A Statistically Based Impact Evaluation of a Direct Install Compact Fluorescent Distribution Program

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This analysis evaluates the actual effect of compact fluorescent lighting retrofits on residential energy consumption. Program design and participant characteristics are such that relatively precise statistical analysis of participant billing data is possible. Given the difficulty of evaluating the effects of residential lighting retrofits, this study should provide valuable information to program operators.

A direct-install compact fluorescent distribution program operated at a New England utility for three years. Over 196,000 compact fluorescents were installed by trained crews in more than 37,200 homes. Participants were urban utility customers with a low incidence of electric space or water heating. Recruitment was through a "neighborhood blitz" approach that yielded a 50% penetration rate. Participants were representative of urban customers, with the possible exception that in all cases at least one person was home when the program was delivered, on weekdays from 8:30 am to 4:30 pm.

Savings equivalent to ten percent of annual electricity consumption were initially predicted based on engineering estimates. A statistical analysis of actual billing data showed savings that were significantly less that ten percent of consumption. This finding spurred an investigation into the basic engineering assumptions.

This paper explores the discrepancy between engineering and billing data based savings estimates for the Energy Fitness program in detail. In addition, insights are provided into measure persistence, changes in customer behavior and changes in program effectiveness over time.

Introduction

The Energy Fitness program targeted low-income customers in the three states served by New England Electric Services (NEES). Under the program, an average of 5.3 compact fluorescent lamps (CFLs) were installed per household at no charge to participants. Other measures were minimal and were projected to contribute at most 25% to overall program savings. The dominance of a single technology, the large number of participants and the low incidence of large electrical end-uses amongst them created a scenario where a relatively straight forward statistical analysis of billing records could produce a significant measure of program savings. Such analyses were completed for the 1990 and 1991 program years. The result is a clearer picture of how much electricity CFL retrofits really save residential customers.

The following paper describes Energy Fitness in more detail, and evaluates the program's impact on customer electricity consumption. Data obtained from the Energy Fitness process evaluations, which quantified mainly non-energy related program effects, are included only as they relate to the impact evaluation.

Description

The Energy Fitness program was one of a number of Demand-side Management (DSM) programs initiated under the Collaborative between NEES, the Conservation Law Foundation and other parties. Energy Fitness began with a pilot delivered by a single vendor to 2,577 residents of the city of Worcester, MA in 1989. The program was expanded the following year to include four additional vendors and several other cities in Massachusetts and Rhode Island. In addition, arrangements were made with local Community Assistance Program (CAP) agencies to deliver Energy Fitness measures through Weatherization Assistance Programs to a small number of customers in New Hampshire, Massachusetts and Rhode Island. By the end of 1991 37,215 participants had been served in six cities. A total of 196,038 CFLs were distributed.

The Energy Fitness program targeted electric utility customers at or below 125% of the federal poverty level[1] and living in urban, low-income neighborhoods. Neighborhoods were chosen in concert with local political and community development officials. Participants were recruited using a door-by-door, "neighborhood blitz" approach. All measures were physically installed by trained field staff who typically spent about 30 minutes in each home. All measures delivered through Energy Fitness were installed at no cost to participants.

Magnetically ballasted CFLs were by far the most prevalent measure, accounting for 75% of projected annual savings. Electronically ballasted CFLs were not distributed by NEES DSM programs due to concerns about their effects on power quality (Pileggi et al. 1992). Additional measures delivered included cleaning refrigerator coils and air-conditioner filters, water heater wraps for customers with electric water heaters and infiltration reduction measures for customers with electric space heat. Water saving measures such as low-flow shower heads and faucet aerators were also installed, regardless of water heating fuel. Participants received energy educational materials and counseling.

The incidence of electric space and water heating amongst participants was very low at around 4% and 5% of total participants, respectively. In addition, more than half of all homes with electric hot water had already had their water heaters wrapped. Residents in electrically heated homes were referred to the Residential Electric Space Heat program. See Table 1 for more complete measure installation information by year.

Energy Fitness was very successful in reaching residents in the targeted communities. Program vendors estimate that as many as 98% of customers who were at home when field staff arrived at their doors ended up participating in the program. For cost and safety reasons, field staff were sent out only during weekdays between 8:30 am and 4:30 pm. Because many homes were empty during this time, overall participation rates in the program averaged about 50%.

Data Acquisition and Management

A Management Information Systems (MIS) arm of one of the program vendors was contracted to track and store data for the entire program. An attempt was made to structure data collection and maintenance so as to minimize the burden upon the field crews and to ensure the integrity of the information. Information followed the paths outlined in Figure 1.

