Impact Report

BC Hydro
Energy Star Appliances

Prepared for: BC Hydro
Power Smart Evaluation

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March 24, 2004

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1. Introduction

1.1 Background

BC Hydro's Power Smart group has been encouraging the use of energy efficient appliances since the late 1980s. Starting in October 2001, Power Smart again emphasized these products with the promotion of Energy Star compliant refrigerators, clothes washers and dishwashers through salesperson incentives. This promotion lasted until the end of March, 2002. Power Smart is considering the promotion of Energy Star appliances for the next several years in order to reduce the growth in residential energy consumption and peak demand, and hence requires a baseline against which to measure the impact of its promotional activities.

This study has two main objectives. First, develop a baseline for sales of Energy Star compliant products in British Columbia. In particular, estimate recent historical and projected future trends in sales of refrigerators, clothes washers and dishwashers in British Columbia, including in particular sales of Energy Star compliant product, in a form that can be readily updated over time. Second, to capture low cost information for program design and evaluation purposes. In particular, 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.

1.2 Energy Star Overview

In the face of increasing evidence of the impact of carbon emissions on climate change, a number of initiatives have been brought forward to deal with increased carbon emissions by reducing energy consumption. In particular, the international community agreed to reduce carbon emissions through the Kyoto Protocol, which Canada signed in December 1997. Canada committed itself to reducing greenhouse gas emissions by six percent below the levels in 1990 between 2008 and 2012, with most OECD countries including the United States committing themselves to somewhat larger reductions. Although Canada and a number of other countries have ratified the Kyoto Protocol, either the United States or Russia will have to ratify before it will come into force.

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. This in turn leads to increased energy efficiency, reduced energy consumption and reduced greenhouse gas emissions.

This program is a voluntary one in which the EPA and DOE enter into agreements with manufacturers allowing these manufacturers to promote qualifying products through use of the Energy Star label. Qualifying appliances and equipment display the Energy Star label that serves to alert consumers to the best in class nature of the product. To receive Energy Star certification, the

products must meet certain defined energy performance and energy use criteria. Efforts of the EPA and DOE have been focused on products where significant improvements in energy use can be achieved without reducing the level of service achieved by the product. Program components include product labels, sales training materials, point-of-purchase advertising materials, consumer education materials and resource materials for purchasing agents. [Webber, Brown and Koomey (2000)].

Energy Star was launched by EPA in 1993 with performance criteria initially covering computers, monitors and printers. The program goal was to promote and encourage the installation of energy-saving features in desktop equipment that were already available in laptop computers. After President Clinton signed Executive Order 12845 requiring that computers, monitors and printers purchased by the Federal government comply with Energy Star, manufacturers were induced to comply with these standards. Energy Star compliant personal computing equipment now overwhelmingly dominates the market [Webber, Brown and Koomey (2000)].

A wide range of additional equipment was subsequently added to the Energy Star program as shown in Exhibit 1.1. Criteria examined in determining whether or not to include an appliance in Energy Star include the following:

- Size of the appliance stock in units.
- Unit energy savings.
- Turnover or replacement rates.
- Potential cost effectiveness.

Exhibit 1.1. Selected Energy Star Developments

Date	Event
1993	EPA launched Energy Star with computers, monitors and printers
1995	Fax machines, copiers, residential HVAC, thermostats, new homes, exit signs added
1996	Refrigerators, room air conditioners, clothes washers, dishwashers added with efficiency standards about 10% above average appliances
1997	Residential lighting fixtures added
1998	Windows added
1999	Screw type CFLs added
2001	New Energy Star standards increased energy efficiency for refrigerators by about 20%, dishwashers by about 13% but left clothes washers essentially unchanged
2001	BC Hydro Energy Star promotion was held from September 2001 to December 2001.
2002	Natural Resources Canada formally begins promoting Energy Star

Initial Energy Star standards for refrigerators, clothes washers and dishwashers came into force in 1996 and were aimed at increasing the energy efficiency of qualifying appliances by about 10% above the average efficiency levels of

equipment available for sale in the market. These were subsequently revised with new standards coming into force on January 1, 2001 for refrigerators and on July 1, 2001 for clothes washers and for dishwashers.

Following a review of options for the promotion of high efficiency equipment, Natural Resources Canada formally began participating in Energy Star in 2002. Energy Star is viewed as complementary to the EnerGuide for Equipment program, which includes minimum energy performance standards as well as the EnerGuide labels. While the EnerGuide labels provide information on model energy consumption as well as a bar chart placing the relative consumption of a given model within the consumption range of its class, the EnerGuide label does not readily provide best in class information. Detailed information on Energy Star is maintained on the Natural Resources Canada website.

1.3 Program Description

BC Hydro's Energy Star Appliance Program was in effect from October 2001 to March 2002, and offered a sales person incentive for Energy Star labeled refrigerators and clothes washers sold in B.C. The $ 20 incentive was funded equally by BC Hydro and Natural Resources Canada. Promotional material included in-store point-of-purchase material as well as training information for retail staff. The promotion included dishwashers as well as the other two appliances, but did not include an incentive as the potential energy savings did not justify the cost.

The program objectives included:

- Reduce residential electricity consumption by 242.6 MWh.
- Increase sales of ENERGY STAR labeled appliances by 700 refrigerators and 560 clothes washers for a total of 1,260 units.
- Earn public support for Power Smart initiatives
- Link Power Smart behaviour to the use of Energy Star labeled appliances
- Support government in accelerating energy efficiency regulations for appliances.

The program included 37 of the 61 retailers in B.C., but these retailers account for 141 of the 165 store locations and about 90% of appliance sales. Three stores modified the $ 20 salesperson incentive. Sears, which represents about 40% of appliance sales in the province, and The Bay negotiated to have the incentive applied to an equivalent value of points for their reward programs. Coast Appliances kept half of the incentive from the sales person and used it for advertising and promotion of the Energy Star appliances.

The program reported that they had provided incentives for a total of 7,134 appliances, of which 3,408 were clothes washers and 3,726 were refrigerators. An internal evaluation (2002, BC Hydro) estimated a net impact of 428 refrigerators and 393 clothes washers.

1.4 Outline of the Report

This report provides a baseline for sales of Energy Star compliant appliances in BC Hydro's service territory as well as an impact analysis of an Energy Star sales promotion conducted by BC Hydro in the fall of 2001. Section 1 provides an overview of the Energy Star program and summarizes this report. Section 2 discusses the study issues and methodology. Section 3 reviews the data and findings for refrigerators. Section 4 reviews the data and findings for clothes washers. Section 5 reviews the data and findings for dishwashers. Section 6 summarizes the impact analysis. Section 7 provides the conclusions of the evaluation and Section 8 provides recommendations.

2. ISSUES AND METHODOLOGY

2.1 Study Objectives and Approach

This study has two main objectives as follows:

First, develop a baseline for sales of Energy Star complaint products in BC Hydro's service territory. In particular, estimate recent historical and projected future trends for sales of refrigerators, clothes washers and dishwashers, including in particular sales of Energy Star compliant product, in a form that can be readily updated over time.

Second, capture low cost information for program design and evaluation purposes. In particular, 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 product.

