentive cost. For this component, the results of the statistical analysis were inconclusive. The OLS regressions showed a positive program impact while the ML regressions showed a negative impact. These mixed results, or lack of a clear impact, may be indicative of the importance of the salesperson's incentive as this was the major difference between the three program components. Detail results have been omitted due to space constraints.

Program Impact

Incremental Sales

The preferred estimates of the program impact on sales are shown in Table 5. According to the econometric models, the salesperson incentive led to an increase in sales of ENERGY STAR® compliant models of 542 refrigerators, and 550 clothes washers for a total of 1,092 appliances over the six months of the promotion.

Table 5. Program Impact on Sales

	Refrigerator	Clothes Washer	Total
Sales (units)	542	550	1,092

Energy Savings

Annual energy savings due to the program are shown in Table 6. Savings are estimated as the product of average consumption for new appliances times incremental savings for ENERGY STAR® qualifying products times the units the program has contributed to savings. Refrigerator savings are estimated at 55.6 MWh per year. Clothes washer savings are estimated at 216.6 MWh per year which includes both direct electricity savings and hot water savings (expressed in kWh). Total savings are 272.2 MWh per year.

Table 6. Program Impact on Energy Sales

	Refrigerator	Clothes Washer	Total
Consumption (kWh)	640	838	-
Incremental savings (ratio)	0.16	0.47	-
Program (units)	542	550	-
Savings (MWh)	55.6	216.6	272.2

Conclusions

Conclusion 1.: Methodology

This study demonstrates an innovative methodology for estimating the energy savings resulting from programs such as BC Hydro's Power Smart's ENERGY STAR® promotion. The methodology appears sound although the results in this study should be interpreted with caution primarily due to small sample sizes. These small sample sizes can produce misleading correlations between the sales of appliances and the two explanatory variables (the quarter and timing of the promotion). For example, the results for refrigerators indicate that the promotion increased sales by 271 units per quarter with a standard error of 61 units. However, the analysis for clothes washers shows an increase in sales of 275 units per quarter but a standard error of 660 units. Given this large standard error, we cannot conclude statistically that the promotion had a positive impact on sales, although the indications are positive. We recommend that the regression equations be recalibrated as more data becomes available over time in order to improve the reliability of the results.

Conclusion 2: Trends in Energy Consumption

Over the 1990s, there was a substantial reduction in the energy consumption of major household appliances in Canada. Average annual refrigerator energy consumption fell from 956 kWh per year in 1990 to 640 kWh per year in 2000. Average annual clothes washer energy consumption fell from 1,218 kWh per year in 1990 to 838 kWh per year in 2000. Average annual dishwasher energy consumption fell from 1,026 kWh per year in 1990 to 637 kWh per year in 2000. ENERGY STAR® appliances are more efficient than these average appliances.

Conclusion 3: Market Share of ENERGY STAR® Appliances

Regressions were developed based on the 2002 retailer survey, the REUS data, and the CAMA 2003 ENERGY STAR® data. Based on these regressions, ENERGY STAR® refrigerators may be expected to increase to about 80% of the retail market and 65% of the total market by 2006, while clothes washers may grow to about 52% of the retail market and 48% of the total market. Dishwashers may grow to 80% of the retail market and 70% of the overall market. There was a rapid increase in ENERGY STAR® refrigerators in 2003, which reflects the introduction of new models in the popular 17 to 19 cubic foot sizes.

Conclusion 4: Program Impact

Based on the econometric models, the salesperson incentive led to an increase is sales of ENERGY STAR® compliant models of 542 refrigerators and 550 clothes washers, for a total of 1,092 appliances. Refrigerator savings are estimated at 55.6 MWh per year. Clothes washer savings are estimated at 216.6 MWh per year. Total estimated savings are 272.2 MWh per year.

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