NEES initially provided a database of its residential customer names, addresses and location identifiers or "locids" to the MIS contractor. When target neighborhoods were chosen, identifying data for customers in that area were pulled from the database and printed on labels. The labels were sent to the program vendors and then into the field. The form that field crews completed for each participant collected about 500 columns of data. Program data points collected include the following:

Measure information;

- Lighting
  - Wattage of incandescent light replaced
  - Wattage of CFL installed
  - Location of installation
  - Customer estimate of hours of use
- Other measures
  - Incidence of installation

Customer information;

- Size of household
- Household income
- Appliance saturation
- Installation date.

After delivering the program to a participant, field staff transferred the label to the completed program data form and returned it to the MIS contractor. Program data and the label information were then entered into the program database. The program database was cross-indexed with the original residential customer database. If the locid on a form was not listed as a residential customer, the record was rejected and returned to NEES for checking.

For program evaluation, a tape containing complete program records was sent from the MIS contractor to NEES Demand Planning where it was matched with billing data from the NEES customer database. The most recent thirty-six months of billing data are maintained on a rolling basis in the customer database and complete records were pulled for all members of the participant and comparison groups used in the evaluation billing analyses in 1990 and 1991. Both actual and estimated meter readings were included and billing corrections were consolidated to yield a single monthly kWh consumption reading. There was no metering of kW demand.

Table 1. Program Data by Year

Energy Fitness	Average Incidence per Participant Group			
Participants	1989	1990	1991	Total
MA, RI and NH	2,577	15,179	19,459	37,215
CFLs: number per participant	5.76	5.47	5.04	5.27
9 W Twin Tubes	1,022	3,607	548	5,177
9 W Quad Tubes	5,012	19,745	17,165	41,922
13 W Quad Tubes	4,794	31,905	33,214	69,913
16 W One-pieces	2,212	12,797	24,271	39,280
22 W Quad Tubes	1,810	15,048	22,888	39,746
Water Heater Tank Wraps: percent receiving	2.2%	1.6%	1.1%	1.4%
Refrigerator Coil Cleaning: percent receiving	11.1%	28.2%	35.5%	30.9%
Space Heating Measures:* percent receiving	3.1%	15.2%	19.7%	16.7%
Engineering Estimate of kWh per participant	363	375	391	383
Displaced Watts per participant	284	258	240	250
Percentage of CFLs found removed by year installed**	45.6%	37.8%	24.8%	31.5%
Electric DHW: percentage of total	4.9%	4.3%	4.7%	5.1%
Electric Space Heat: percentage of total	3.0%	3.0%	5.8%	3.9%

* Customers who received weatherization measures or at least one air-conditioner filter cleaning or replacement.

** From 1991 Process Evaluation on-site survey conducted late in 1991.

Methodology

As required by the terms of incentive regulation in place in all three states served by Energy Fitness, impact evaluations were carried out in 1991 and 1992 on the Program as delivered during the previous year. For both years, the impact evaluation methodology consisted of two basic parts: (1) the calculation of an engineering estimate of savings based on program data and (2) the analysis of billing information based on customer billing data.

Both a billing analysis and an engineering estimate were necessary because the billing analysis approach used for the evaluation required a complete year of post-installation billing data. This meant that a billing analysis of all customers in 1990, for example, could not be completed until early 1992. However, regulators required results in early 1991. Therefore, an analysis of a smaller sample of participants who had accumulated sufficient billing data was used to adjust an engineering estimate for all participants in the program year.

To illustrate this process, in 1992 engineering estimates based on program data were made of savings realized by program participants in 1990 and 1991. At the same time, a billing data based savings analysis was also made for