2.2 Study Issues and Methods

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

- Issue 1. Review trends in energy 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 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 consumption.

An outline of the issues, data sources and methods for this study are shown in Exhibit 2.1. Issue 1 was addressed mainly using Natural Resources Canada data on average appliance energy consumption level. Issues 2, 3 and 4 were addressed mainly through information collected through 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

[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.

CAMA. Issue 5 was addressed mainly through information collected through program interviews and a document and literature review.

The REUS survey was conducted in March 2003 and included a mail survey of some 5,685 BC Hydro residential customers. In addition to a wide range of additional questions on household energy use, respondents were asked if they had various major household appliances, when they had purchased these appliances, and whether or not the appliances were Energy Star.

Exhibit 2.1. Study Issues, Data Sources and Methods

Issue	Data Sources	Methods
1. Review trends in energy consumption for refrigerators, clothes washers and dishwashers	Natural Resources Canada	Trend analysis
2. Estimate historical sales of refrigerators, clothes washers and dishwashers	CAMA Residential End Use Survey (n = 5685 residential customers)	Ratio analysis
3. Estimate market share of Energy Star refrigerators, clothes washers and dishwashers	CAMA Residential End Use Survey (n = 5685 residential customers)	Market share analysis
4. Forecast future sales of total and Energy Star compliant refrigerators, clothes washers and dishwashers	Canadian Appliance Manufacturers Association Residential End Use Survey (n = 5685 residential customers)	Regression analysis
5. Evaluate program impact on sales of Energy Star appliances and electricity consumption	Program interviews Literature and documents review	Engineering algorithms

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 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 labelling 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 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) $Sales_{ijk}$ = Purchases by $respondents_{ijk}$*(1,442,597/5,685)*$Adjustment_{ij}$

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 was 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.

(2) $Market\ share_{ik} = (Sales_{iESk} / Sales_{iTk})$

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) $Sales_{iTk} = \alpha + \beta\ Quarter_{iTk} + \varepsilon_{iTk}$

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) $Sales_{iESk} = \alpha + \beta\ Quarter_{iESk} + \gamma\ Program + \varepsilon_{iESk}$

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) $Energy\ Savings_i = Consumption_i * Incremental\ Savings_i * Program_i$.

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 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.

3. REFRIGERATORS

3.1 Trends in Energy Consumption

Exhibit 3.1 shows trends in refrigerator energy consumption. 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.

Exhibit 3.1. Refrigerator Consumption

	Consumption (kWh)
1990	956
2000	640
Percentage reduction	33.1%

3.2 Historical Sales

Based on the Residential End Use Survey 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 in Exhibit 3.2 two features stand out: first, total refrigerator sales appear to be growing over time; second, total refrigerator sales appear to have a seasonal pattern with sales peaking in the fourth quarter. Sales of Energy Star refrigerators have followed a similar trend to that for all refrigerators, with growth in Energy Star sales over time and sales peaking in the fourth quarter. Comparing year-over-year changes in the Energy Star share of total refrigerator sales, the Energy Star share appears to have grown slightly when the first four quarters are compared with the last four quarters.

Exhibit 3.2. 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

3.3 Program Impact

We model refrigerator sales with several regression models as shown in Exhibit 3.3. For each model, the regression coefficients are shown in a column with the standard error of the regression coefficient shown below the coefficient in parenthesis. OLS means that the model was estimate 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 log likelihood is the log of the likelihood of the estimated likelihood function, sometimes used as criterion for model selection. The Durbin-Watson statistic is used to detect the presence of autocorrelation in the residuals, with a value of 2.0 indicating no autocorrelation. Values either greater or smaller than two indicate increasing autocorrelation.

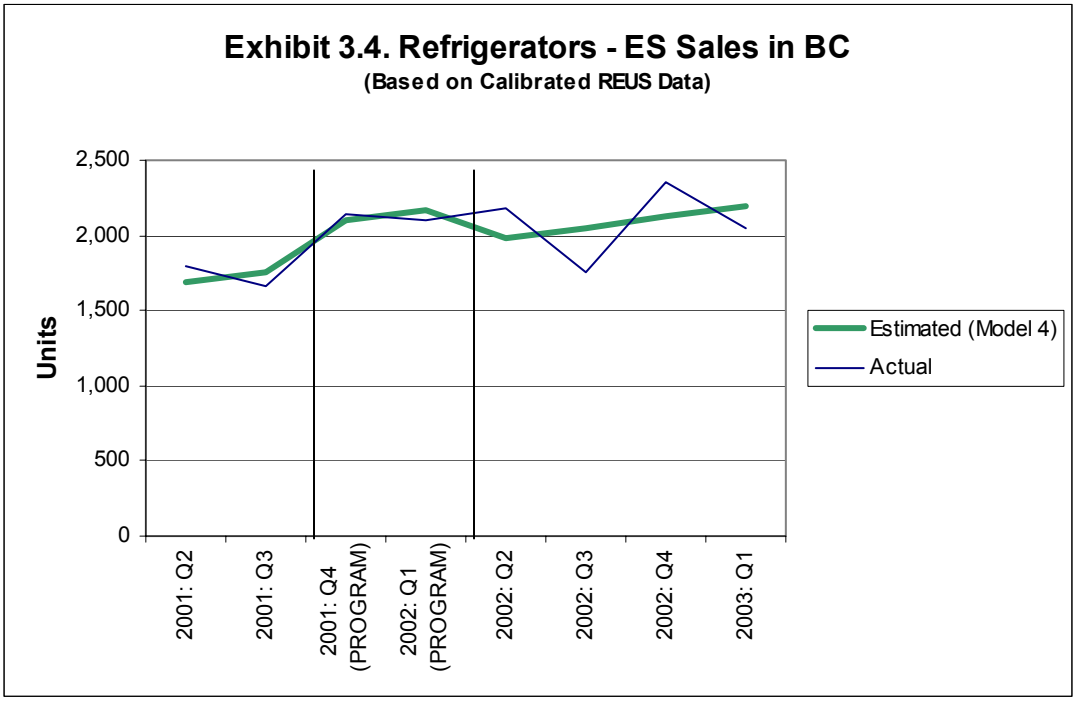
Because of the short length of the time series we are not able to model seasonal effects on sales, but once there are sixteen quarters of survey data, it would be straight forward to model seasonal effects by using a dummy variable for three of the seasons retaining the fourth season as the base. This would substantially improve both the historical tracking and the forecasting accuracy of the regression models.

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 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 two 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.

Exhibit 3.3. Refrigerator Regression Discontinuity 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	0.13	-	0.44	-
Log-likelihood	-	-70.9	-	-46.8
Durbin-Watson	2.65	2.36	3.59	3.17

Exhibit 3.4 shows this regression graphically, and shows the impact on ENERGY STAR sales during the period of the promotion.



3.4 Projected Baselines

A separate regression model was used to forecast the changing Energy Star appliances shares into the future as shown in Exhibit 3.5. These regressions were based on the 2002 BC retailer survey and 2003 CAMA Energy Star data rather than the REUS data as this was thought to provide the best baseline information upon which to base the forecasts.

