Elements of Residential Efficient Lighting Savings

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Energy efficient residential lighting technologies are very popular elements in DSM program offerings due to their universal applicability and high potential for energy savings. This paper presents the findings of an evaluation of the Northeast Utilities' Lighting Catalog Program for calendar year 1991. This program is a mail order catalog program which offers high efficiency lighting at reduced prices with the aim of introducing and promoting energy-efficient lighting technologies to all residential customers.

The overall goal of this paper is to present the variety of approaches used to address the elements of savings, discuss the methods used to integrate the results of these approaches, and provide recommendations for planning similar studies by highlighting the value of each technique. A secondary goal is to present results obtained for this residential lighting program. Data collection methods employed during this evaluation include telephone surveys, on-site surveys, lighting diaries and time-of-use lighting loggers. [1] The focus of the paper is on hours of use estimates developed from the various data collection techniques. Telephone and on-site survey data pertaining to replaced wattages, installation and removal rates, free riders, free driver and snapback is addressed as well.

Introduction

Northeast Utilities' Lighting Catalog Program offers efficient lighting products at substantially reduced prices to residential customers in its Massachusetts and Connecticut service territories. An engineering algorithm incorporating hours of use, displaced wattage, and installation and removal rates from earlier evaluation efforts provides the basis for engineering estimates of savings for the program.

The overall goal of this paper is to present the variety of approaches used to address the elements of savings for this program, discuss the methods used to integrate the results of these approaches, and provide recommendations for planning similar studies by highlighting the value of each technique. A secondary goal is to present results obtained for this residential lighting program.

During this evaluation, a variety of methods were used to investigate the inputs for residential lighting savings. In order to provide the most accurate estimate of savings for the program, the study took a comprehensive look at all components of the engineering algorithm used to develop the estimates of savings. The emphasis was on hours of use, which can greatly over- or under-estimate energy savings and peak demand reductions. The hours of use variables of interest were average daily hours of use in winter, summer and shoulder months, average annual hours of use, and use during the hours of summer and winter system peak. Displaced wattage, installation and removal rates, free riders, free driver and snapback were addressed as well,

Methods and Findings

This section presents the data collection and analysis methods employed as well as the results of these methods. The section is organized by the various elements of savings, beginning with hours of use.

Hours of Use

Hours of use during time of system peak were gathered through four independent methods. These were (1) telephone surveys, (2) lighting diaries, (3) on-site surveys, and (4) time-of-use lighting loggers. The first three methods have the advantage of being relatively inexpensive and therefore pre-disposed to implementation in a large sample. They have the disadvantage, however, of being based on customer reported information rather than metered hours of use. In contrast, the lighting loggers used directly measure operating hours on a time of use basis. The drawbacks associated with the use of lighting loggers include a higher upfront investment cost for equipment, costs associated with installing and removing equipment and a typically limited time period of measurement dictated by the study's time frame. In this study, all four data collection methods were examined to determine the most reliable hours of use estimates.

The pyramid shown in Figure 1 represents the hierarchy of data collection methods employed. The lighting loggers at the top of the pyramid represent the method with the least measurement bias. The logger data therefore served as the benchmark against which to assess the accuracy of results in the lower levels of the pyramid and make appropriate adjustments. Differences in hours of use between the various levels of the pyramid were compared through a ratio analysis. In this analysis, a ratio was developed by dividing the average result of one method by the average result of another method *within the same sample of lamps.* For example, on-site and logger results were compared by dividing the average logger value by the average on-site value *in the logger sample.* The analysis was done for each type of product offered, e.g., 18 watt and 27 watt compact fluorescent fixtures were considered separately.

