Behaviour and Energy Savings in Residential Dwellings

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ABSTRACT

Research on energy savings in residential dwellings has been dominated by an engineering economic paradigm, in which economic agents adopt practices and technologies that are cost effective. This paper, along with its companion paper on behaviour and energy savings in business[i], develops an alternate model for energy savings behaviour. It presents the results of an initial methodology, and reports on a detailed behaviour study done with BC Hydro residential customers. The paper uses data that was collected from surveys of 1,000 residential customers as a part of the Conservation Potential Review (CPR) developed by BC Hydro in 2006 and 2007.

The surveys focused on several main residential energy end uses, including indoor and outdoor lighting, space heating, hot water usage, refrigeration and plug loads. For each end use, respondents were asked a series of scaled questions about their satisfaction levels; their ability to change or modify; and the extent to which they performed energy efficient actions and behaviours. The results of the data collected showed that modifying uses of lighting, temperature settings, hot water, and plug loads were particularly effective means of achieving energy savings for the residential sector.

Introduction

Research on energy conservation has been dominated by an engineering economics paradigm, in which economic agents adopt those technologies and practices that are cost effective. Some key references to this literature include Duke and Kammen[ii], Gorlove and Eto[iii], Horowitz and Haeri[iv], Jaffe and Stavins[v] and Joskow and Marron[vi]. Within this literature, analysis of energy savings opportunities typically proceeds by estimating net life cycle costs, and then assuming that the technologies and practices with the best lifecycle costs will be adopted by economic agents, whether they are businesses or households.

This modeling however does not work well for behavioural change, if for no other reason than, behavioural changes do not typically include a financial cost to the participant. There are fundamental differences between product marketing, where the financial reward to the decision maker tends to be both significant and immediate, and behaviour programs where the direct rewards are small, often accrue more to society as a whole; and occur in the future. Behaviour programs tend to more resemble Social Marketing.

The behavioural literature currently available on residential customers' decision-making processes (how they make decisions on the choice of technologies and how they use these technologies) has had little impact on energy efficiency policies. Some key references include California Energy Commission[vii], Janda et al.[viii], Katvetz and Johnson[ix], Lutzenhiser[x] and Stern[xi]. The behavioural literature in specific and defined context attempts to understand how and why economic agents make decisions on energy use and conservation behaviour.

Methodologies to develop behavioural baselines and estimates of uptake for behaviour change are not as well developed as the engineering economics paradigm. The California electricity crisis of 2001 re-ignited interest when it was found that behaviour changes accounted for more of the load reduction than did technology changes[xii]. At BC Hydro, some efforts were made to assess the potential for energy savings due to changes in behaviour in the early 1990's, but these efforts languished until the recent update of the Conservation Potential Review in 2006/ 2007.

Method

This project was undertaken as part of the 2006 / 2007 Conservation Potential Review (CPR). This was an integrated study of the potential for more efficient technologies, fuel substitution, alternate energy, behaviour change and lifestyle change. Data for the behaviour change component was developed as part of an Internet panel research study which obtained results for 1,000 households across British Columbia in early 2007. The Internet panel data was weighted by geographic region and dwelling type to match BC Hydro's customer base.

The behaviours were developed in consultation with the CPR project team which included internal and external stakeholders as well as external experts. This resulted in a list of 24 behaviours in eight groups for the Residential sector. Two principal types of behaviour were considered, repetitive behaviour (such as turning off the TV when no one was watching), and periodic behaviour, (such as installing storm windows or turning off the hot water when away from the house on vacation).

In addition to specific behaviours, the concept of "behaviour on demand" was tested with questions on how much additional reduction in electricity consumption people would be willing to do if called upon by BC Hydro in response to a crisis such as a failure of a transmission line. The intent here was to assess how stated intention to act compared with the actual experience in California in 2001.

The modeling used in this study simplifies the previous models and argues that adoption of conservation and energy efficiency actions and practices has three main components: (1) the customer's level of concern around energy efficiency; (2) the customer's capacity to act; and (3) the conditions and constraints surrounding the action.