Exhibit 3.5. Refrigerator Regression Forecast Models

	Model 5 Total Sales OLS	Model 6 Total Sales ML	Model 7 ES Sales OLS	Model 8 ES Sales ML
Constant	16898 (2519)	16904 (2502)	-1074 (1002)	-891 (1194)
Quarter	470 (499)	470 (496)	1257 (198)	1222 (232)
R-squared	0.13	-	0.87	-
Log-likelihood	-	-74.8	-	-67.3
Durbin-Watson	2.02	2.04	1.47	1.77

Each of the regression models were used to make a twelve quarter forecast for refrigerator sales as shown in Exhibit 3.6. Using Model 5, total refrigerator sales are forecast to rise from about 21,129 in 2004:Q1 to about 26,301 in 2006:Q4. Using Model 6, total refrigerator sales are forecast to rise from about 21,132 in 2004:Q1 to about 26,300 in 2006:Q4. Using Model 7, Energy Star refrigerator sales are forecast to rise from about 10,237 in 2004:Q1 to about 24,062 in 2006:Q4. Using Model 8, Energy Star refrigerator sales are forecast to rise from about 10,105 in 2004:Q1 to about 23,544 in 2006:Q4.

Exhibit 3.6. Refrigerator Baseline Forecast

	Model 5 Total Sales OLS	Model 6 Total Sales\ ML	Model 7 ES Sales OLS	Model 8 ES Sales ML
2002: Q1	15268	15268	1003	1003
2002: Q2	19290	19290	1873	1873
2002: Q3	22269	22269	2796	2796
2002: Q4	17652	17652	2520	2520
2003: Q1	14963	14963	3484	3484
2003: Q2	19393	19393	6506	6506
2003: Q3	24385	24385	9716	9716
2003: Q4	18888	18888	8755	8755
2004: Q1	21129	21132	10237	10105
2004: Q2	21599	21602	11494	11327
2004: Q3	22070	22072	12751	12548
2004: Q4	22540	22542	14008	13770
2005: Q1	23010	23011	15265	14992
2005: Q2	23480	23481	16521	16214
2005: Q3	23950	23951	17778	17435
2005: Q4	24420	24421	19035	18657
2006: Q1	24890	24891	20292	19879
2006: Q2	25361	25361	21549	21100
2006: Q3	25831	25831	22806	22322
2006: Q4	26301	26300	24062	23544

Exhibit 3.7 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 for total sales. However a regression forecast of the total market is required so that a forecast can be made for the Energy Star market shares in the future. The rapid increase in Energy Star models starting in 2003 is also noteworthy. This is attributed to a number of new Energy Star models in the 17 – 19 cu. Ft. size, which is the most common size in BC, coming into the market.

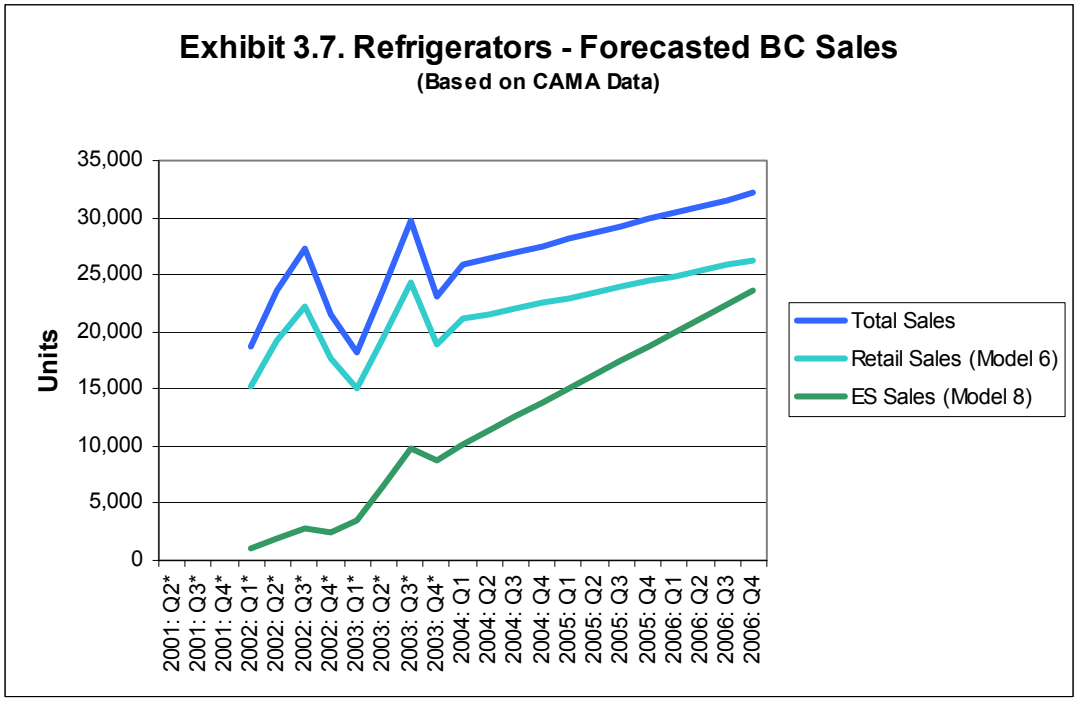


Exhibit 3.8 shows the forecast share of Energy Star refrigerators over the next three years and shows that they may be expected to grow to about 90% of the retail market and about 73% of the overall market. One caution should be noted however. This forecast is strongly influenced by the number of new refrigerator models introduced during 2003, and this rapid rate of growth may not be maintained in future years. It may be advisable to re-run the regressions in a year when the 2004 Energy Star data becomes available to determine if this trend continues.

