Transforming a Residential Lighting Market: Estimating the Impact of Ten Years of DSM Activities in British Columbia

I. M. Sulyma, Research4Results and K. H. Tiedemann, BC Hydro

ABSTRACT

In 2001, BC Hydro established a second ten year demand-side management plan. A key component of the plan focussed on transforming the residential lighting market. The purpose of this study was to consolidate and reconcile ten years of residential lighting evaluations and identify key lessons on how to transform a residential market. The research design was a quasi-experiment with a comparison group in another jurisdiction used to inform detailed engineering algorithms. Purchase and installation of CFLs and attitudes towards CFLs were based on annual customer surveys; hours of use, load shapes, peak demand, and peak coincidence, and take back were based on in-situ metering; and information on types, shares, prices and wattages of lamps were based on annual shelf stock surveys. Key findings included the following. (1) By the end of ten years, residential lighting energy savings were more than 540 GWh per year. (2) For the first three years of the program, energy savings were primarily due to the direct impacts of incentives, but by the fourth program year, market impacts due to advertising and market transformation were dominant. (3) The number of CFLs increased from 0.4 per household in 2002 to 9.3 per household in 2011. (4) Based on the transformation of the lighting market, British Columbia put in place minimum energy performance standards for general service lamps on January 1, 2011.

Introduction

Market transformation programs create new challenges and opportunities for program evaluators. On the one hand, traditional evaluation techniques such as use of pre/post comparisons with treatment and control groups in a single jurisdiction may not be possible if the treatment group is potentially the whole population. On the other hand, quasi-experimental techniques, using a similar jurisdiction without program activity, can potentially deal with confounding market effects including free riders and spill-over in a comprehensive and credible manner. This means that it may be possible to avoid subjective, and potentially unreliable, survey based approaches to measuring market transformation.

Several previous studies have used quasi-experimental methods to analyze the impact of market transformation programs. Duke and Kammen (1999) found that accounting for interaction between the demand response and production response for electronic ballasts increases the consumer benefit cost ratio. Horowitz (2001) found that coordinated national electronic ballast programs were more cost effective than local efforts. Horowitz and Haeri (1990) found that the cost of energy efficiency investments was fully capitalized in housing prices and that purchasing an energy efficient house was cost effective. Jaffe and Stavins (1990) found that insulation levels in new residential housing appropriately reflect energy prices. Tiedemann (2007) found significant market transformation effects in U.S. residential appliance markets. Nadel, Thorne, Sachs, Prindle and Elliott (2003) provide a comprehensive overview of market transformation activities in the United States, mostly based upon customer self-report surveys.

The treatment effects approach to program evaluation uses an experimental or a quasi-experimental design to represent the DSM program. Three are three main ways to represent what treatment behaviour would have been absent the program: (1) treatment's pre-participation behaviour (pre/post difference) ; (2) comparison's behaviour during the post-program period (post/post difference); and (3) or the double

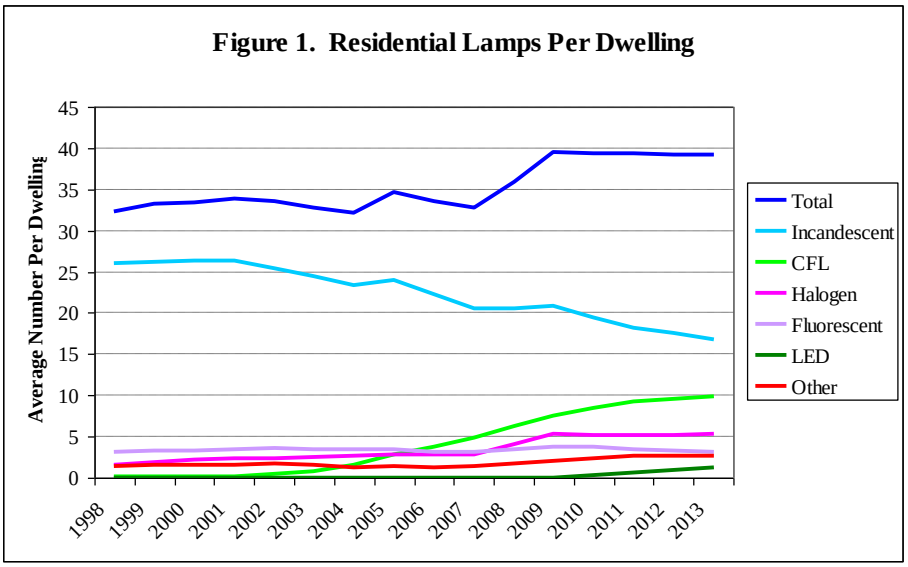
difference. There are two ways to represent non-participants: (1) the control group approach where participant and control group members are randomly selected from the same population; and (2) the comparison group approach where comparison group come from a different population than the treated, and the comparison group are selected to resemble the treatment group on some set of relevant characteristics.