As data was typically collected on multi-point scales a number of "standards" were developed to assist in the systematic interpretation of the survey results. Key aspects of the preliminary data analysis included the following:

1. First, it was recognized that while some people performed the behaviour on a consistent basis (such as always turning off the TV when no one was in the room), other people only did this sporadically. Since Behaviour Potential was defined as "all the people performing the behaviour all of the time", it was necessary to use the concept of a "full-time equivalent" (FTE). For example, two people performing a behaviour 50% of the time are assumed to have the equivalent impact of one person performing the behaviour all the time.

2. Data from the survey were then analyzed to determine the share of the current population who state that they are currently undertaking the specified behaviours and how frequently. These data were collected on a four-point scale (always, usually, occasionally, never). It was agreed that the FTE baseline would be estimated by taking 100% of the people who said "always" and 0% for those who say "never". The intermediate values were set at 66% of the people who said "usually" and 33% of the people who said "occasionally."

3. For some repetitive behaviours, where the action is taken multiple times a day, and can be taken by multiple members of the household, a further test of the reported frequency was developed by asking those respondents who did the behaviour "always" or "usually" how frequently they experienced a lapse in the stated behaviour frequency. For example, after asking the respondent how frequently they turned off the lights when no one was in the room, they were then asked how often they went into an empty room and found the lights left on. This "failure rate" response was used to "de-rate" the estimated FTE responses.

4. Reviewing the failure rate response data, it was noted that only a small share of respondents noted that they "always" (1%-3%) or "usually" (4%-6%) noticed a lapse, but a much larger group (40%-60%) reported an "occasional" lapse. It was decided to only use the "always" and "usually" responses to de-rate the baseline behaviours. The calculation was to de-rate by 100% of the "always" and 50% of the "usually" when estimating the baselines.

5. To assist in the development of the achievable potential, a series of additional questions were included in the Panel Survey. Typically after a question about how often they performed a specific behaviour, respondents were provided with some data on the energy impact of that behaviour. They were asked how likely they would be to do the behaviour in the future. The answers were recorded on a five-point scale (definitely will, probably will, might or might not, probably will not, definitely will not). To recognize that people often overstate future behaviour, and in line with common market research practices, the response share was calculated by taking 80% of the "definitely will" and 20% of the "probably will."

6. After the response to the information question, typically two questions were asked. First, for those who did not "always" or "usually" undertake the behaviour, what would motivate the respondent to undertake the desired behaviour, and then, what are the reasons why the respondent would not undertake the behaviour (barriers). In the panel survey, a series of possible responses was provided, and then respondents were asked to list any other reasons.

In the CPR, this data was used to determine the share of the Base Year consumption that goes to the production of energy services (i.e.: heat, light etc) that are not being used and hence are available for conservation.

The approach used in the CPR was to develop simple engineering estimates to approximate the amount of unused energy services that are embedded in each end use from the Base Year consumption estimates. For example, if 37% of the households are not doing temperature set-back at night, and that temperature setback will reduce heating consumption by 7%, then the share of the space heating consumption that is available as a savings from increasing this behaviour can be estimated. (37% X 7% X Space Heat End Use Consumption). These are referred to as unused energy services.

Space Heating

Table 1 summarizes the four behaviours that were assessed related to indoor heating: temperature setback at night; temperature setback during the day when no-one was at home; keeping part of the house cooler when unused and draftproofing.

For day and night temperature setback, it was assumed that all homeowners have the ability to turn down the temperature. The table shows that about 61% on an FTE basis do turn down the temperature at night while 54% do during the day. The failure rate (people who report that they usually or always turn down the temperature, but then find the temperature was not

turned down) is quite low, at 3% and 8% respectively, while 17% and 11% indicate that they would respond to an information message on the benefits or impact of turning down the temperature.

The survey also determined that 69% of the respondents had unoccupied parts of the house, and 84% of these had some ability to reduce the temperature of those parts of the house. Of these, about 84% routinely reduced the temperature in those parts of the house, with a relatively low failure rate of 3%, while 21% indicated that they would respond to an information message.

A similar approach was taken to draftproofing, where 47% reported that their houses were "always" or "somewhat" drafty, and 53% indicated that they draftproofed their house at least once a year. Eleven percent of the respondents said they would undertake draftproofing in response to an information message.