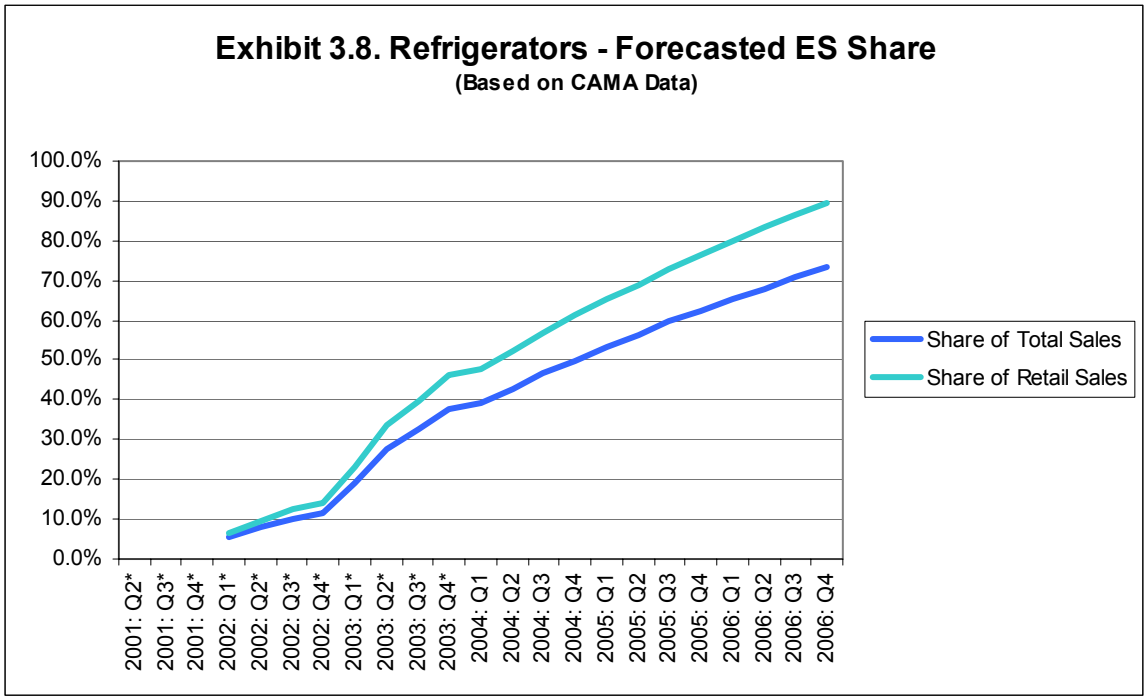


Exhibit 3.8. Refrigerators - Forecasted ES Share
(Based on CAMA Data)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
2001: Q2*
2001: Q3*
2001: Q4*
2002: Q1*
2002: Q2*
2002: Q3*
2002: Q4*
2003: Q1*
2003: Q2*
2003: Q3*
2003: Q4*
2004: Q1
2004: Q2
2004: Q3
2004: Q4
2005: Q1
2005: Q2
2005: Q3
2005: Q4
2006: Q1
2006: Q2
2006: Q3
2006: Q4
Share of Total Sales
Share of Retail Sales

4. CLOTHES WASHERS

4.1 Trends in Energy Consumption

Exhibit 4.1 shows trends in clothes washer energy consumption. Average annual clothes washer energy 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:

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

Exhibit 4.1. Clothes Washer Consumption

	Consumption (kWh)
1990	1218
2000	838
Percentage reduction	31.2%

4.2 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 Exhibit 4.2, total clothes washer sales appear to be growing over time and total clothes washer sales appear to have a seasonal pattern with sales peaking in the first quarter. Sales of Energy Star clothes washers have followed a more erratic pattern that for all clothes washers, with steady growth in Energy Star sales but some shifting of the peak quarter for sales. Comparing year-over-year changes in the Energy Star share of total clothes washer sales, the Energy Star share appears to have grown rapidly.

Exhibit 4.2. 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

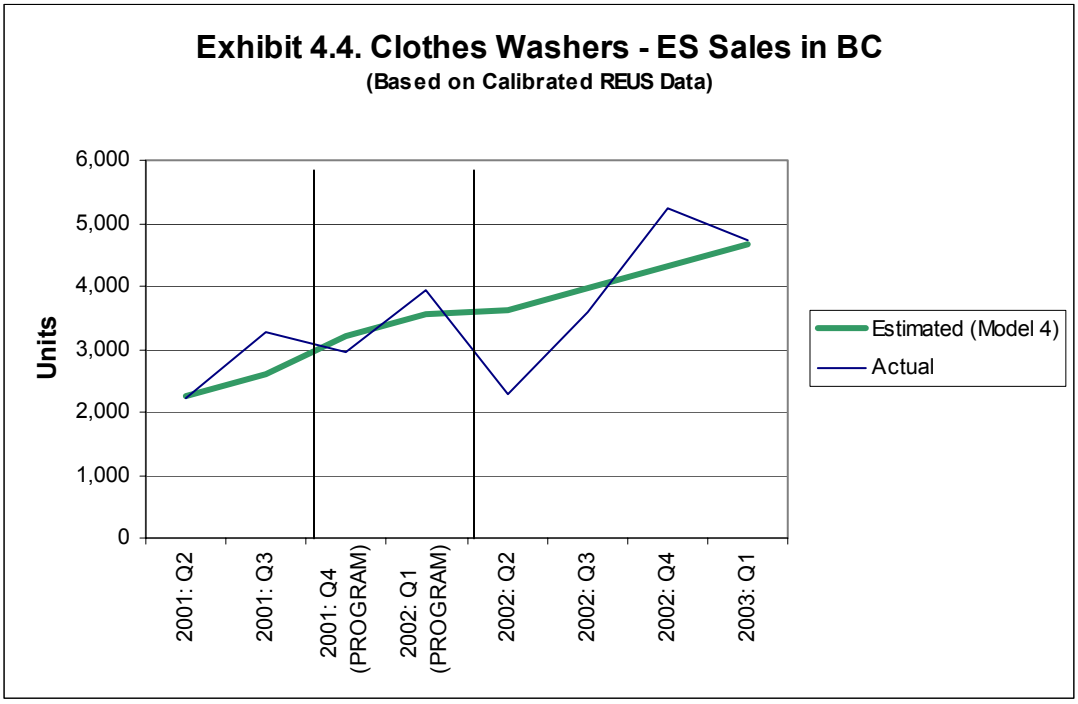
4.3 Program Impact

We model clothes washer sales with several regression models as shown in Exhibit 4.3. Again, for each model, the regression coefficients are shown in a column with the standard error of the regression coefficient shown below the coefficient in parenthesis. In most respects, the statistical results are good. 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, but with a program impact of 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.

Exhibit 4.3. 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	0.44	-	0.58	-
Log-likelihood	-	-71.8	-	-63.1
Durbin-Watson	2.16	2.06	2.31	2.08

Exhibit 4.4 shows this regression graphically, and shows the impact on ENERGY STAR sales during the period of the promotion.



4.4 Projected Baselines

A separate regression model was used to forecast the changing Energy Star appliances shares into the future as shown in Exhibit 4.5. These regressions were based on 2002 BC retailer survey and 2003 CAMA Energy Star data rather than the REUS data as this was thought to provide the best baseline information upon which to base the forecasts.

Exhibit 4.5. Clothes Washer Regression Forecast Models

	Model 5 Total Sales OLS	Model 6 Total Sales ML	Model 7 ES Sales OLS	Model 8 ES Sales ML
Constant	14929 (888)	14927 (916)	2612 (135)	2617 (121)
Quarter	227 (176)	227 (181)	423 (27)	421 (24)
R-squared	0.22	-	0.98	-
Log-likelihood	-	-66.5	-	-51.3
Durbin-Watson	1.91	1.90	2.29	2.17

Each of the regression models were used to make a twelve quarter forecast for clothes washer sales as shown in Exhibit 4.6. Using Model 5, total clothes washer sales are forecast to rise from about 16,969 in 2004:Q1 to about 19,463 in 2006:Q4. Using Model 6, total clothes washer sales are forecast to rise from about 16,967 in 2004:Q1 to about 19,460 in 2006:Q4. Using Model 7, Energy Star clothes washer sales are forecast to rise from about 6,416 in 2004:Q1 to about 11,065 in 2006:Q4. Using Model 8, Energy Star clothes washer sales are

forecast to rise from about 6,407 in 2004:Q1 to about 11,039 in 2006:Q4.

