Estimating Lighting Programmme Impacts Using Self Report Surveys and Market Sales Analysis

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Abstract

Evaluation of public policy programs often focuses on the twin issues of whether there is an observed change in an outcome variable of interest and how much of the change is due to the policy intervention. Much of this research uses randomized controlled trials to ensure internal validity, but this research option is frequently not feasible for the evaluation of energy efficiency programs where participants opt into the programme and are not randomly selected. One common approach to attribution for energy efficiency evaluations is the use of self report surveys of programme participants, but self report surveys have a number of limitations and biases. Some researchers have proposed the use of quasi-experiments using market sales data as a feasible alternative to self report surveys. This paper applies and compares the self report approach and the market sales approach to the evaluation of the specialty CFL and LED components of BC Hydro's Energy Star Lighting program. It finds that the market sales approach may be a useful alternative to the self report approach for net to gross analysis.

Introduction

Evaluation of public policy programs, including energy efficiency programs, often focuses on two main issues. First, has there been an observed change in an outcome variable of interest coincident with the delivery period? Second, how much, if any, of this change is attributable to the program? In many areas of social science research, these two issues are dealt with simultaneously by using a randomized controlled trial. In a randomized controlled trial, subjects are randomly assigned to a treatment group or to a control group, post-treatment outcomes are measured and compared between the treatment group and the control group, and the statistical significance of the difference can be calculated using standard statistical methods. The randomized controlled trial is sometimes referred to as the "gold standard" for social science research because randomization controls for sources of outcome variation not impacted by the treatment. That is, randomized control trials have strong internal validity for estimating the additional or incremental changes in the outcome variable of interest that are attributable to the program.

Experience with randomized controlled trials in energy efficiency research has been mixed. On the one hand, there have been a number of credible experiments using some combination of behavioral cues, differential energy prices or energy use reporting to influence energy use behavior. The most prominent of these have perhaps been the OPower experiments which have often found significant reductions in residential energy use based on providing residential customers with comparative bill analysis reporting combined with energy saving tips. But on the other hand, randomized controlled trials have been rare in mainstream energy efficiency programs supporting replacement of energy using equipment such as lamps, ballasts, motors or drives by more efficient models. Evaluation of retrofit programs and market opportunity programs have instead often relied on engineering methods to estimate gross energy and peak savings and on self report surveys to estimate the net to gross ratio and net, incremental or additional, energy and peak savings. Papers which draw on randomized controlled trials include Tiedemann and Sulyma (2010) and Vine et al (2010).

One reason for the rarity of randomized controlled trails in retrofit applications is that most energy efficiency programs require participants to opt in to the program, so that randomization is not feasible, and self selection or free ridership of programme participants are therefore major confounding issues for energy efficiency evaluations. Given the difficulties in applying randomized controlled trails, the evaluation of energy efficiency programs has often therefore relied on self report surveys of market actors, most often the purchasers and users of energy efficient equipment. Self report surveys are attempts to estimate the counterfactual state, that is, to estimate what would participants have done absent the program. Self report surveys take a variety of formats, but in the simplest case they ask the survey respondent how important participation in the programme was in her decision to install the energy efficient equipment, using one or more scaled questions. Self report surveys have several potential weaknesses.

- There may be social response bias as the respondent may provide a response which she views as socially acceptable.
- The respondent may tend to rationalize past decisions perhaps by indicating that she would have taken a given action even in the absence of the program.
- The weighting of scaled responses may be subject to arbitrariness in scoring.
- It may be difficult for the respondent to accurately recall a past decision making process.

Papers which present or draw upon studies using self report surveys include Austrian Energy Agency (2015), Sulyma and Tiedemann (2014), (2004), Meyers et al. (2003), Nadel et al. (2003), and Jaffe and Stavins (1995).

One alternative to the self report approach is to use market sales data to infer the impact of programme activity on purchase and installation of energy efficient equipment. These market sale studies compare programme period sales of an efficient product with non-programme period sales of an efficient product to estimate the difference, if any, the programme had on efficient product sales. Since non-programme period sales provide the counterfactual or the comparison group, market sales studies can be view as quasi-experiments. Market sales studies also take a variety of formats including simple pre/post comparisons and regression modeling. Market sales studies also have several potential weaknesses.