Fully 33% of the windows are still single paned in B.C., of which approximately 70% are in rental accommodations. The survey questions focused on the use of glass storm windows, or if these were not available, then the use of plastic temporary windows. The lower response to information for this behaviour, 6%, may be related to either the cost of storm windows or the unattractiveness of the plastic windows.

Table 1: Space Heating Conditions, Capacity, Baseline Targets

Behaviour	Conditions	Capacity	Baseline Behaviour	Failure Rate	Response to Information
Night Setback	100%	100%	61%	3%	17%
Day Setback	100%	100%	54%	8%	11%
Part of house cooler	69%	84%	84%	3%	21%
Draftproofing	47%	100%	53%	na	11%
Install Storm Windows	33%	100%	20%	na	6%

Note: Due to limitations in the length of the survey, not all questions were asked for all end uses. Where the question was not asked, "na" is indicated in the tables.

Based on the engineering estimates, the technical potential for behaviour in this end use is 9% of the base load for the end use.

Lighting

Table 2 summarizes the three behaviours that were assessed for both internal and external lighting: for internal lighting, assessment was done on turning off lighting if no one was in the room and low wattage bulbs for dimmers and chandeliers: for external lighting, the ability to turn off lights not controlled by motion detectors was the main focus.

For the three behaviours it was assumed that all homeowners have the ability to perform these functions. Based on the response to turning off inside lights 76% (FTE) of respondents reported that they do it, while 65% of respondents turned off the outside lights. Approximately 65% of respondents replied that they consciously look for low wattage bulbs to replace their incandescent bulbs.

Table 2: Indoor/Outdoor Lighting Conditions, Capacity, Baseline Targets

Behaviour	Conditions	Capacity	Baseline Behaviour	Failure Rate	Response to Information
Turn off lights – empty room	100%	100%	76%	9%	9%
Use Low Wattage Bulbs	100%	100%	65%	na	28%
Turn off Outside Lights	64%	100%	65%	na	16%

Based on the engineering estimates, the technical potential for behaviour in this end use is 14% of the base load for the end use.

Hot Water Usage

Table 3 summarizes the four behaviours that were assessed; cold water wash and rinse; air dry dishes in dishwasher; checked domestic hot water (DHW); and turn of DHW when away on vacation were the main focus.

For the cold water wash and rinse currently 59% of respondents currently do it with cold water; however this could be increased by another 8%. For air drying their dishes in dishwasher, 34% of respondents currently air dry their dishes.

Similarly for the DHW 52% of respondents said they checked the temperature of their hot water at home. The survey showed that 20% of the respondents turned off their hot water heater when they were away for more than 2-3 days.

Table 3: Hot Water Usage Conditions, Capacity, Baseline Targets

Behaviour	Conditions	Capacity	Baseline Behaviour	Failure Rate	Response to Information
Cold Water Wash	41%	100%	8%	na	Na
Dish Washer – Air Dry	100%	100%	34%	na	Na
Check DHW Temperature	100%	100%	52%	na	Na
Turn off DHW on Away/Vacation	50%	100%	20%	na	16%

Based on the engineering estimates, the technical potential for behaviour in this end use is 29% of the base load for the end use.

Refrigeration

Table 4 summarizes the behaviour that was assessed; whether the respondents check and adjust the temperature of the refrigerator; and the freezer and if the respondents defrost the freezer more frequently.

When asked if the customer checked and adjusted the refrigerator since its installation, or in the past few years, 61% of respondents had done so. Likewise when asked the same if they did the same for the freezer only 34% of respondents checked and adjusted the temperature.

Literature suggests that freezers should be defrosted when light frost is showing or at least once per year, 53% of respondent did so appropriately.

Table 4: Refrigeration Conditions, Capacity, Baseline Targets

Behaviour	Conditions	Capacity	Baseline Behaviour	Failure Rate	Response to Information
Check & Adjust Fridge Temp.	100%	100%	61%	na	Na
Check & Adjust Freezer Temp.	100%	100%	34%	na	Na
Defrost Freezer More Frequently	100%	100%	53%	na	Na

Based on the engineering estimates, the technical potential for behaviour in this end use is 12% of the base load for the end use.