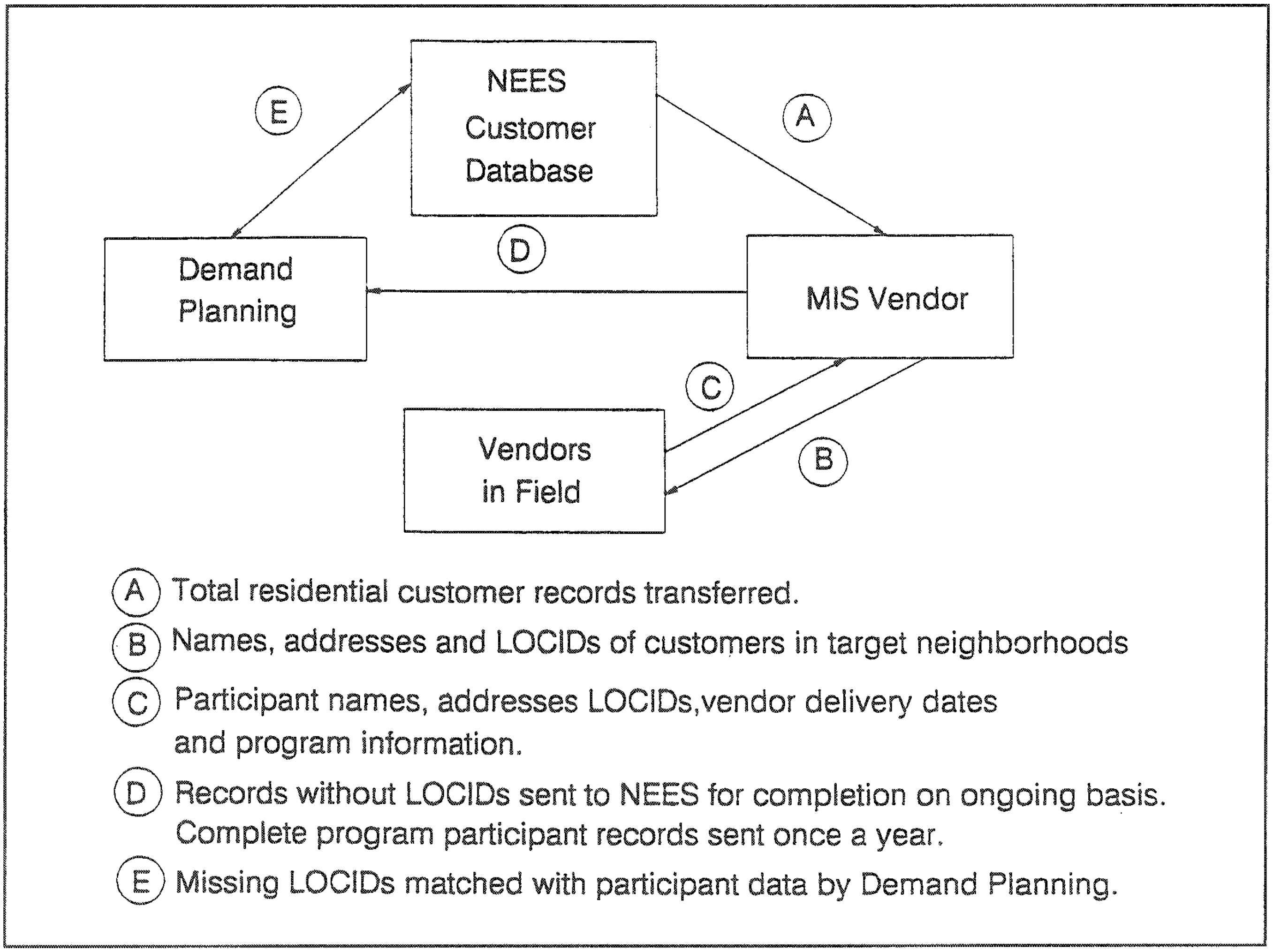

Figure 1.

some of the 1990 customers. The results of the two techniques were compared for the 1990 participants, yielding a "billing analysis to engineering estimate savings ratio" (billing/engineering ratio). Upon the assumption that this 1990 ratio also held for 1991, it was applied to the engineering savings estimate for participants in that year to produce a final, adjusted savings estimate for 1991. Independent of its function in the regulatory process, the billing/engineering ratio provides a measure of how well engineering algorithms are predicting actual measure performance[2].

Engineering Estimates

Engineering estimates of kWh savings were built up on a measure by measure basis from the program database for each participant. The calculations were performed on NEES's mainframe computer using programs developed by the author. The basic algorithms used were constructed as follows in Equation 1:

$$\mathit{Total\ kWh} = (A - B) * (C * 365.25) * (1 - D) * (1 - E) \quad (1)$$

A = Original kW. Rated wattage of actual incandescent lamp being replaced, from program records.

B = Replacement kW. Rated wattage of CFL lamp - ballast combination retrofit, from program records.

C = Hours of use. Estimated hours of used collected from participants at time of installation, from program records.

D = Free-ridership. The percentage of participants who would have purchased Energy Fitness measures in the absence of the program, from process evaluation (Applied Management Science 1990).

E = Measure Removal Rate, from process evaluation.

Non-lighting measure engineering estimates of kWh savings were based upon industry sources.[3]

Billing Data Analysis

Measured savings for Energy Fitness Program participants were based on a comparison between one year of billing history before and one year of billing history following installation for a participant sample. Non-program related changes in energy use were corrected for by comparing the participant group's changes in consumption with a comparison group's changes in consumption over the same time period.