- It may be difficult to collect comprehensive information on product sales in the market of interest.
- Sales information is typically available for less than 100% of market actors, so sales of reporting firms must be expanded to represent the whole market, which may involve somewhat arbitrary estimates of firm market shares.
- Changes in market sales may be also be driven by factors which are not included in the modeling.

Papers which present or draw upon market sales studies include Sulyma and Tiedemann (2013), Vine et al. (2010), Tiedemann (2007), Mauldin et al. (2003), Rosenberg (2003), Titus and Feldman (2003), Horowitz (2001), and Horowitz and Haeri (1990).

The purpose of this paper is to apply and compare the self report approach to the market sales data approach for a residential lighting programme in British Columbia focusing on specialty compact fluorescent lamps (CFL) for the self report analysis and light emitting diode (LED) lamps for the market analysis for fiscal year 2012. An outline of the paper is as follows. The next section briefly describes BC Hydro's Energy Star Lighting program. The following section summarizes the research questions, data sources and method for the study. This is followed by the detailed study results organized by research question. The last section provides a summary and conclusions.

Policy Context and Programme Description

The 2007 BC Energy Plan set an ambitious conservation target (50% of electricity demand growth) and encouraged utilities to offer cost effective and competitive demand-side management (DSM) programs to their customers. The 2010 Clean Energy Act[1] reaffirmed utilities' mandate to offer demand-side measures to consumers. This includes displacing 66% of BC Hydro's increase in demand via demand side management initiatives. The Ministry sets guidelines for the evaluation of the cost effectiveness of DSM programs using the Demand-Side Measures Regulation[2]. In 2008 the BC Hydro Long Term Acquisition Plan, including the twenty-year Implementation Plan for Energy-Focused Demand Side Management (DSM Plan)[3], was approved. The DSM Plan includes energy and demand savings from demand-side management initiatives, rate initiatives and changes in standards and codes. This paper addresses the one of the largest contributors to residential energy savings, the residential energy efficiency lighting programme during the 2012 – 2014 (fiscal years) DSM funding envelope.

BC Hydro's (BCH's) Energy Star Lighting programme is a multiple year initiative which encourages its residential customers to purchase and install energy efficient lighting including Energy Star qualifying specialty CFL and LED lamps. The purpose of the programme is to increase sales of energy efficient lighting products while the broader objective is to reduce energy and peak demand consumption. In order to achieve the Energy Star label, manufacturers must certify that their products meet the energy efficiency criteria which are jointly set by Natural Resources Canada, the United States Department of Energy and the United States Environmental Protection Agency. Certified products may include the Energy Star label on their packaging and related material. Energy efficiency criteria are periodically reviewed as technologies improve, so that in general only the most efficient 25% of lighting products can earn the Energy Star label.

The BCH Energy Star Lighting programme has three main activities: retailer training, consumer education and product rebates. (1) Retailer training is provided through both on site workshops and through web-based on line training. The output of this training is increased sales person knowledge of energy efficient lighting. (2) Consumer education is provided through mass media advertising, web based education and point of purchase material. The output of these coordinated educational activities is increased customer knowledge of and interest in energy efficient lighting products. (3) Product rebates are provided through point of purchase rebates which are frequently supplemented by manufacturer buy downs. The output of the rebates is reduced first cost for energy efficient lighting products.