Plug Loads

Table 5 summarizes the survey information for the various plug load devices. Some 33% of respondents indicated they have unplugged brick chargers when not in use.

About 71% of respondents reported they always turn off the TV (note: 6% of respondents reported that TV is always on).

For the computers 55% turned off the whole system when not in use while 45% of the remainder turned off the monitors. About 85% of the respondents were using the power management.

Table 5: Plug Load Conditions, Capacity, Baseline Targets

Behaviour	Conditions	Capacity	Baseline Behaviour	Failure Rate	Response to Information
Brick Chargers	82%	100%	33%	na	29%
Turn off TV – no one watching	100%	100%	71%	na	19%
Unplug – after each use	100%	100%	na*	na	8%
Unplug – Away/Vacation	100%	100%	Na*	na	21%
Computer – all off	100%	100%	55%	na	30%+
Computer – monitor off	100%	100%	45%	na	30%+
Computer – Power Mgmt.	100%	100%	85%	na	30%+

*It was assumed that no one currently does these behaviours

+Question asked for all behaviours. The technical potential baseload for this end use is 3.6%.

Behaviour on Demand

The California energy crises of 2001 demonstrated that, when the public believes there is a crisis in the electrical system, they are willing to reduce consumption to help prevent blackouts. As part of the survey used in this project, a hypothetical question (in this case a failure of a major transmission system, which would result in one or more outages during the next few week) was included and respondents were asked how much they thought they could reduce their consumption. About 50% of the respondents said that they would undertake additional activities, and the mean estimated savings was 13%. About 10% of respondents suggested that they could save in excess of 30% of their energy consumption.

By way of comparison, during the California crisis in 2001, energy consumption over the year declined by 7% while demand reduction peaked at about 14% over a one month period.

Motivators

The engineering economics paradigm focuses on cost effectiveness, or the self-interest of the decision maker. However, as noted previously, the model is less applicable for behaviour change programs. One of the objectives of the study was to better understand the types of motivators for behaviour change and their relative strengths. Table 6 summarizes three classes of motivators that were hypothesized: self interest (what is the direct benefit to me); altruism (it is the right thing to do – such as reduce global warming) and civic norms (I do it because others around me do it). In addition, a response was included to assess the number of people who said that nothing would motivate them to change their behaviour.

Table 6: Classes of Motivators

	Self Interest		Altruism		Civic Duty		
	Higher Rates	Know Savings	Global Warming	Power Shortage	Others	Do It	Nothing
Temperature							
Temp. Setback (Day/Night)	10%	35%	18%	18%		3%	26%
Keep part of home cooler	35%	24%	17%	12%			17%
Draftproof							
Draftproofing	8%	25%	15%	12%			42%
Windows							
Storm windows	8%	20%	6%	5%			47%
Lighting							
TO lights / lower W bulbs	14%	24%	14%	5%		2%	51%
Outside Lights	15%	30%	11%	12%		2%	60%
Hot Water							
Turn off when on Away/Vacation	11%	31%	17%	15%		1%	41%
Refrigeration							
Check temperature	11%	43%	18%	18%		1%	34%
Plug Loads							
Unplug Brick Chargers	14%	29%	17%	23%		1%	53%
Turn off TV	5%	28%	29%	14%			51%
PC Power Management	30%	14%	40%				49%

"Knowing the Savings" had the highest share of responses as a potential motivator. However, as the actual direct savings from changing most of these behaviours is small, effective motivation from providing this information is likely low. It is interesting to note that increasing the rates typically was listed as a motivator by fewer respondents (typically 5 – 15% rather than the 14 to 43% for "know the savings".

The "altruistic" appeals of reducing global warming or helping to prevent a power shortage had an appeal to 5 – 30% of the respondents. This was lower than for knowing the savings, but slightly higher than for rates. Assuming that knowing the actual savings would not

be a strong motivator, this would seem to imply that the "carrot" of altruism motivators is about on a par with the "stick" of higher rates.

The appeal of "civic norms" was very low, in the range of 1 – 3%, where it was rated at all. These were surprisingly low.

Finally, it should be noted that between 20 and 50% of the respondents noted that nothing would motivate them to change their behaviour.