Exhibit 4.6. Clothes Washer Baseline

	Model 5 Total Sales OLS	Model 6 Total Sales ML	Model 7 ES Sales OLS	Model 8 ES Sales ML
2002: Q1	14953	14953	3051	3051
2002: Q2	16079	16079	3654	3654
2002: Q3	16392	16392	3816	3816
2002: Q4	15141	15141	4217	4217
2003: Q1	13935	13935	4425	4425
2003: Q2	17016	17016	5299	5299
2003: Q3	17547	17547	5534	5534
2003: Q4	16530	16530	6115	6115
2004: Q1	16969	16967	6416	6407
2004: Q2	17196	17193	6839	6828
2004: Q3	17423	17420	7261	7249
2004: Q4	17650	17647	7684	7670
2005: Q1	17876	17873	8107	8091
2005: Q2	18103	18100	8529	8513
2005: Q3	18330	18327	8952	8934
2005: Q4	18556	18553	9375	9355
2006: Q1	18783	18780	9797	9776
2006: Q2	19010	19007	10220	10197
2006: Q3	19237	19233	10643	10618
2006: Q4	19463	19460	11065	11039

Exhibit 4.7 shows the forecast sales of clothes washers 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. Again, CAMA provides forecasts of market growth which may be preferable to this estimate, but it is necessary to develop a regression based estimate of the total market in order to estimate the Energy Star shares.

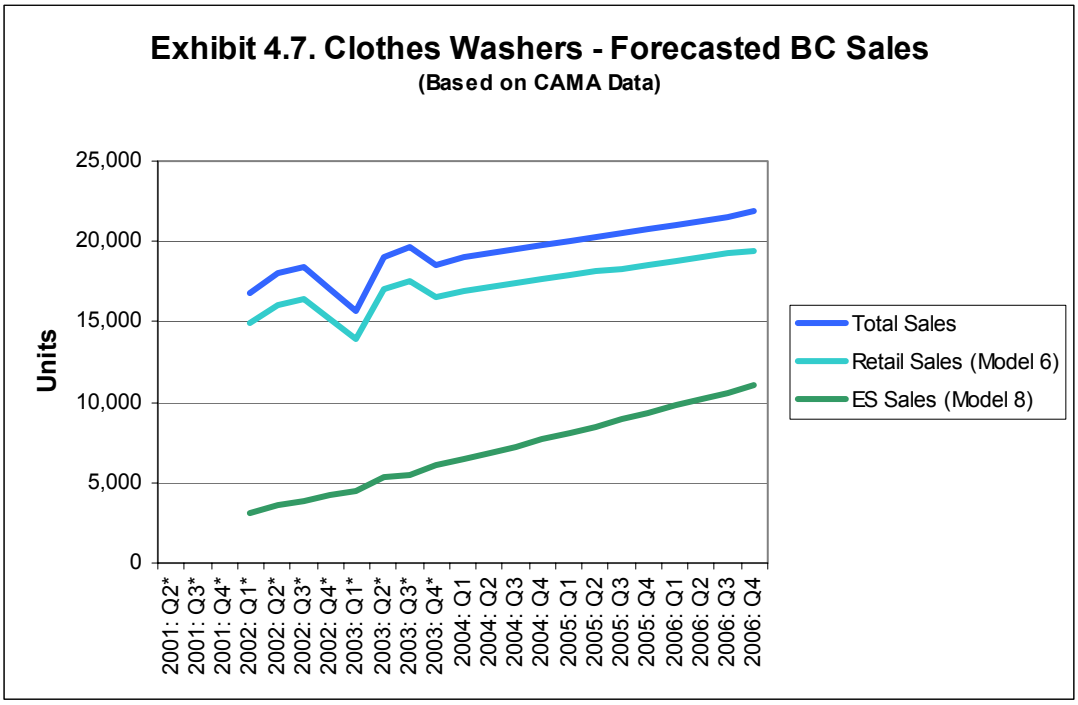
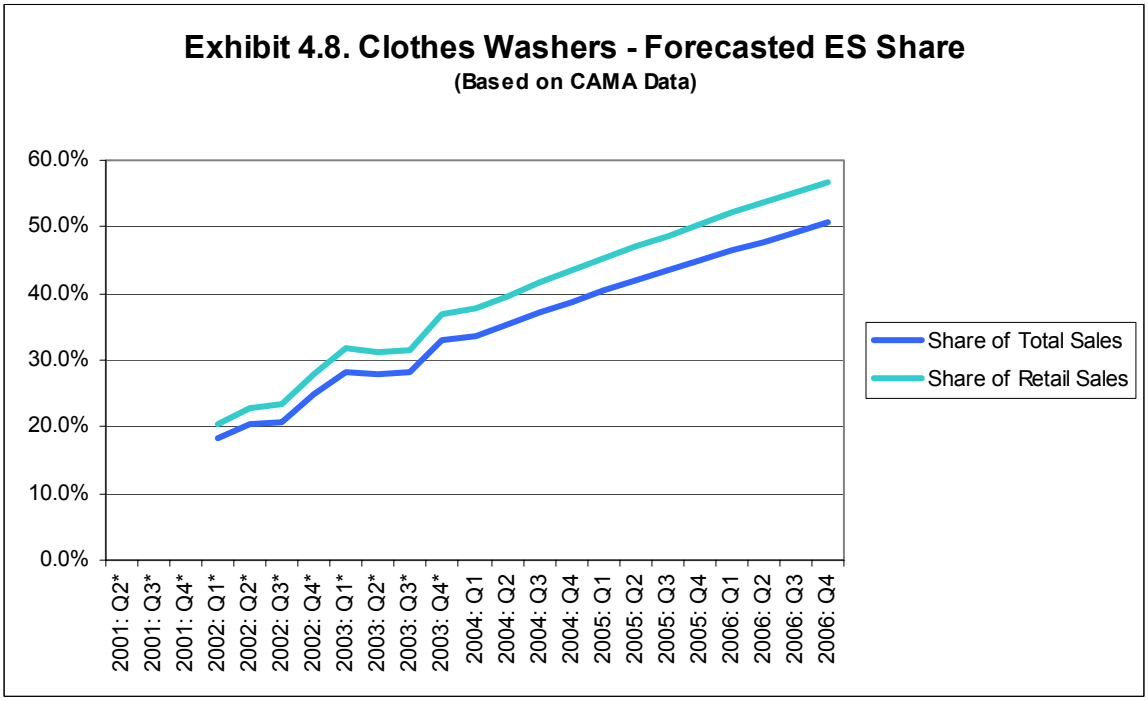


Exhibit 4.8 shows the forecast share of Energy Star clothes washers over the next three years and shows that they may be expected to grow to about 57% of the retail market and about 50% of the overall market.



5. DISHWASHERS

5.1 Trends in Energy Consumption

Exhibit 5.1 shows trends in dishwasher energy consumption. Average annual dishwasher energy consumption fell from 1,026 kWh per year in 1990 to 637 kWh per year in 2000. This is a percentage reduction of 37.9% in unit energy consumption over ten years. Key factors leading to this decrease include:

- Improvements in gaskets and seals.
- Improvements in motors and drive systems.
- More flexible controls that allow better matching of the washing and drying cycles to load washing and drying requirements.