BC Hydro has had more than ten years of experience using residential lighting programs in order to acquire energy savings and to transform the residential lighting market. The purpose of this study is to consolidate and reconcile ten years of residential lighting evaluations and to identify key lessons on how to transform a residential market. The research design was a quasi-experiment with a comparison group in another jurisdiction used to inform detailed engineering algorithms based on on-site metering and data collection.

Market Overview

Before examining the evolution of BC Hydro's residential lighting programs, it is useful to have an overview of trends in the residential lamp market in British Columbia. Figure 1 presents information on the saturation of residential lamps per dwelling for the period 1998 through 2013. Please note that a fiscal year in British Columbia covers the period April 1 through March 31 of the following year, so that fiscal year 1998 (1998), for example, covers the period April 1, 1997 through March 31, 1998. Estimated lamp saturations are based on information from the Residential End Use Surveys (REUS). REUS is a comprehensive end use survey conducted by mail or on-line at the discretion of the customer. The sample is stratified to allow a high level of precision at the regional level. A typical survey has six to seven thousand completions which provide a maximum margin of error of ± 1.5%. REUS is conducted at least once every two years, so for those years when there was no survey, the estimates are interpolated from the two adjacent years. Several observations on the trends in residential lamp saturations are worth noting.

- First, the total number of lamps per dwelling was fairly stable for ten years from 1998 through 2007, but it subsequently increased by about 20% through 2013 to 39.2 lamps per dwelling.
- Second, the number of incandescent lamps decreased by about nine units per dwelling from 1998 (26.0) through 2013 (16.8), which was essentially offset by the increase of CFLs, which increased by about ten units per dwelling for the same period (from 0.1 to 9.9).
- Third, the number of halogen lamps increased by about four units per dwelling from 1998 (1.6) through 2013 (5.3), but changes in saturations for linear fluorescents, LEDs and other lamps were relatively small.



Program Phases

Overview. Through the 1990s, BC Hydro undertook a number of activities aimed at increasing energy efficiency in the residential lighting market. Although they were cost effective, these activities were aimed at short-term energy savings rather than market transformation, and they had a relatively small impact on the saturation of energy efficient lighting. As shown in Table 1 above, the saturation of CFLs was only about 0.1 per household by 2008. Power Smart's residential lighting activities have subsequently been rolled out in three phases, and Table 2 summarizes the dates of these phases and some key aspects of the evaluation activity for each phase.

Table 2. Program Summaries and Evaluation Activities

Dates	Summary	Target group	Comparison group	Main evaluation method
2001-2004	Re-launching the CFL using product give aways and vouchers for free CFLs	BC Hydro's residential customers with a focus on capacity constrained Vancouver Island	Residential customers in the province of Saskatchewan	Treatment installation rate minus control installation rate for each product type
2005-2007	Promotion of CFLs, seasonal LEDs, and CFL torchieres using instant in-store discounts and manufacturer buy-downs	BC Hydro's residential customers	Residential customers in the province of Saskatchewan	Treatment installation rate minus control installation rate for each product type
2008-2011	Promotion of specialty CFLs, LEDs, Energy Star	BC Hydro's residential customers	Residential customers in the states of North and	Treatment installation rate minus control

	fixtures and LED fixtures using instant in-store discounts and manufacturer buy-downs		South Dakota	installation rate for each [product type

Phase 1: Re-launching the CFL (FY 2001-2004). Beginning in 2001, BC Hydro decided to re-launch its residential lighting program with a focus on both energy acquisition and market transformation. To facilitate program planning, implementation and evaluation, a comprehensive CFL market characterization and baseline study was undertaken. The market characterization and baseline study examined both the demand and supply sides of the CFL market separately, and it then integrated the results as basis for recommendations for further program development. Demand-side recommendations included: (1) implement a point-of-sale rebate coupon campaign; and (2) expand efforts to educate consumers about CFLs. Supply-side recommendations included (1) expand efforts to work with supply side actors including large retailers, chains, grocery stores and up-stream actors; and (2) develop and distribute materials to retailers.