Lessons Learned

The potential for behaviour savings in the residential sector is significant. The preliminary estimates for savings developed as part of this project indicate that savings may be on the order of 11% of residential energy consumption. These estimates will be refined in future iterations of behaviour analysis.

Motivations to encourage behaviour are "different" than those required to motivate the purchase of more energy efficient technologies. While the three classes of motivators (self interest, altruism and civic duty) may be used for both types of programs, the balance is different with less reliance on self interest and more on altruism or "the greater good" required for behaviour programs.

The initial research in British Columbia indicates that there is a significant portion of the population (20 – 50%) who stated at the outset that nothing will motivate them to change their behaviour.

For repetitive behaviours the base level of behaviour ranges from 20 – 65%, with most in the higher range. Only for the more esoteric behaviours, such as unplugging the TV and stereo the base levels are lower, but this likely reflects a lack of awareness of these actions on the part of the consumers.

For repetitive behaviours such as turning off the lights, the failure rate is quite low (3 – 8%) which is quite encouraging for two reasons. One, it increases the level of confidence that the response to these types of questions is fairly robust, and secondly, it tends to indicate that, while a typical household is made up of a number of members, it is possible to have high levels of appropriate behaviour.

The response to information was quite strong with a range of 6 – 30% of respondents indicating that they would undertake the behaviour when provided with information on the impacts of the behaviour.

This research was initially done as part of a comprehensive Conservation Potential Review, to provide some indication of the energy savings potential that may be available, and to indicate the end uses with the largest potential. It is recognized that there are issues (biases) with self-reported data of this type. However Power Smart is introducing a comprehensive program intended to educate and influence behaviour for residential customers, and is also introducing a stepped rate program. The behaviour survey will be used as a baseline for a longitudinal study to determine how the self-reported behaviours change over time. In addition, it is expected that billing analysis will be done for people who sign up for the behaviour program, and the longitudinal behaviour survey will support program evaluation. A pilot program is currently being evaluated, and a broader based program is being designed. As the program is rolled out and managed over the next few years, it is expected that our understanding of behaviour, how to influence it and how to measure it will expand greatly from these modest beginnings.

References

[i] Tiedemann, K., Sulyma, I., Sahota, R. and Habart, J. (2008) Behaviour and Energy Savings in Business Establishments

ii Duke, R. and D. Kammen, "The Economics of Energy Market Transformation Programs,"Energy Journal, 20(4), 1999.

iii Gorlove, W.H. and J.E. Eto, Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency, Berkeley, CA: Lawrence Berkeley Laboratory, 1996.

iv Horowitz, M. and H. Haeri, "Economic Efficiency versus Energy Efficiency: Do Model Conservation Standards Make Good Sense?," Energy Economics, Vol. 12, 1990.

v Jaffe, A. and R. Stavins, "Dynamic Incentives of Environmental Regulations: The Impact of Alternative Policy Instruments on Technology Diffusion," Journal of Environmental Economics and Environment, Vol. 29, 1995.

vi Joskow, P. and D. Marron, 'What Does a Negawatt Really Cost: Evidence From Utility Conservation Programs," The Energy Journal 13, 1992.

vii California Energy Commission, Public Interest Energy Strategies Report. Staff Report 100-03-012D, 2003.

viii Janda, K., C.T. Payne, R. Kunkle and L. Lutzenhiser, "What Organizations Did (and Didn't Do): Three Factors That Shaped Conservation in California's 2001 Crisis,: Proceedings of the 2002 ACEEE Summer Study, Washington, DC: ACEEE Press Vol. 8, 2002.

ix Katvetz, R. and T. Johnson, "Promoting Energy Conservation: An Analysis of Behavioral Research, Boulder, CA: Westview Press, 1987.

x Lutzenhiser, L., "Marketing Household Energy Conservation: The Message and the Reality," in P.C. Stern and T. Dietz, eds., New Tools for Environmental Protection: Education, Information and Voluntary Measures, Washington, DC: National Academy Press, 2002.

xi Stern, P.C., "Toward a Coherent Theory of Environmentally Significant Behavior," Journal of Social Issues, 56, 2000.

[xii] Lutzenhiser, L. "Appendix A: Conservation Behaviour by Residential Consumers During & After the 2000 – 2001 California Energy Crisis", P168