Exhibit 5.1. Dishwasher Consumption

	Consumption (kWh)
1990	1026
2000	637
Percentage reduction	37.9%

5.2 Historical Sales

Sales of dishwashers to BC Hydro customers by quarter for the period 2001:Q2 to 2003:Q1 are shown in Exhibit 5.2. For the eight quarters shown in Exhibit 5.2 total dishwasher sales appear to be growing over time but the peak sales quarter is not stable. Sales of Energy Star dishwashers have grown steadily with sales peaking in the first quarter. Comparing year-over-year changes in the Energy Star share of total dishwasher sales, the Energy Star share appears to have grown.

Exhibit 5.2. Recent Dishwasher Sales

	Total (units)	Energy Star (units)	Energy Star share (%)
2001: Q2	11942	3538	29.6
2001: Q3	10694	4491	42.0
2001: Q4	10694	4491	42.0
2002: Q1	12119	5308	43.8
2002: Q2	9981	4219	42.3
2002: Q3	15684	6941	44.3
2002: Q4	17467	6805	39.0
2003: Q1	11585	7349	63.4

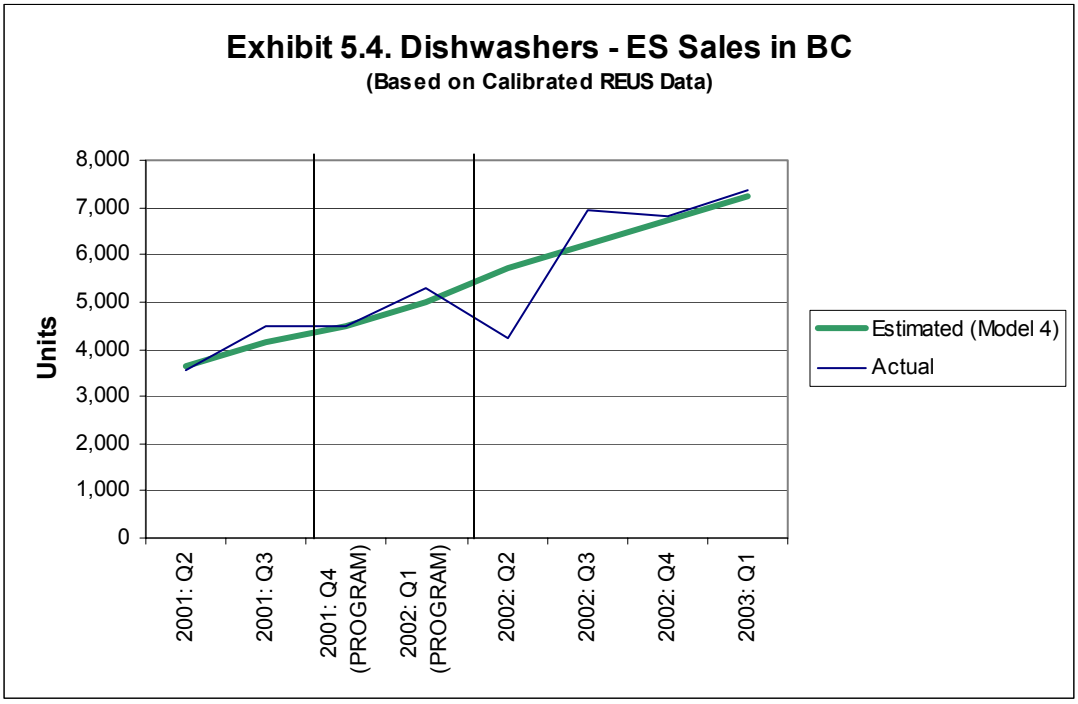
5.3 Program Impact

We model dishwasher sales with several regression models as shown in Exhibit 5.3. Once again, for each model, the regression coefficients are shown in a column with the standard error of the regression coefficient shown below the coefficient in parenthesis, and again in most respects, the statistical results are good. Model 1 indicates that total sales are growing by about 526 units per quarter. Model 2 indicates that total sales are growing more rapidly at about 561 units per quarter, although autocorrelation is higher for Model 2. Model 3 suggests that Energy Star sales are increasing by about 532 units per quarter, and the program impact is 104 units. Model 4 suggests that Energy Star sales are increasing by about 514 units per quarter, but with a negative program impact on sales, again with this estimate perhaps preferred to Model 3 since autocorrelation is reduced. Given these mixed results from the two models, the results of the promotion (and no salesperson's incentive) are inconclusive.

Exhibit 5.3. Dishwasher Regression Models

	Model 1 Total Sales OLS	Model 2 Total Sales ML	Model 3 ES Sales OLS	Model 4 ES Sales ML
Constant	10153 (1944)	10011 (1811)	2984 (661)	3129 (463)
Quarter	526 (385)	561 (360)	532 (121)	514 (83)
Program	-	-	52 (640)	-191 (468)
R-squared	0.24	-	0.80	-
Log-likelihood	-	-72.7	-	-61.6
Durbin-Watson	2.16	2.39	2.89	2.22

Exhibit 5.4 shows graphically the results of the discontinuity impact for the dishwashers. The chart is based on Model 4, and again shows the inconclusive results of the analysis.



5.4 Projected Baselines

A separate regression model was used to forecast the changing Energy Star appliances shares into the future as shown in Exhibit 4.5. These regressions were based on 2002 BC retailer survey and 2003 CAMA Energy Star data rather than the REUS data as this was thought to provide the best baseline information upon which to base the forecasts.

Exhibit 4.5. Dishwasher Regression Forecast Models

	Model 5 Total Sales OLS	Model 6 Total Sales ML	Model 7 ES Sales OLS	Model 8 ES Sales ML
Constant	12148 (941)	12366 (527)	3444 (1326)	3350 (1419)
Quarter	299 (186)	261 (106)	569 (263)	590 (279)
R-squared	0.30	-	0.44	-
Log-likelihood	-	-65.4	-	-69.7
Durbin-Watson	3.12	2.18	1.81	1.94

Each of the regression models were used to make a twelve quarter forecast for dishwashers sales as shown in Exhibit 5.5. Using Model 5, total dishwasher sales are forecast to rise from about 14,838 in 2004:Q1 to about 18,127 in 2006:Q4. Using Model 6, total dishwasher sales are forecast to rise from about 14,715 in 2004:Q1 to about 17,585 in 2006:Q4. Using Model 7, Energy Star dishwasher sales are forecast to rise from about 8,567 in 2004:Q1 to about 14,829 in

2006:Q4. Using Model 8, Energy Star dishwasher sales are forecast to rise from about 8,663 in 2004:Q1 to about 15,158 in 2006:Q4.