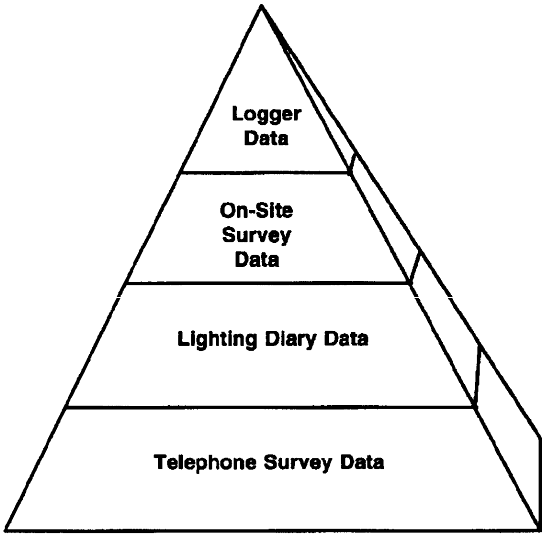

Figure 1. Hierarchy of Data

Table 1 shows the sample size for each method employed. The on-site visit, lighting diary, and lighting logger samples were all nested within the telephone survey sample. The telephone surveys provided information from the largest number of customers and the largest number of lamps, while the on-site visits provided the most detailed information on a subset of these customers. The lighting diaries gathered data at 48 homes for 48 lamps while the lighting loggers gathered data for 14 homes for a maximum of 2 lamps per customer.

In the table, the telephone survey number of bulbs represent a maximum of five bulbs per customers, as opposed to all bulbs purchased by these customers. On average, customers in the 1991 program purchased just over ten items each, with some customers in our sample purchasing in excess of thirty lamps. For the telephone survey only, a random sample of five lamps was selected in order to limit the survey to 30 minutes.

Table 1. Hours of Use Data Collection

Data Collection Technique	No. of Customers	No. of Lamps
Telephone Surveys	599	1,500
On-Site Visits	26	154
Lighting Loggers	14	27
Lighting Diaries	48	48

Table 2 shows the target variables for the corresponding data collection techniques. The on-site survey provided information on all variables of interest. The telephone survey obtained more limited information in order to control the length of the phone call. Results from both the lighting loggers and the lighting diaries are relevant to the winter only, as all data collection was conducted in the winter season.

Table 2. Sources of Information for Hours of Use

Hours Variable	Telephone Survey	Site Visit	Lighting Logger	Lighting Diary
Winter Average Daily Hours	X	X	X	X
Winter Peak Hour (5-6 pm)	X	X	X	X
Summer Average Daily Hours	X	X		
Summer Peak Hour (2-3 pm)	X	X		
Shoulder Average Daily Hours		X		

Table 3 presents a comparison of the winter hours of use resulting from the lighting loggers and lighting diaries. The second column shows the average total daily hours while the third displays use during the hour of system peak. The logger hours of use which reflected direct

Table 3. Hours of Use Comparison for Diary and Logger Lamps

	Winter Hours	
Data	Total Hours	Peak (5PM-6PM)
Logger/Diary Comparison (14 lamps)		
Logger	2.6	0.2
Diary	3.6	0.2
Logger/Diary Ratio	0.72	1.0
Logger/On-Site Comparison (28 lamps)		
Logger	2.5	0.2
On-Site	3.1	0.4
Logger/On-Site Ratio	0.81	0.5
Diary/On-Site Comparison (24 lamps)		
Diary	3.6	0.2
On-Site	4.2	0.6
Diary/On-Site Ratio	0.86	0.3

measurement, served as the benchmark for assessing the accuracy of the winter hours reported in the diary. As shown in the table, the use of a diary proved to be an accurate method of recording use during the peak hour but over-estimated total daily use. The daily use determined by logger measurement was 72% of that recorded in the diaries for the sample of 14 lamps.

The accuracy of the self-reported winter hours of use gathered during the on-site survey can also be assessed through a comparison to the logger data. In this case, the on-site over-estimated *both* peak usage and average daily use for a somewhat larger sample of 28 lamps. According to the logger results, daily use was 81% of that recorded in the on-site while peak use was 50% of that recorded in the on-site.

Because this study was conducted in the winter months, lighting logger measurement was not used as the benchmark for variables other than winter hours of use, but provided insight into the direction of the bias resulting from self-reported hours of use. In this study, data collected on-site served as the benchmark for summer and shoulder periods. As both the on-site and the telephone survey results are *self-reported,* using the on-site as a benchmark assumes that the in-person on-site interview yielded more reliable results than the telephone survey. This assumption is supported by the fact that the *winter* hours of use reported during the on-site were closer to the logger values than those reported during the telephone survey.

Table 4 presents a comparison of the on-site and telephone hours of use for the winter and summer hours. The original plan was to develop a ratio of the average on-site value and average telephone value for the five lamps included in the telephone survey sample. However, it was often difficult to determine which of the on-site lamps were addressed in the telephone survey. Therefore, we developed a ratio of results using *all* telephone survey and on-site survey lamps for a given measure type. This way, the ratio reflected two differences: (1) a difference in the methods applied, and (2) a difference in the sample of lamps considered. The ratio of on-site to telephone results trued-up the telephone result for any bias caused by limiting the sample to five lamps.