The BCH Energy Star Lighting programme was re-launched in March 2002 with three pilot projects in small BC communities and involved bulk purchase of CFLs by BC Hydro, which were

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1 http://www.bclaws.ca/civix/document/id/complete/statreg/10022_01#part1
2 http://www.bclaws.ca/civix/document/id/complete/statreg/326_2008
3 http://www.bcuc.com/Documents/Proceedings/2008/BCH_LTAP_B-1-1_APPENDICES/Appendix%20K.pdf

distributed free to customers using redeemable coupons at in-store events at retail partner establishments. The initiative was expanded to the whole province and regular Fall (October-November) and Spring (February-March) campaigns were implemented. By the Fall of 2004 the programme included two-tiered rebates to encourage purchase of the most energy efficient products and mail in coupons for regular spiral CFLs, CFL torchieres, Energy Star fixtures and LED seasonal lighting. In the Fall of 2006 the programme initiated use of in-store coupons and point of sales marketing. Participating Energy Star fixture retailers were classified as silver or gold depending on their level of support; at silver retailers, mail-in rebate coupons were available for purchase of qualifying product; at gold retailers, there was a wide range of promotional activities including in-store events, and a Prius vehicle draw.

In the Fall of 2007 the CFL programme component began a transition from regular spiral CFLs to specialty CFL bulbs. CFL coupons were replaced by instant in-store discounts and manufacture buy-downs, with an increased focus on non-incentive promotional activities including advertising and in-store events. In Fall 2011 (2012 fiscal year) increased focus was placed on promotion of specialty CFLs, LEDs, Energy Star fixtures and LED fixtures. Instant in-store discounts and manufacturer buy-downs continued to be offered. Provincial minimum energy performance standards for 75W-100W General Service A type lamps came into force in January 2011 (fiscal year 2011). New major retail partners were added to increase market penetration of energy efficient lighting technologies.

Table 1 provides a programme logic model for BC Hydro's Energy Star Lighting program. A programme logic model typically divides a programme into its key components and then examines the logic chain of inputs, outputs, purpose and goal for each programme component. It also includes the critical assumptions needed for the programme to effectively move from one layer of the logic to the next layer. A logic model serves several purposes: (1) to provide a shared understanding of the nature of the program; (2) to identify key metrics which need to be monitored during programme implementation; and (3) to determine whether the programme logic is sound. The programme logic model was developed based on personal stakeholder interviews and a documents review, and the review and analysis concluded that the basic programme logic was sound. That is, there are strong and credible linkages among the inputs, outputs, purpose and goal; and it is reasonable to expect the programme to meet its goal given the resources available.

Table 1. Programme Logic Model

	Retailer Training	**Consumer Education**	**Product Rebates**	**Critical assumptions**
Inputs	In person and online retailer staff training conducted	Advertising, promotions and point of purchase material provided	Power Smart and manufacturers rebates in place	Suitable inventory available in participating stores
Outputs	Sales person knowledge of energy efficient lighting increased	Increased customer knowledge of and interest in energy efficient lighting	First cost of energy efficient lighting products reduced	Energy efficient lighting meets customer lighting service requirements
Purpose	Increased sales of 679,00 energy efficient lamps and 186,000 energy efficient fixtures by fiscal year 2014			Rebound effect is not significant
Goal	Energy consumption reduced by 41 GWh/year, fiscal years 2012 - 2014 (funding envelope)			

Approach

The study approach included telephone surveys with participants and non-participants from another jurisdiction, shelf stock surveys of retail trade allies, market sales data from retail trade allies, and on-site load research for lighting fixture. For this study of fiscal 2012 impacts there were six main research questions as follows.

1. Is there a difference in product awareness for specialty CFL and LED lamps between BC and Dakotas customers?
2. Is there a difference in purchase behavior for specialty CFL and LED lamps between BC and Dakota consumers?
3. Is there a difference in installation rates for specialty CFL and LED lamps between BC and Dakotas consumers?
4. What are the unit gross energy and peak demand savings for CFLs and LEDs ?
5. What are the net to gross ratios for CFLs and LEDs?
6. What are the total energy and peak demand savings for CFL and LEDs?

Residential customers in British Columbia (BC) were the treatment group and residential customers in North and South Dakota (the Dakotas) were the comparison group. Detailed customer information on lighting product purchase behavior was collected through telephone surveys of 601 residential customers in British Columbia (treatment group) and 601 residential customers in the Dakotas (comparison group). The Dakotas were chosen as the comparison group because Dakotas residents were similar to those of British Columbia in terms of key household and demographic variables, and there was no significant amount of utility DSM programs in the Dakotas. The survey information was used in two main ways.