A pilot CFL initiative was launched in the communities of Courtenay, Comox and Quesnel. Bulk CFL purchases were made by BC Hydro and distributed free to customers using redeemable coupons at retail partners. Pilot CFL program was expanded to the remainder of Vancouver Island, reflecting desire to slow load growth in response to transmission constraints. An initial CFL torchiere campaign provided incentive coupons to encourage customers to purchase CFL torchieres rather than halogen torchieres. Table 3 summarizes program activities in Phase 1.

Table 3. Residential Lighting Phase 1: Program Activities

Dates	Activity	Description
2001-2002	Product Endorsement Program	Power Smart brand used to endorse and promote CFLs by Phillips, GE and Osram Sylvania using point of sale material at over 600 retail establishments
2001-2002	Power Smart h.e.l.p Campaign	The h.e.l.p Campaign combined newspaper, radio, and internet advertisements, point-of-sale materials, on-line energy audits, and 25,000 CFL give aways, and distribution of 2.8 million rebate coupons through bill inserts
2001-2004	Power Smart New Home Program	Program worked with builders and developers to include energy efficient fluorescent lighting in some 8,000 new homes
Spring 2002	Courtenay, Comox Valley and Quesnel Give Away	Program featured vouchers for two free CFLs and a discount coupon for a third CFL with some 42,000 vouchers distributed
Spring 2003	Torchière Pilot	Initial CFL torchière campaign provided incentive coupons to encourage customers to purchase CFL torchieres rather than halogen torchieres.
2003	Vancouver Island Give Away	Voucher program expanded to the rest of Vancouver Island as part of efforts to constrain load growth

		because of distribution constraints

To estimate direct energy savings for Phase 1, we used the following engineering algorithm, which was based on in-store stocking studies and customer surveys in British Columbia. Incented units is the number of units receiving incentives, unit power savings is the average difference in watts between the base unit and the average incented unit, installation rate is the percentage of CFL purchases made that are installed and considered a new installation (i.e., did not replace an existing CFL), hours of use is the average hours of use based on customer survey, cross effects are the additional heating requirement related to lower lamp heat losses during the heating season (for electrically heated dwellings)[1], net to gross was based on customer self-reports, and the summation is over the various lighting products supported by the program. Similar algorithms were used for the subsequent periods, with the types of lighting products included changing as the program evolved.

$$\Delta kWh = \Sigma_i \{\text{incent units}_i * \text{install rate}_i * \text{unit power save}_i * \text{hours of use}_i * \text{cross effects}_i * \text{net to gross}_i\} \quad (1)$$

To estimate market effects for Phase 1, we used the following engineering algorithm, where incremental units are based on differences between BC Hydro installations and Saskatchewan installations. This is a quasi-experimental design where the treatment group is BC Hydro customers and comparison group is Saskatchewan customers. Note that what was done was to use the quasi-experimental design to estimate total program impact, which was then disaggregated into direct effects and market effects. The total effect is therefore estimated with a higher degree of reliability than the component direct and market effects.

$$\Delta kWh = \Sigma_i \{\text{incremental units}_i * \text{unit power savings}_i * \text{hours of use}_i * \text{cross effects}_i * \text{net to gross}_i\} \quad (2)$$

Table 4 summarizes the evaluated energy savings for Phase 1. In F2002, direct impact energy savings were 2.0 GWh/year, and market energy savings were 4.2 GWh/year. In F2003, direct impact energy savings were 17.0 GWh/year, and market energy savings were 15.6 GWh/year. In F2004, direct impact energy savings were 102.2 GWh/year, and market energy savings were 31.8 GWh/year. For Phase 1, direct impact energy savings were 121.0 GWh/year, and market energy savings were 51.6 GWh/year, so direct impacts dominated market impacts. By F2004, the saturation of CFLs had risen to 1.5 CFL lamps per dwelling, and it was believed that the stage had been set for more aggressive marketing efforts.