Exhibit 5.6. Dishwasher Baseline

	Model 5 Total Sales OLS	Model 6 Total Sales ML	Model 7 ES Sales OLS	Model 8 ES Sales ML
2002: Q1	11551	11551	3088	3088
2002: Q2	14042	14042	4868	4868
2002: Q3	12611	12611	6533	6533
2002: Q4	14783	14783	7831	7831
2003: Q1	11712	11712	3559	3559
2003: Q2	14037	14037	5610	5610
2003: Q3	14746	14746	7529	7529
2003: Q4	14463	14463	9024	9024
2004: Q1	14838	14715	8567	8663
2004: Q2	15137	14975	9136	9254
2004: Q3	15436	15236	9705	9844
2004: Q4	15735	15497	10275	10435
2005: Q1	16034	15758	10844	11025
2005: Q2	16333	16019	11413	11616
2005: Q3	16632	16280	11982	12206
2005: Q4	16931	16541	12552	12796
2006: Q1	17230	16802	13121	13387
2006: Q2	17529	17063	13690	13977
2006: Q3	17828	17324	14259	14568
2006: Q4	18127	17585	14829	15158

These results are shown graphically in Exhibit 5.7 below. It shows the forecast sales of clothes washers 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. Again, CAMA provides forecasts of market growth which may be preferable to this estimate, but it is necessary to develop a regression based estimate of the total market in order to estimate the Energy Star shares.

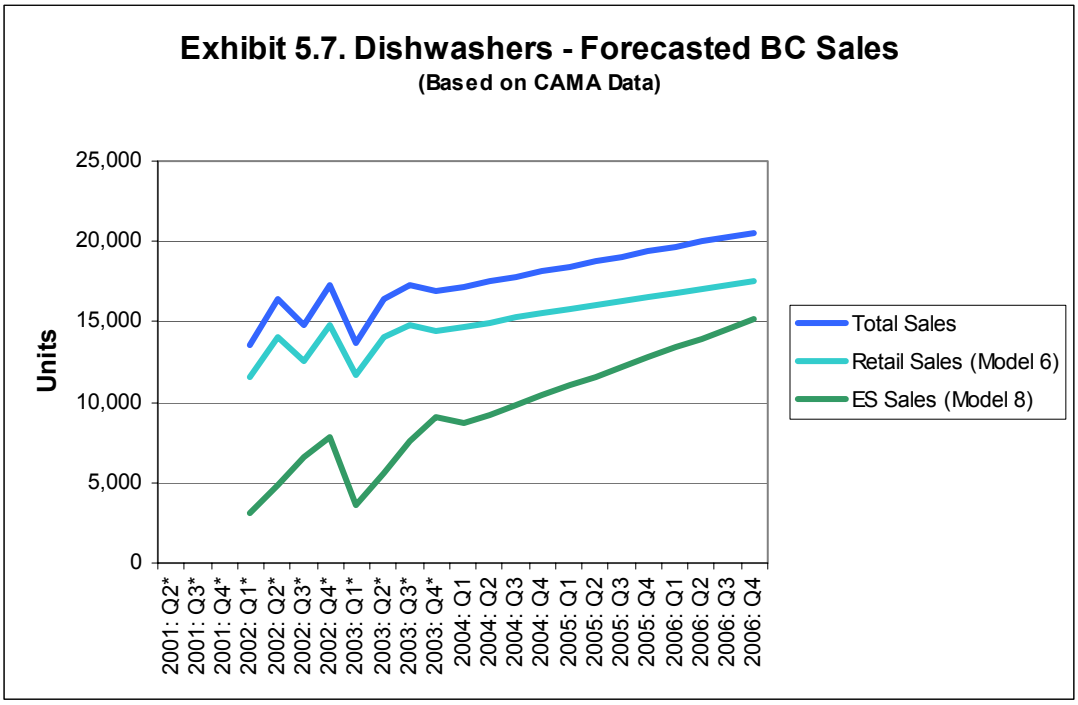
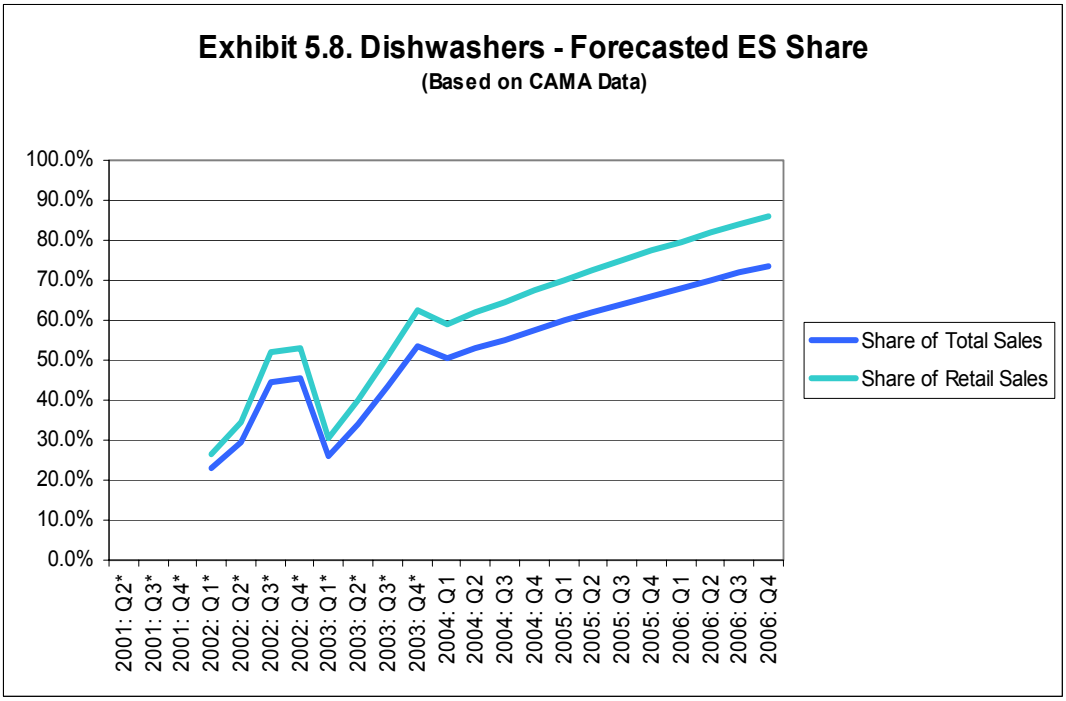


Exhibit 5.8 shows the forecast share of Energy Star dishwashers over the next three years and shows that they may be expected to grow to about 85% of the retail market and about 75% of the overall market.



6. PROGRAM IMPACT

6.1 Incremental Sales

The impact of the Power Smart Energy Star promotion, which took place from September 2001 to March 2002, was estimated by the regression model according to equation (5) on page 6. This type of modeling is referred to as a regression discontinuity model as it assumes a discontinuity for the period the program is in effect which is then statistically quantified.

Based on the preferred estimates of the program impact on sales are shown in Exhibit 6.1. According to our 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.

Exhibit 6.1. Program Impact on Sales

	Refrigerator	Clothes Washer	Dishwasher	Total
Sales (units)	542	550	0	1092

6.2 Energy Savings

Energy Star unit energy savings are shown in Exhibit 6.2. These are derived from the savings ratios in the paper by Webber, Brown and Koomey (which surveyed available information on the impact of a variety of Energy Star qualified products) and from the unit energy consumption estimates from Natural Resources Canada (2003) in Exhibit 6.3.