- This information was used to answer the first three research questions by making a statistical comparison of British Columbia and Dakotas respondents using the z-test for differences in sample proportions.
- This information was used to calculate the self report net to gross ratio for CFLs for British Columbia. The self report method involved weighting a scaled programme influence question as shown below.

Comprehensive product information was collected through shelf stock surveys of 40 retail establishments in British Columbia. The shelf stock survey collected information on prices, quantities, wattages, rated lumens, shelf placement and promotional material as part of a multi-year effort to track market trends for lighting products. For the narrow purpose of the present study, the shelf stock study information was used to estimate average delta watts, the difference between baseline and energy efficient lamp consumption. For CFLs, delta watts was estimated as the average CFL wattage minus the wattage of an incandescent lamp with the same output in lumens. For LEDs, delta watts was estimated as the average LED wattage minus the wattage of an incandescent lamp with the same output in lumens.

Please note that some LEDs may replace CFLs so that unit savings may be overestimated and that it would be useful to supplement the shelf stock survey with customer reports on the bulb replaced by the target energy efficient bulb.

Market sales data was collected from trade allies representing about 80% of the LED market in British Columbia, and this information was expanded by 20% to represent the whole market. This information was collected through interviews with major trade allies who provided both their own sales data and their estimates of their share of the market. LED sales information was collected for the eight weeks of the Fall Energy Star Lighting Promotion, the four weeks before the Fall Promotion and the four weeks following the Fall Promotion. Sales during the Fall Promotion represented the treatment period, sales before and after the Fall Promotion represented the comparison period, and this sales information was used to calculate the net to gross ratio for LEDs.

On-site load research was conducted for 333 lighting fixtures for thirteen months, and this involved several steps. Some 40 households were randomly recruited for the research, and initial visits were held which included a customer survey, a complete inventory of lamps and fixtures, selection of lamps for load research, and installation of monitoring equipment. Follow up visits were held at three months intervals to download data and ensure that the monitoring equipment was operating properly. Final visits were held to download data, conduct exit interviews and remove equipment. Metered data was cleaned and weighted to represent the actual mix of installed lamps and fixtures. This information was used to estimate annual hours of use and peak coincidence, where BC Hydro's peak occurs between 16:00 hours and 20:00 hours on a winter weekday.

Engineering algorithms were used to estimate the impact of the program. Energy savings were estimated using Equation (1) where ΔGWh is the change in energy consumption, ΔWatts is the difference in watts between the baseline lamp and the efficient lamp, Hours is annual hours of use, Installation Rate is the share of lamps installed as opposed to going into storage, Net to Gross is the net to gross ratio, Cross Effects is the adjustment for the heating interactive effect, and No. of Lamps is the number of lamps incented by the program.

(1) $\Delta GWh = \Delta Watts \cdot Hours \cdot Installation\ Rate \cdot Net\ to\ Gross \cdot Cross\ Effects \cdot No.\ of\ Lamps$

Peak demand savings were estimated using Equation (2) where ΔMW is the change in peak demand, Coincidence is the peak coincidence factor, and the other factors are the same as before.

(2) $\Delta MW = \Delta Watts \cdot Coincidence \cdot Installation\ Rate \cdot Net\ to\ Gross \cdot Cross\ Effects \cdot No.\ of\ Lamps$

Evaluation research questions, data sources and methods are summarized in Table 2.

Table 2. Research Questions, Data Sources and Methods

Research questions	Data sources	Methods
Is there a difference in product awareness for specialty CFL and LED lamps between BC and Dakotas?	BC survey (n = 601) Dakotas survey (n = 601)	Z-test for differences in sample proportions
Is there a difference in purchase behavior for specialty CFLs and LEDs between BC and Dakotas?	BC survey (n = 601) Dakotas survey (n = 601)	Z-test for differences in sample proportions
Is there difference in installation rates for specialty CFLs and LEDs between BC and Dakotas?	BC survey (n = 601) Dakotas survey (n = 601)	Z-test for differences in sample proportions
What are unit gross energy and peak savings for CFLs and LEDs?	BC survey for installation rates (n = 601) Establishment shelf stock survey for delta watts (n = 40) On-site metering for hours of use and peak coincidence (n = 333)	Load research analysis Engineering algorithms
What are the net to gross ratios for CFLs and LEDs?	BC survey for CFLs (n = 601) Distributor sales data for LEDs	Self report for CFLs Market analysis for LEDs
What are the total energy and peak savings for programme incented CFLs and LEDs?	Above information Programme data for incented sales Engineering data for cross effects	Engineering algorithms