Table 4. Residential Lighting Phase 1: Energy Savings (GWh/year)

Period	Direct	Market	Total
2002	2.0	4.2	6.2
2003	17.0	15.6	32.6
2004	102.2	31.8	134.0
2002-2004	121.2	51.6	172.8

Phase 2: Transforming the Market (FY 2005-2007). In 2005, BC Hydro launched a second phase of its residential lighting program. New market analysis indicated that although British Columbia had the highest penetration of CFLs in Canada, there were still considerable opportunities for cost effective market transformation to reinforce and support traditional CFL giveaways and deep price discounts. Market effects

[1] Cross effects or the heating and cooling interaction effect refer to the reduction in energy savings that occurs when relatively cooler operating CFLs replace incandescent lights, thus negatively impacting the heating load of electrically heated homes during the winter heating months.

were defined as incremental sales for energy efficient lighting products due to BC Hydro's efforts to reduce supply-side and demand side barriers which limit availability, accessibility, affordability, awareness and acceptance of energy efficient lighting. The Fall 2005 Lighting Campaign included mail in coupons and in-store exchange events focussing on CFLs, seasonal LEDs (SLEDs) and CFL torchieres. This lighting campaign introduced two-tiered rebates to encourage purchases of most efficient lighting products Energy Star Fixtures program introduced to motivate customers to switch from halogen and incandescent technologies to Energy Star lighting fixtures. The Fall 2006 Lighting Campaign used in-store coupons and point of sales marketing. Participating Energy Star fixture retailers classified as silver or gold depending on level of support; at silver retailers, mail-in rebate coupons were available for purchase of qualifying product; at gold retailers, there was wide range of promotional activities including in-store events, and Prius draw. Table 5 summarizes program activities in Phase 2.

Table 5. Residential Lighting Phase 2: Program Activities

Dates	Activity	Description
Spring 2004	Lower Mainland Give Away	Voucher program for free CFLs expanded to the Lower Mainland to increase customer exposure to and experience with CFLs, supported like the following activities by radio and newspaper advertising, bill stuffers and in-store promotions
Spring 2004	Lower Mainland Coupons	Coupon program for discounted CFLs expanded to the Lower Mainland to increase customer exposure to and experience with CFLs
Fall 2004	Lower Mainland and Vancouver Island In-store Coupons	Campaign featured CFLs, CFL torchières and seasonal LEDs with mail-in discount coupons and in-store lighting exchange events
Fall 2004	All Region Mail-in Coupon	Campaign featured CFLs, CFL torchières and seasonal LEDs with mail-in discount coupons
Fall 2005	All Region In-store Coupons	Campaign featured CFLs, CFL torchières and seasonal LEDs with in-store discount coupons
Fall 2005	All Region Mail-in Coupons	Campaign featured CFLs, CFL torchières and seasonal LEDs with in-store discount coupons
Fall 2006	Two-tier Retail Program	Two-tier campaign feature Energy Star fixtures and CFLs with silver retailers with mail-in coupons and gold retailers with higher value instant rebate coupons and in-store events including draw for a Prius car

To estimate direct energy savings for Phase 2, we used engineering algorithm (1), which was based on on-site metering, in-store stocking studies and customer surveys in British Columbia and Saskatchewan. To estimate market effects for Phase 2, we used engineering algorithm (2), where incremental units are now defined as the difference in annual installations between BC respondents and Saskatchewan respondents minus program incented units, so that this is a quasi-experimental design where BC customers are the treatment group and Saskatchewan customers are the comparison group.

Table 6 summarizes the evaluated energy savings for Phase 2. In 2005, direct impact energy savings were 22.8 GWh/year, and market energy savings were 95.9 GWh/year. In 2006, direct impact energy savings were 4.2 GWh/year, and market energy savings were 28.3 GWh/year. In 2007, direct impact energy savings were 7.6 GWh/year, and market energy savings were 72.5 GWh/year. For Phase 2, direct impact energy

savings were 34.6 GWh/year, and market energy savings were 196.7 GWh/year, so market effects were greater than direct effects.

Table 6. Residential Lighting Phase 2: Energy Savings (GWh/year)

Period	Direct	Market	Total
2007	22.8	95.9	118.7
2006	4.2	28.3	32.5
2007	7.6	72.5	80.1
2005-2007	34.6	196.7	231.3

Phase 3: Broadening the Market (FY 2008-2011). In 2008, the CFL component of the residential lighting program began a transition from spirals to specialty bulbs. CFL coupons were replaced by instant in-store discounts and manufacture buy-downs, with increased focus on non-incentive promotional activities including advertising and in-store events. During this phase, the General Service Lighting (GSL) Regulation was developed. In 2009 and 2010, increased focus was placed on promotion of specialty CFLs, LEDs, Energy Star fixtures and LED fixtures. Instant in-store discounts and manufacturer buy-downs continue to be offered. Provincial minimum energy performance standards for 75W-100W General Service A type lamps came into force in January 2011, and, due to Federal government delays, this is three years in advance of parallel federal legislation. New major retail partners were added to increase market penetration of energy efficient lighting technologies. Table 7 summarizes program activities in Phase 3.