Comparing these average hours of use revealed higher totals reported during the telephone survey. The winter daily hours of use for the on-site survey results were 72% of the telephone survey result. For winter peak hours of use, there was a one-to-one relationship between the telephone and on-site results. The average summer hours of use reported in the telephone survey were also higher than those reported in the on-site. The on-site results suggested that the telephone average daily hours be adjusted by 86% and that the telephone daily peak use be adjusted by 33%.

Table 4. On-Site/Phone Hours Comparison

	Winter Hours		Summer Hours	
Data Source	Total Hours	Peak 5-6pm	Total Hours	Peak 2-3pm
On-Site	2.8	0.5	1.8	.02
Phone	3.9	0.5	2.1	.06
On-Site/Phone	0.72	1.0	.86	.33

In examining the findings of the various data collection methods, it appears that usage during peak periods was more consistently estimated than total daily hours of use. However, the finding was not universal, as the on-site and telephone results were substantially different for the summer peak and the logger and on-site results were substantially different for the winter peak. Across the board, an upward bias in customer reported or even diary-recorded results was substantiated by comparing self-reported versus measured hours of use using loggers. This finding underscores the importance of logger measurement in accurately estimating hours of use.

Annual Hours of Use. Annual hours of use for each product type were calculated by aggregating hours of use for the winter, summer and shoulder seasons. The following details the adjustments made to the hours of use for the winter, summer, and shoulder seasons by product type.

Winter Hours. Phone survey responses provided the basis for average winter daily hours of use, with adjustments made for on-site survey and lighting logger results. Equation (1) below displays the equation used to calculate the hours of use.

$$\frac{Winter\ Hours_{LOG}}{Winter\ Hours_{ONS}} \times \frac{Winter\ Hours_{ONS}}{Winter\ Hours_{PHO}} \qquad (1)$$

The first ratio shown was developed in the logger sample of 28 lamps, while the second ratio was developed in the on-site sample by lamp type. These two ratios are applied to each lamp in the telephone survey sample to calculate daily winter hours of use. This daily hours was multiplied by the number of days in the winter season to determine the total hours for the winter season.

Summer Hours. Telephone survey responses provided the basis for daily hours, with adjustments made for on-site results by type. No adjustment was made for logger results as they were collected in the winter season. In addition, the summer survey results may have been subject to a different level of measurement bias than the winter survey results, as the surveys were conducted in the winter season. The resulting daily hours were multiplied by the number of days in the summer season to determine the total hours for the summer season. An option to this approach would have been to assume that the measurement bias in the survey data was consistent across seasons, and adjust accordingly to reflect the logger results.

Shoulder Hours. The 154 lamps reported on in the on-sites provided the basis for shoulder hours of use. This information was extrapolated to the population of telephone survey respondents by developing a ratio of shoulder hours to winter hours in the on-site sample. This ratio was then applied to the winter hours for each lamp reported on in the telephone survey to develop the estimate of daily hours for the shoulder months. This estimate was then multiplied by the number of days in the shoulder months to calculate total hours for the shoulder months.

Displaced Wattage

The telephone survey queried each customer on the replaced wattage of up to five lamps.[3] This wattage was subtracted from the known total wattage of the lamp purchased to provide displaced wattage for each measure. If a lamp did not replace an existing fixture (1% of the sample) or if a customer did not know the wattage replaced (19% of the sample), the equivalent incandescent wattage for comparable lumens served as the pre-wattage. These savings in watts were divided by 1,000 to convert to kilowatts. Equation (2) shows the calculation:

$$kW\ Savings = (Old\ Wattage - New\ Wattage)/1000 \qquad (2)$$

These results were then grouped by product to determine displaced watts by product.

Installation and Removal Rates

Table 5 exhibits the installation rates as determined by the telephone survey. A total of 4,935 lamps are considered, with 70% installed in the utilities' service territory, 1% installed outside of the territory, 22% not yet installed at the time of the survey, and 7% installed and then removed. The majority of installations and removals occurred within six months of purchase.