Exhibit 6.2. Energy Star Unit Savings

	Refrigerator	Clothes Washer	Dishwasher
Savings (kWH/yr)	102	394	83

Exhibit 6.3 allocates unit energy savings to electricity and gas savings respectively. For clothes washers and dishwashers, it is assumed that hot water accounts for 80% of the savings while motors, pumps and heaters account for 20% of the savings

Exhibit 6.3. Unit Savings Analysis

	Refrigerator	Clothes Washer	Dishwasher
Consumption (kWh)	640	838	637
Incremental savings (ratio)	0.16	0.47	0.13
Unit savings (kWh)	102	394	83
Electric savings (kWh)	102	79	17
Hot Water savings (kWh)	-	315	66
Electric water heat (share)	NA	0.38	0.38
Gas water heat (share)	NA	0.62	0.62
Electric water heat savings (kWh)	-	120	25
Gas water heat savings (kWh)	-	198	41
Total electricity savings (kWh)	102	199	42
Total natural gas savings (kWh)	-	195	41

Annual energy savings due to the program are shown in Exhibit 6.4. Savings are estimated as the product of unit savings times estimated program impact on sales. Refrigerator savings are estimated at 55 MWh for electricity. Clothes washer savings are estimated at 110 MWh for electricity and 107 MWh for natural gas. Total savings are estimated at 165 MWh for electricity and 107 MWh for natural gas.

Exhibit 6.4. Program Impact on Energy Savings

	Refrigerator	Clothes Washer	Dishwasher	Total
Unit electricity savings (kWh)	102	199	42	-
Unit gas savings (kWh)	-	195	41	-
Incremental Units	542	550	0	1092
Electricity savings (MWh)	55.3	109.5	0	164.8
Gas savings (MWh)	-	107.3	0	107.3
Total savings (MWh)	55.3	216.8	0	272.1

7. CONCLUSIONS

Conclusion 1. Trends in Energy Consumption. Over the 1990s, there was a substantial reduction in the energy consumption of major household appliances. 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 1218 kWh per year in 1990 to 838 kWh per year in 2000. Average annual dishwasher energy consumption fell from 1026 kWh per year in 1990 to 637 kWh per year in 2000.

Conclusion 2. Sales of Appliances. Based on the adjusted Residential End Use Survey data, we estimated quarterly sales of appliances for the period 2001:Q2 to 2003:Q1. Total refrigerator sales appear to be growing, and sales appear to have a seasonal pattern with sales peaking in the fourth quarter. Sales of Energy Star refrigerators have followed a similar trend, with growth in Energy Star sales and sales peaking in the fourth quarter. Clothes washer sales appear to be growing and total clothes washer sales appear to have a seasonal pattern with sales peaking in the first quarter. Sales of Energy Star clothes washers have followed a more erratic pattern that for all clothes washers, with steady growth in Energy Star sales but some shifting of the peak quarter for sales.

Conclusion 3. Market Share of Energy Star Appliances. Regressions were developed based on the 2002 retailer survey and the CAMA 2003 Energy Star data. Based on these regressions, Energy Star refrigerators may be expected to increase to about 90% of the retail market and 73% of the total market by the end of 2006, while clothes washers may grow to about 57% of the retail market and 50% of the total market. Dishwashers may grow to 85% of the retail market and 75% of the overall market. It is interesting to look at the rapid increase in Energy Star refrigerators in 2003, which reflects the introduction of new models in the popular 17 to 19 cubic foot size. However, it should be noted that this rapid increase in new models will influence the projection, and it is recommended that the regressions be re-run with 2004 CAMA data when it becomes available.

Conclusion 4. Baseline Forecast Sales. Using the preferred maximum likelihood estimates, total refrigerator sales are forecast to rise from about 21,100 in 2004:Q1 to about 26,300 in 2006:Q4, and Energy Star refrigerator sales are forecast to rise from about 10,100 to 23,500. Total clothes washer sales are forecast to rise from about 17,000 to about 19,500 and Energy Star clothes washer sales are forecast to rise from about 6,400 to about 11,000. Total dishwasher sales are forecast to rise from about 14,700 to about 17,600 and Energy Star dishwasher sales are forecast to rise from about 8,700 in to about 15,200. It should be noted that this is a statistical forecast based on historical data rather than forward looking data such as new housing starts. The CAMA forecast may be preferable when forecasting the overall market.

Conclusion 5. Program Impact. According to the econometric models, there was an increase in sales of Energy Star compliant appliances during the period of the salesperson incentives and promotion. This includes an increase of 542 refrigerators and 550 clothes washers, for a total of 1,092 appliances. These results are 13% less than the program target of 1,260 appliances, but greater than the internal evaluation estimate of 820 appliances.

Savings are estimated as the product of average consumption for new appliances times incremental savings for Energy Star qualifying products times program savings. Refrigerator electricity savings are estimated at 55 MWh per year. Clothes washer electricity savings are estimated at 110 MWh per year. Total electricity savings are 165 MWh per year.

There are also significant natural gas savings. Clothes washer natural gas savings are estimated at 107 MWh per year.

Conclusion 6. Salesperson incentives. The Energy Star appliance promotion contained information on dishwashers, and the major program difference between dishwashers and the other appliances was the lack of the salesperson incentive. Given that there was no measurable increase in dishwasher sales over the period of the promotion while there was for the other two appliances, this is an indication of the effectiveness of the salesperson incentive.

8. Recommendations

Recommendation 1. Recalibrate the Energy Star appliance shares against the CAMA Energy Star data as it becomes available. Preliminary data, which is expected to be published in April 2004, was obtained from CAMA for this study. However, as noted, the projections were based on one year of CAMA quarterly data and market share data based on a retail survey for the previous year. Additional data will improve the quality of the regressions, and will help to confirm the market share data for refrigerators where a significant market change in 2003 influences the projection.

Recommendation 2. The econometric approach of using interrupted time series analysis shows good statistical results for this analysis, and this approach should be considered in other evaluation projects. While the econometric approach does not cover the issue of attribution (which can be handled with techniques such as Discrete Choice Theory), it does eliminate the issues of free riders and free drivers.

Recommendation 3. Now that CAMA quarterly Energy Star data is available, it can provide a powerful basis for the analysis of any future promotions, as quarterly data is available for BC and for a number of other regions across Canada. This data combined with statistical techniques such as "Seemingly Unrelated Regressions" (SUR) will allow estimation of program impacts at a reasonable cost.

In the SUR approach, the equations for appliance sales in each province are estimated simultaneously as a system of equations instead of as individual equations. This allows data from one province to inform the results in other provinces and improves the statistical efficiency of the estimates. For example, the GST rebate program for Energy Star appliances in Ontario could affect indirectly the sale of efficient appliances in other provinces.

Recommendation 4. Power Smart should include the savings in natural gas usage for water heating in the total resource cost test. Further, to the extent that GHG reductions are included in the program evaluation, the GHG impacts for reduced burning of natural gas should be included.

Recommendation 5. Data collection of quarterly appliance purchases and Energy Star statistics should be continued in the bi-annual REUS surveys. Consideration should be given to expanding the definition of Energy Star ratings to explain that it differs from the EnerGuide label.

Recommendation 6. Power Smart should investigate the level of Energy Star sales in the builder sector. It is expected that the penetration is this sector will be much lower than the retail sector, and may provide an opportunity for a cost effective program.

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