Table 7. Residential Lighting Phase 3: Program Activities

Dates	Activity	Description
Fall 2007	Specialty CFL Program	CFL program began transition for standard spiral to specialty CFL bulbs
Fall 2007	Mid-stream Incentives	Program began using mid-stream incentives to broaden reach
Fall 2008	Specialty CFL Program	CFL program continued transition for standard spiral to specialty CFL bulbs
Fall 2008	Mid-stream Incentive	Program expanded use of mid-stream incentives to increase leverage of limited program resources
Fall 2009	Fall Lighting Promotion	Increased focus was placed on promotion of specialty CFLs, LEDs and Energy Star fixtures
Fall 2010	Fall Lighting Promotion	Increased focus was placed on promotion of specialty CFLs, LEDs, Energy Star fixtures and LED fixtures

To estimate direct energy savings for Phase 3, we used engineering algorithm (1), which was based on on-site metering, in-store stocking studies and customer surveys in British Columbia and North and South Dakota. North and Dakota were chosen as the comparison group because the start of utility programming in Saskatchewan made it unusable as a comparison group, and North and South Dakota were the jurisdictions in North America which met the two conditions of having no utility programming and matching British Columbia on key demographics.

To estimate market effects for Phase 2, we used engineering algorithm (2), where incremental units are now defined as the difference in annual installations between BC respondents and Saskatchewan

respondents minus program incented units, so that this is a quasi-experimental design where BC customers are the treatment group and Saskatchewan customers are the comparison group.

Table 8 summarizes the evaluated energy savings for Phase 3. In 2008, direct impact energy savings were 10.3 GWh/year, and market energy savings were 31.5 GWh/year. In 2009, direct impact energy savings were 3.4 GWh/year, and market energy savings were 52.5 GWh/year. In 2010, direct impact energy savings were 3.8 GWh/year, and market energy savings were 31.5 GWh/year. In 2011, direct impact energy savings were 5.7 GWh/year, and market energy savings were zero. For Phase 3, direct impact energy savings were 23.2 GWh/year, and market energy savings were 115.5 GWh/year, so market effects were again greater than direct effects.

Table 8. Residential Lighting Phase 3: Energy Savings (GWh/year)

Period	Direct	Market	Total
2008	10.3	31.5	41.8
2009	3.4	52.5	55.9
2010	3.8	31.5	35.3
2011	5.7	0.0	5.7
2008-2011	23.2	115.5	138.7

Market Transformation Assessment

At the time of program launch, five barriers to residential lighting market transformation were identified. These were defined as follows.

- **Availability** - availability refers to the quantity and variety of energy efficient lighting products available in the market.
- **Accessibility** - accessibility refers to the relative share of lighting shelf space devoted to energy efficient lighting, as well as stocking behaviour and display characteristics.
- **Affordability** - affordability refers to regular purchase prices, price discounts, and life cycle costs for energy efficient compared to other lighting products.
- **Awareness** - awareness refers to customer and trade ally awareness of the characteristics, quality, costs and benefits of energy efficient lighting.
- **Acceptance** – acceptance refers to customer and trade ally satisfaction and installation penetration of energy efficient lighting products.

Table 9 summarizes some key information on market barriers at the beginning and end of the evaluated program period. This evidence suggests that all five market barriers have been successfully addressed: availability has increased; accessibility has improved; prices have fallen; awareness has increased; and acceptance has increased.

Table 9. Market Barriers in 2002 and 2011

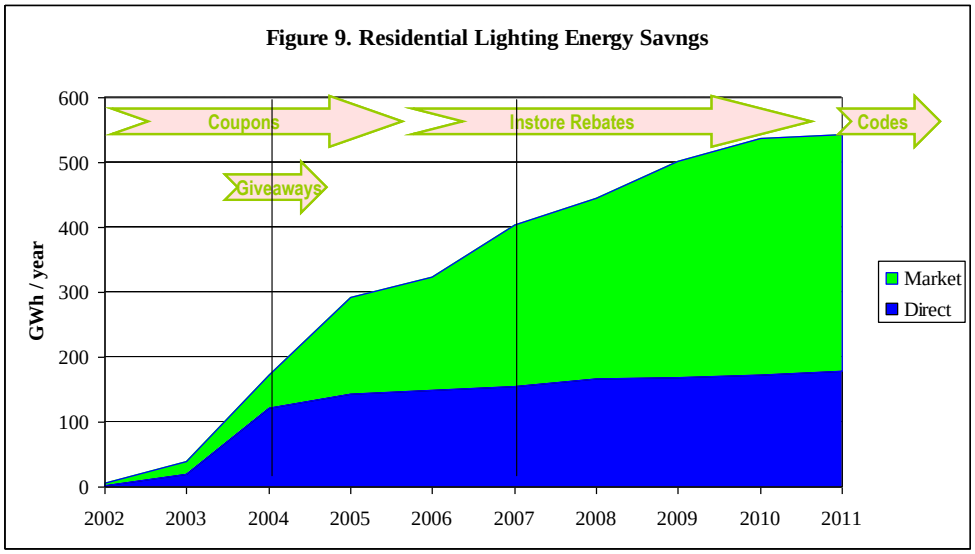
Barrier	2002	2011
Availability	In 2002, there were about 90 unique CFL models available for sale in BC There were seven major types of CFLs	By 2011, the number of unique CFL models had increased significantly, but an accurate estimate is difficult because