Table 5. Installation and Removal Rates

Action Taken	Total Lamps	% of Total
Installed Within Service Territory		
In Customer's Home	3,240	65%
In Other Home	225	5%
Total	**3,465**	**70%**
Not Installed in Service Territory		
Outside Svc. Terr.	55	1%
Installed & Removed	327	7%
Plans To Install	650	13%
Never Plans to Inst.	438	9%
Total Sample	**4,935**	**100%**

The 70% of the lamps installed in the service territory includes lamps that are (1) installed in the purchasing customer's home, and (2) lamps installed in another home in the utility service territory. A total of 65% of the lamps were in the purchasing customers' homes. The remaining 5% were in other homes, perhaps that of a friend, relative, or vacation home.

Customers reported that they plan to install 13% of the lamp of the lamps at a later date. As customers did not install these lamps in the first year after purchase, these lamps contributed zero savings to the program during the first year. In terms of savings in later years, the lamps which will replace existing efficient lighting will increase the persistence of savings by extending the life of lamps currently installed. On the other hand, those lamps replacing non-efficient lighting will represent additional savings. Thus, an additional 5% savings are expected in years to come.

Installation and removal rates in the first year were based on the telephone survey as adjusted by on-site findings. The total 1991 installation rate based on the phone survey is 70%, representing lamps installed in the NU service territory 0 to 6 months after purchase. The 70% was adjusted by 77% to reflect the ratio of on-site to phone survey installation rates observed in the on-site sample to yield an overall rate of 53.9% (In developing the engineering estimates of savings, installation rates by product developed in a similar manner are used).

The remaining lamps not installed are correspondingly adjusted to 46.1%. Using the proportions observed in the phone survey, the 46.1% represents 1.5% installed outside of the NU service territory, 10.8% installed and removed, 20.0% planned to install, and 13.8% never to be installed. The lamps planned for installation represent delayed savings while all others represent potentially lost savings.

Revised Gross Engineering Estimates

The revised engineering estimates for each product were developed using factors obtained from the telephone surveys, and verified in the on-site surveys, to the existing engineering algorithm. Equation (3) shows the calculation for determining residential lighting savings:[2]

$$\textit{kWh/year Savings} = \textit{Watt Savings} \times \frac{1\ \textit{kW}}{1{,}000\ \textit{Watts}} \times \frac{\textit{hours}}{\textit{year}} \qquad (3)$$

The engineering estimates were developed using this equation, and then adjusted by the individual measure type installation rates to develop the final engineering estimates of annual savings. Table 6 displays the sample size, pre- and post-wattage, delta kW, hours of use, gross kWh savings, installation rate, and adjusted gross kWh savings by product type. Please note that these adjusted gross annual savings figures have not been adjusted for the free rider,

Table 6. Gross Annual Energy Savings

						Gross Annual Energy Savings		
Product Type	**Sample w/data**	**Pre-Watts**	**Post-Watts**	**Delta kW**	**Daily Hours**	**Gross kWh Savings**	**Inst. Rate**	**Adjusted Gross Savings (kWh)**
13WATT F	41	75	15.4	0.060	5.3	116.6	72%	83.7
26WATT F	23	127	30.8	0.096	5.3	186.2	72%	133.7
28WATT F	26	134	33	0.101	5.3	196.8	72%	141.3
32WATT F	16	97	37	0.060	5.3	116.3	72%	83.5
50WATT F	17	118	60	0.058	5.3	113.2	72%	81.3
54WATT F	35	129	64	0.065	5.3	126.8	72%	91.1
32WATT FR	14	96	37	0.059	3.8	81.6	13%	10.0
18WATT I	843	76	18	0.058	2.9	61.2	58%	35.7
9WATT M	109	60	11.4	0.049	2.5	44.9	62%	27.8
13WATT M	253	72	15.5	0.056	2.5	51.5	62%	31.9
22WATT M	399	80	27	0.053	2.5	48.3	62%	29.9
13WATT MR	23	75	15.4	0.060	3.4	74.5	22%	16.5
22WATT MR	63	85	27	0.058	3.4	71.9	22%	15.9

F = Fixture FR = Fixture Replacement Lamp I = Integral Lamp M = Modular Lamp
MR = Modular Replacement Lamp

free driver, or snapback effects discussed in the following sections.

Free Riders

Although free ridership and free driver were considered during this study, they were not the main focus of the research. The results presented here should be viewed in light of the fact that, while questions were included to address these issues, a comprehensive free rider or free driver study was not conducted.