Results

Table 3 addresses the first three research questions with respect to specialty compact fluorescent lamps. British Columbia respondents indicated a higher level of awareness of specialty compact fluorescent lamps (94.5%) than did Dakotas respondents (91.8%), and this difference was statistically significant at the 10% level. Dakotas respondents were more likely to have purchased one or more specialty compact fluorescent lamps (10.8%) than were British Columbia respondents (10.4%), but this difference was not statistically significant at the 10% level. British Columbia respondents were more likely to have installed one or more specialty compact fluorescent lamps (15.3%) than were Dakotas respondents (13.9%), but this difference was not statistically significant at the 10% level.

Table 3. Customer Survey Responses: Specialty Compact Fluorescent Lamps

	British Columbia (%)	Dakotas (%)	Difference (%)	Z-test score
Product awareness	94.5	91.8	2.7*	1.83
Purchased one/more	10.4	10.8	-0.4	-0.09
Installed one/more	15.3	13.9	1.3	0.65

Note. One, two or three asterisks indicate that the difference is significant at the 10%, 5% or 1% level respectively.

Table 4 provides gross unit energy savings and peak demand savings for specialty compact fluorescent lamps in British Columbia. Unit energy savings of 49.5 kWh/year is the product of delta watts and annual hours. Unit demand savings of 16.4 watts is the product of delta watts and the peak coincidence factor.

Table 4. Gross Unit Savings: Specialty Compact Fluorescent Lamps

Delta watts (ΔW)	Annual hours (hours)	Peak coincidence	Unit energy savings (kWh/year)	Unit demand savings (W)
53	934	0.31	49.5	16.4

Table 5 provides the estimated net to gross ratio for specialty compact fluorescent lamps. BC survey respondents were asked how influential programme activity was in their decision to purchase a specialty compact fluorescent lamp, and an attribution rate was calculated by finding a weighted average using the weights as shown. The net to gross rate for specialty compact florescent lamps is 0.81, so that using this measure 81% of programme related sales are attributable to the program.

Table 5. Net to Gross: Specialty Compact Fluorescent Lamps

	Very influential	Somewhat influential	Not too influential	Not at all influential	Net to gross ratio
Share	0.43	0.57	0.00	0.00	
Weight	1.00	0.67	0.33	0.00	
Weighted share	0.43	0.38	0.00	0.00	0.81

Table 6 provides the annual net total energy and net total peak demand savings for specialty compact lamps for fiscal year 2012. Unit energy and unit demand are defined above. Installation rate is the share of lamps which were installed (as opposed to going into storage) and is based on the BC consumer survey. Net total energy savings is the product of unit energy, the installation rate, the net to gross ratio, one minus cross effects and units. Net total energy savings is 8.5

GWh/year for fiscal year 2012. Net total demand savings is the product of unit demand, the installation rate, the net to gross ratio, one minus cross effects and units. Net total demand savings is 2.8 MW for fiscal year 2012.

Table 6. Energy and Demand Savings: Specialty Compact Fluorescent Lamps

Unit energy (kWh/year)	Unit demand (W)	Installation rate	Net to gross ratio	1 - cross effects	Units (mn)	Net total energy (GWh/year)	Net total demand (MW)
49.5	16.4	0.94	0.81	0.95	0.237	8.5	2.8

Table 7 addresses the first three research questions with respect to LED lamps. British Columbia respondents indicated a higher level of awareness of specialty LED lamps (71.7%) than did Dakotas respondents (63.7%), and this difference was statistically significant at the 1% level. British Columbia respondents were more likely to have purchased one or more LED lamps (12.3%) than were Dakotas respondents (7.7%), and this difference was statistically significant at the 1% level. British Columbia respondents were more likely to have installed one or more LED lamps (13.5%) than were Dakotas respondents (8.3%), and this difference was statistically significant at the 1% level.