Barrier	2002	2011
	available ranging from A-lines to reflectors and spirals.	of very similar CFLs with different SKU numbers.
Accessibility	In 2002, CFLs made up about 6% of lighting shelf space.	In 2011, CFLs made up about 24% of shelf space plus with an additional 3% of shelf space for LEDS.
Affordability	In 2002, typical CFL price was about $20.00 compared to typical incandescent lamp price of about $1.50.	In 2011, typical CFL price was about $4.50 compared to typical incandescent lamp price of about $1.00.
Awareness	In 2002, about 74% of surveyed residential customers were aware of CFLs.	In 2011, about 95% of surveyed residential customers were aware of CFLs.
Acceptance	In 2002, about 25% of surveyed residential customers had ever purchased a CFL. The average number of CFLs per dwelling was 0.4.	In 2011, about 80% of surveyed respondents had purchased a basic CFL. The average number of CFLs per dwelling was 9.6.

Summary, Conclusions and Lessons Learned

Figure 9 presents cumulative direct, market and total energy savings for the BC Hydro Power Smart residential CFL program for the period 1998 through 2013.

Figure 9. Residential Lighting Energy Savngs



Summary. Beginning in 2001, BC Hydro decided to re-launch its residential lighting program with a focus on both energy acquisition and market transformation. To facilitate program planning, implementation and evaluation, a comprehensive CFL market characterization and baseline study was undertaken. Demand-side recommendations from this study included: (1) implement a point-of-sale rebate coupon campaign; and (2) expand efforts to educate consumers about CFLs. Supply-side recommendations included (1) expand efforts to work with supply side actors including large retailers, chains, grocery stores and up-stream actors, and (2) develop and distribute materials to retailers. From 2001 through 2011, BC Hydro implemented he recommendations of the baseline study in three phases.

Conclusions. (1) By the end of ten years, residential lighting energy savings were more than 540 GWh per year. (2) For the first three years of the program, energy savings were primarily due to the direct impacts of incentives, but by the fourth program year, market impacts due to advertising and market transformation were dominant. (3) The number of CFLs increased from 0.4 per household in 2002 to 9.3 per household in 2011. (4) Evidence suggests that all five market barriers have been successfully addressed: availability has increased; accessibility has improved; prices have fallen; awareness has increased; and acceptance has increased.

Lessons Learned. (1) Evaluation practice in most areas of social science emphasizes the use of randomized controlled trails or experiments with randomly selected treatment and control groups or where that is not feasible the use of quasi-experiments with a treatment group and a comparison chosen to be as similar to the treatment group as feasible. Energy program evaluation is unusual in that gross are first estimated using engineering methods and then adjusted with a net to gross ration usually based on self-report surveys. Psychological methods research suggests that self-report surveys can be subject to significant biases, which reduces the credibility of studies based on a self-report approach. This study, together with work recently completed or underway in several US utilities, shows that it is feasible to use a quasi-experimental approach to evaluate at least some DSM programs. (2) Using a quasi-experimental design requires considerable care in research design and implementation. The comparison group should be as close as possible to the treatment group in terms of the relevant drivers of measure installation and use, but it

should be subjected to a minimum and preferably to no similar program activities. The comparison group should be monitored over time so that if program activity occurs in the comparison group service territory, the implications of this for continued use of that comparison group can be understood. (3) Commitment to the use of a quasi-experimental design involves a significant use of resources. Costs for customer surveys and other related data collection efforts can easily be doubled compared to the use of the customer self-report method of assessing the net to gross ratio.

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