To determine free ridership, the following items were considered in three separate analyses: (1) non-utility aided purchases by nonparticipants who have not heard of the program and motivations for these purchases, (2) non-utility aided purchases by participants prior to participating in the program and motivations for these purchases, and (3) the participants' motivation for purchasing lamps through the catalog. The three analyses used in estimating free ridership are discussed below.

1. The assumption for the first analysis is that the actions of nonparticipants unfamiliar with the program might represent the hypothetical actions of participants had they not participated in the program. This assumption is subject to the limitation that participants may be different, as they were aware of the program while the nonparticipants being considered were not. The analysis considered only the nonparticipants unfamiliar with the program, in order to minimize potential free driver effects or self-selection effects coming into play. There were 504 nonparticipants who stated they had not heard of the Lighting Catalog program. A total of 61 or 12% made a lighting purchase while 53 of these, or 10.5%, made non-utility purchases in the last three years.

   Examining quantities purchased reveals that some of these customers are only partial free riders. The nonparticipant group of 504, analyzed as a proxy for participants in the absence of the program, purchased a total of 287 lamps. In order to calculate free ridership, one has to consider how many lamps these customers would have purchased through the program. If they would have purchased more through the program than in the absence of the program, then they represent partial rather than full free riders. In the program, customers purchased an average of 10 products each. These 504 customers would have therefore purchased 5,040 lamps. Based on the 504 nonparticipants analyzed, the free rider effect is therefore 287/5 ,040 or 5.7%. Thus, under the assumption that participants would have acted similarly were they not familiar with the program, the free rider percentage based on this nonparticipant analysis is 5.7%.

   Also of interest are these nonparticipants' motivations for prior non-utility purchases. 51% of these nonparticipants unfamiliar with the program, gave saving money on their electric bill as a reason for purchase. The second most frequent response at 17% was saving energy.

2. The second free rider analysis considers what participants did prior to participating in the program. This analysis assumes that participants would have continued their pre-program behavior in the absence of the program. The analysis also assumes that all prior purchases occurred outside of a utility-sponsored program. Two facts provide the basis for this assumption: (1) participants were screened for participation in Lighting Catalog in the pre-period, and (2) in this time period, Lighting Catalog was the only utility program through which residential customers could buy energy efficient lighting.

   Prior to participation, 83 or 14% of participants purchased an average of 2.3 lamps each for a total purchase of 191 lamps. Thus, there was a free rider purchase of 191 lamps by the 600 customers interviewed. Through the program, these 600 customers would have purchased approximately 6,000 lamps. The free ridership total of 191 lamps is thus a portion of the total savings, which can be expressed as 191/6,000 or 3.2%. This free rider effect of 3.2% assumes that customers who purchased efficient lighting before the program would have continued to purchase efficient lighting on their own at the same rate.

   It is valuable to compare the purchase motivations of these participants to those for the nonparticipants who made prior purchases. The participants appeared to give more reasons for prior purchases than nonparticipants. A total of 43% stared they wanted to save money on their electric bill, 39% stated they wanted to save energy, and 30% stated that the price of the lamps was a motivating factor.

3. The third analysis considered in free rider evaluation was a question to participants on the importance of the reduced catalog prices. When asked how important the program's financial incentives were to the decision to purchase, 75% of respondents said it was very important while 18% stated it was somewhat. Only 4% of participants stated that the reduced prices were somewhat unimportant or not at all important to the decision to purchase. Treating this group of respondents as free riders yields a free ridership percentage of 4%.

   In verifying the reasonableness of these customers' responses, one can also consider the prior purchases of the 4% who downplayed the importance of the catalog prices. Of all participants who participated in the program, only one (less than 1%) both (1) said the catalog prices were not important to their decision to participate and (2) purchased high efficiency lighting prior to participation.

The three different analyses considered in evaluating free ridership yielded percentages of 5.7%, 3.2% and 4%. These values were averaged to provide a free ridership adjustment of 4.3%, suggesting that the equivalent of 4.3% of participants are full free riders with zero savings. The reason for combining the three estimates was to recognize the limitations of each.

The first analysis considers nonparticipants, who seem to differ from the customers who participated in the program in their motivations for purchase.

The second analysis considers what participants did prior to participation, and does not necessarily reflect what they would have done at the time of participation in the absence of the program.

The third analysis was the only one utilizing a question that addresses participant actions at the time of participation. However, it is a hypothetical question, rather than one on actual actions taken. In addition, prior purchases do not support responses to this question. Only one of the customers who stated that price was not important had actually purchased the lights on their own.