Table 7. Customer Survey Responses: LED Lamps

	British Columbia (%)	Dakotas (%)	Difference (%)	Z-test
Product awareness	71.7	63.7	8.0***	2.96
Purchased one/more	12.3	7.7	4.6***	2.69
Installed one/more	13.5	8.3	5.2***	2.87

Note. One, two or three asterisks indicate that the difference is statistically significant at the 10%, 5% or 1% level.

Table 8 provides gross unit energy savings and peak demand savings for LED lamps in British Columbia. Unit energy savings of 41.1 kWh/year is the product of delta watts and annual hours. Unit demand savings of 13.6 watts is the product of delta watts and the peak coincidence factor.

Table 8. Gross Unit Savings: LED Lamps

Delta watts (ΔW)	Annual hours (hours)	Peak coincidence	Unit energy savings (kWh/year)	Unit demand savings (W)
44	934	0.31	41.1	13.6

Table 9 provides the estimated net to gross ratio for LED lamps. BC lighting product distributors provided sales data for the eight weeks of the Fall Lighting Programme campaign (in campaign sales) as well as four weeks before and four weeks after the fall campaign (out of campaign sales). Responding distributors represented 80% of the market, so that their responses were grossed up by the ratio 1.25 to represent the whole market. With out of campaign sales representing the baseline, the net to gross rate for LED lamps is 0.89, so that using this measure 89% of programme related sales are attributable to the program.

Table 9. Net to Gross: LED Lamps

Out of campaign sales (8 weeks)	In campaign sales (8 weeks)	Out of campaign sales/ In campaign sales	Net to gross ratio
5,924	55,474	0.11	0.89

Table 10 provides the annual net total energy and net total peak demand savings for LED lamps for fiscal year 2012. Net total energy savings is 4.0 GWh/year for fiscal year 2012. Net total demand savings is the product of unit demand, the installation rate, the net to gross ratio, one minus cross effects and units. Net total demand savings is 1.3 MW for fiscal year 2012.

Table 10. Energy and Demand Savings: LED Lamps

Unit energy (kWh/year)	Unit demand (W)	Installation rate	Net to gross ratio	1 - cross effects	Units (mn)	Net total energy (GWh/year)	Net total demand (MW)
41.1	13.6	0.82	0.89	0.94	0.140	4.0	1.3

Discussion

This paper reviews the results of a detailed evaluation of BC Hydro's Energy Star Lighting programme for fiscal year 2012. The Energy Star Lighting programme provided retailer training, consumer education and product rebates to increase sales of energy efficient lighting products. The goal of the programme was to reduce residential energy consumption by 41 GWh per year by fiscal year 2014. Net energy and peak savings for specialty CFLs were 8.5 GWh/year and 2.8 MW while net energy and peak demand savings for LEDs were 4.0 GWh/year and 1.3 MW for fiscal year 2012, the first year of the programme funding envelope.

The study approach included estimation of the net to gross ratio for specialty CFLs was based on participant survey responses while the net to gross ratio for LEDs was estimated from market sales data from retail trade allies representing 80% of the LED market in BC. Unfortunately, in the following two years of the funding envelope, trade ally support for providing sales information waned, and subsequent evaluations relied on participant surveys and retail stock shelving studies. While a useful method to estimate net to gross ratios, sales data from participating, and most particularly non-participating, trade allies is difficult to maintain over time. However, when a new funding envelope involving a new technology within a product category, such as LED bulbs, is under consideration at the programme level, there are opportunities to at least periodically expand information from responding trade allies to represent the whole market.

In conclusion, both self report surveys and market sales analysis provide useful methods of estimating net to gross ratios in support of energy efficiency programme evaluations. However, issues with market sales analysis are primarily implementation issues rather than problems with the market sales analysis methodology per se. The market sales approach is a useful alternative to the self report method for net to gross analyses.

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