Several different comparison groups were investigated during the 1990 analysis. A database of non-participant households was compiled from customers who lived in the neighborhoods targeted by Energy Fitness, but who did not participate in the program. However, a major barrier to participation appeared to be that the program was delivered during the day when many people were not home. Non-participant homes were therefore more likely to be empty during the day than participant homes, and further checking showed that they also tended to have lower annual kWh consumption.

Eventually, it was decided to use a sample of Energy Fitness participants who received the Program after the end of the post-period as a comparison group. In addition to having annual kWh consumption that was not significantly different from the participant group, they also had the advantage of being subject to whatever other biases might have been introduced by customer self-selection into the program.

Raw monthly bills were processed on NEES's mainframe computer using programs developed by the author. A variety of different approaches were used to decrease the amount of variance in the annual kWh consumption data for both the participant and control groups. Data for both participant and comparison groups were cleaned to exclude records which: (1) had more than 120 days without a valid bill; (2) showed annual consumption before or after program installation of less than 500 kWh or greater than 15,000 kWh; (3) showed a greater than 75 percent change in annual kWh consumption between pre- and post-periods. In addition, participant group members were cleaned to eliminate; (4) the small number of customers with electric space heat (on the assumption that because their kWh consumptions were higher and seasonal, the effects of the Energy Fitness measures would be lost) and; (5) all engineering estimates of annual kWh savings equal to 0, or engineering estimates of savings greater than actual consumption.

Confidence intervals at the 90% confidence level for the program savings estimates were computed in two steps: First, paired-difference standards deviations were calculated for the difference between the pre- and post periods in both groups using Equation 2. Then, a pooled estimate of the standard deviation of the difference between the differences was determined using Equation 3.

$$s_d = \sqrt{\frac{\sum (d_i - d_m)^2}{n-1}} \quad (2)$$

d_m = mean of difference between group annual pre- and post-period kWh consumption.
n = group sample size.
s_d = standard deviation of group paired-differences.

$$s = \sqrt{\frac{\sum (y_i - y_{m1})^2 + \sum (y_i - y_{m2})^2}{n_1 + n_2 - 2}} \quad (3)$$

y_{m1} = mean of difference between participant group annual pre- and post-period kWh consumption.
y_{m2} = mean of difference between comparison group annual pre- and post-period kWh consumption.
n_1 = participant group sample size.
n_2 = comparison group sample size.
s_d = pooled standard deviation.

Confidence intervals were calculated by multiplying the pooled standard deviation by a t-value of 1.645.

Results

1990 Energy Fitness Program

A Process Evaluation of 1989 participants was completed in August of 1990 and provided the basis for several assumptions that went into the engineering estimate of savings. No free-ridership for CFLs was found in program participants surveyed, and was therefore assumed to be zero for all measures. During on-site visits to participant households CFLs equivalent to 20% of installed, avoided wattage were found to have been removed (earlier telephone surveying of participants had yielded a lower removal rate).

Incorporating these factors, the engineering estimate of the 1990 participant sample group projected an average of 493 kWh annual savings per household, or about 10% of pre-program kWh consumption.

The billing data analysis for 1990 Energy Fitness partici pants was developed in early 1991. The households chosen for the participant group were amongst the very first program participants who received installations in 1989. Comparison group members were chosen from customers who participated in the Program after October 1990.

Data cleaning yielded a group of 983 participants who received installations in June, July and August of 1989. The most prevalent reason, by far, for exclusion from the participant sample was incomplete billing data. The participant sample was compared to a group of 1,205 customers who participated in the program after October of 1990. Concurrent participant and comparison group pre- and post-participation periods were chosen to run April 1, 1988 through June 1, 1989, and September 1, 1989 through November 1, 1990 respectively (pre- and post-periods contained 14 months to allow truing of monthly billing data to the beginning and end of calendar months, as opposed to billing cycle months).

The billing data analysis of the 1990 evaluation sample produced an estimate of net annual savings per household of 295 kWh plus or minus 116 kWh at the 90% confidence level. (See Table 3 for details). Pre-program mean annual kWh consumption was essentially identical for the participant and comparison groups.

1991 Energy Fitness Program

The main changes in 1992 from the 1991 impact evaluation were that (1) more customers had participated, allowing both the participant and control groups to be larger and (2) five vendors were operating, as opposed to only one during the previous year. This allowed an inter-vendor comparison to be done, on both the engineering estimate and billing analysis estimate of savings (see Table 2).