One additional source of data to inform free ridership is questions asked only of on-site participants. One question was the likelihood of purchase in the absence of the program. Of the 26 on-site participants, 46% stated it was likely or somewhat likely that they would have purchased the lamps in the absence of the program. It is also interesting to consider the percentage of these customers that made purchases on their own prior to participating in the program. Of the 46%, 25% had made purchases prior to their participation in the program. These customers represent 12% of all on-site participants. This suggests a higher free ridership estimate than yielded from the other sources of information. It may be that free riders tend to agree more readily to participating in the on-site research project, due to a greater interest in energy conservation in general.

Free Driver Effects

In considering free driver effects in the nonparticipant group, the analysis examined: (1) non-utility aided purchases of energy efficient lamps by nonparticipants familiar with the program, and (2) non-utility aided purchases by nonparticipants unfamiliar with the program. The actions of these two different nonparticipant groups were compared to see if having heard of the program had any effect on energy efficient lighting purchases. The assumption is that the difference, if any, between the two groups could be attributed to the Lighting Catalog Program. Of all nonparticipants, 504 stated they had not heard of the Lighting Catalog Program while 96 were familiar with the program.

Of the nonparticipants familiar with the program, 17% (16) made efficient lighting purchases in the last three years. A lesser 10.5% (53) of the nonparticipants unfamiliar with the program made efficient lighting purchases. Considering only the purchase percentages results in an estimate of 17.0%-10.5%, or 6.5% free driver effects due to the Lighting Catalog Program.

However, the respective quantities purchased does much to inform this result. Both nonparticipant groups bought an average of 0.6 products per customer. Based on this analysis, no nonparticipant purchases can be attributed to free driver effects for the Lighting Catalog Program, as there was no difference between these groups.

It is also interesting to compare the motivation for non-utility purchases of nonparticipants familiar with and unfamiliar with the program. For nonparticipants unfamiliar with the program, 51% stated a motivation of saving money on their electric bill while 17% gave savings energy as a motivation. For nonparticipants familiar with the program, 75% stated they purchased the lamps to save money on their electric bill while 37.5% stated they wanted to save energy. This suggests that nonparticipants who had heard of the program were somewhat more aware of the energy saving benefits of energy efficient lighting.

There does not appear to be a free driver effect among nonparticipants in the immediate future either, as only 3% of nonparticipants familiar with the program plan to purchase efficient lighting in the coming year as opposed to 10% of nonparticipants unfamiliar with the program. For the nonparticipants planning purchases, all 3% of the nonparticipants familiar with the program have seen the products in the store, while slightly over a third of nonparticipants unfamiliar with the program and planning non-utility purchases have seen the products in the store.

Participant Free Drivership. It is also important to consider what effect participating in the program had on participants' purchase activities: did their purchase patterns change since participation? In this case, we consider the number of participants who (1) made non-utility purchases since participating in the program, and (2) had not made pre-program purchases. Following participation, 26 participants purchased non-utility efficient lighting who had not made purchases prior to participation. The average purchase was 2.5 lamps for a total of 65 lamps. These 65 lamps for the 600 customers interviewed reflect an average free driver purchase following participation of 65/600 or 0.11 lamps per participant. A ratio of 0.11 free driver lamps divided by the average number of lamps purchased through the prograrn, 10, can translate these results into program savings. This yields a 1.1% free driver effect among program participants. These savings would have been realized mainly in 1992 and beyond.

One can also consider customer motivations for non-utility purchases since participation to those prior to participation, as stated above. The most frequent motivation for purchases since participation was the price of the lamps, at 26%. The second and third most frequent responses were saving money on the electric bill at 23% and saving energy at 13%. Although customers gave more reasons for purchase prior to participation, the reasons were in the same order of frequency as those since participation.

Snapback

Snapback was not addressed in the telephone survey, again to limit the length and intrusion to the customer. The on-site survey of 26 participants took an initial look at potential snapback associated with the lighting end-use by asking participants: "Has your use of lighting changed and why?" The great majority of participants, at 77%, reported no change in their lighting use due to their participation in the program. Thus, according to customer responses, there is some behavioral effect for 23% of the participants. One on-site participant stated they used their lighting less while another 5 or 23% of participants stated they used their lighting more due to the program. Of the 6 who reported a change, 5 stated the change was in the 0-25% range and 1 stated a 25-50% change. Thus, the extent of the change may have been minor in five of the six cases. While these results indicate some snapback effect, the issue requires more investigation before any conclusions can be made.

Peak Demand Reduction

Demand reduction estimates for the winter peak hour between 5 p.m. and 6 p.m. and the summer peak hour between 2 p.m. and 3 p.m. were developed. The primary source of information for usage during peak hours was the telephone surveys. As with the winter daily hours of use, the winter peak hour on the telephone survey was adjusted to reflect a 50% measurement bias revealed through logger measurement. The telephone peak hour results were adjusted by 0.50 prior to developing demand reduction estimates. The demand savings were developed by multiplying the delta kW by the coincidence factor, or the average percentage of the hour that residents reported their lights to be on.

Conclusions

This study yielded valuable and comprehensive primary data for residential lighting DSM. In addition, the study tested various approaches for deriving this data on the elements of savings, which can be improved upon in future evaluations at NU and elsewhere. In particular, the analysis of free riders and free drivers utilized a variety of approaches and customer groups to evaluate the issues from a wide range of perspectives. This work provides a strong starting point for future evaluations addressing these issues.

Additionally, this study offers some practical lessons for future evaluations targeting hours of use. While this study compared and contrasted a number of different data collection methods, future studies might use lighting loggers in combination with one other supporting method. The results of our evaluation suggest some strengths and weakness which might be considered in selecting an approach. This discussion should be prefaced by saying that this is of course not the final word on the useful application of these methods for residential lighting, as this was simply one study at one utility. We should continue to add to these findings by tracking and comparing the performance of different methods. Building on this knowledge will allow a more comprehensive understanding of the methods most appropriate for estimating the potential of this universal residential DSM application.

Across the board, an upward bias in customer reported or even recorded results was substantiated by examining self-reported versus measured hours of use using lighting loggers. The obvious strength of the logger measurement is that it measures actual hours of use. However, the loggers are more costly than survey approaches and, unless you have a long-range project, the period of data collection may be limited.

Using on-site and telephone surveys allows you to collect self-reported data about usage throughout the year. In addition, telephone surveys are relatively inexpensive to conduct in comparison to the loggers or on-site surveys, so they are practical for smaller programs with correspondingly smaller budgets. However, for programs such as this where a large number of lamps were involved, telephone surveys seemed to be somewhat confusing for the participant and limited the percent of purchased lamps which could be addressed. For similar programs, on-site surveys may be a more reliable approach, particularly for daily hours of use.

In contemplating either a telephone survey or an on-site survey approach, it is important to consider that without measured results for comparison, these self-reported values can lead to biased results. While the surveys provided adequate data for winter hours when asking the questions *in the winter,* it was not possible to truly determine how well the surveys performed for the summer or shoulder hours. For those programs where survey approaches are the only cost-effective alternative, it may be useful to adjust the results based on metering/on-site studies conducted by other utilities in the region. The database of residential logger metered data is continuously growing, as utilities take advantage of this relatively inexpensive version of end-use metering.

Of course, for utilities interested in determining residential hours of use on an annual basis, the ideal approach is to conduct a logger metering study that extends across a full year. The costs for this type of study can be controlled by metering a small sample of homes using lighting loggers and then extrapolating the logger information to the population, without actually having to conduct the metering at every site.

If the utility is more interested in use during peak hours, which did not seem to be well-estimated by telephone or on-site survey approaches, it may be better to link logger metering with a diary approach. Diaries seemed to be more accurate than the survey approaches in estimating use during the hour of system peak, while they were less accurate in estimating total daily hours of use. Those utilities interested in use during a peak hour or hours in a particular season can benefit from a study conducted in a limited timeframe. In these situations, a lighting diary study alone or a diary/logger study applied in the short-term may be very appropriate in providing the needed data.

Acknowledgments

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Endnotes

1. The Lighting Diary was a form developed to collect the hours of operation for a chosen Lighting Catalog lamp within a customer’s home. Customers were asked to write down the times they turned on and off this lamp for a period of one week and return the diary by mail. Upon receipt of the diary, the customer was mailed a $20.00 incentive.

2. Appendices to Determination of Energy Savings Document for Measures Installed in 1991, NU, May 12, 1992.

3. The survey collected wattage and hours of use information for lamps installed in the customer’s home *at that time.* To keep the survey length reasonable, information was obtained on a maximum of five lamps.