A second Process Evaluation was performed in late 1991 on participants from 1989, 1990 and early 1991 and was used to reformulate inputs to the engineering algorithms for the 1991 analysis (see Table 2). In this extensive study, free-ridership for CFLs was identified at 1.4%[4]. Free-ridership for non-lighting measures was still assumed to be zero. The average removal rates for all CFLs installed across the three program years were found to be 31% based on on-site surveys. This figure was used in the engineering estimate for the sample because sample members received their measures in the chronological middle of the program.

Finally, a sample of participants were asked to keep diaries of their lighting use. The results of the diaries were compared with the sample's initial estimate of hours of use collected when the program was delivered, and were found to be substantially lower. Therefore, for the 1991 analysis, participant estimates of hours of use were decreased by 37%, which was the average difference between the initial estimate of hours of use at time of installation and the estimate of hours of use based on the diary.

Incorporating these factors, the engineering estimate of the 1991 analysis participant sample group projected an average of 297 kWh annual savings per household, or about 6% of pre-program kWh consumption.

The billing data analysis for 1990 Energy Fitness participants was developed in early 1992. The households chosen for the participant group were from program participants who received installations in May, June and July of 1990. Comparison group members were chosen from customers who participated in the Program in November and December of 1991. Data cleaning yielded a participant group of 2,234 customers and a comparison group of 1,308 customers. Once again, the primary reason for exclusion from the participant group was incomplete data. Concurrent participant and comparison group pre- and post-participation periods were chosen to run from March 1, 1989 through May 1, 1990, and August 1, 1990 through October 1, 1991 respectively.

These data produced an estimate of net annual savings per household for the 1991 evaluation sample of 143 kWh plus or minus 65 kWh at a 90% confidence level (see Table 3 for details). Pre-program mean annual kWh consumption was 4% higher for the participant group than the comparison group, but this was considered to be small enough not to require correction.

Discussion of Evaluations

In both evaluations, the Energy Fitness program produced statistically significant kWh savings. However, there are insufficient data to assume that the large change in savings identified between the two billing analyses (295 kWh vs. 143 kWh) is due to a change in program effectiveness over time. The second process evaluation did find that a larger number of CFLs had been removed when the 1991 evaluation was performed, compared to the 1990 evaluation. However, Energy Fitness measures only affected a small percentage of participants' total kWh consumption. The effect of exogenous factors on electricity consumption is large enough to distort the magnitude of savings when considered for a single year. Billing data were not weather or temperature adjusted and there were economic fluctuations during the analysis period which may have affected participant electricity consumption.

Table 2. Program Data and Measured Savings by Vendor

Energy Fitness	Total Program Data by Vendor				
Vendor	1	2	3	4	5
Participants MA and RI	5,503	6,029	5,531	11,401	8,680
CFLs: number per participant	5.4	6.1	5.7	4.2	5.8
Water Heater Tank Wraps: percent receiving	1.2%	2.0%	1.0%	1.2%	1.8%
Refrigerator Coil Cleaning: percent receiving	14.0%	52.9%	49.3 %	17.0%	32.9%
Space Heating Measures:* percent receiving	4.3%	26.4%	31.8 %	14.0%	11.0%
Engineering Estimate of kWh per participant	271	370	369	223	287
Billing Analysis of kWh per participant	195	148	123	177	248
Displaced Watts per participant	260.6	279.7	280.5	199.7	271.3
Percentage CFLs found removed by vendor**	38.3%	25.7%	30.7 %	32.0%	32.7%
Electric DHW: percentage of total	4.9%	5.1%	3.2%	2.8%	8.7%
Electric Space Heat: percentage of total	4.5%	4.1%	2.3%	1.2%	7.0%

* New Hampshire participants were served by CAPs, and are therefore not included in this comparison

** From 1991 Process Evaluation on-site survey conducted in late 1991 on participants receiving installations in 1990 and 1991.

Despite the additional refinements of updated information from a second process evaluation, and the addition of the hours of use reduction, the engineering algorithms remained fairly inaccurate, at least as a way of predicting billing analysis results. A number of reasons for the large discrepancy between the two methods were investigated:

1. Perhaps more than other energy efficiency measures, CFLs are susceptible to removal if they are not an adequate retrofit for a customer's accustomed energy service (lighting). The quality of the lighting service that a CFL provides is dependent upon the quality of the product being installed and of the installation process. Magnetically ballasted CFLs often do not provide an identical lighting service to incandescent lights. For example, they may flicker when turned on and take a minute to come to their full brightness. These characteristics may have influenced end use.

   For Energy Fitness, the decision not to use electronically ballasted CFLs, and availability problems that occasionally limited the choice of CFL wattages available to field staff, probably resulted in participant dissatisfaction, and some percentage of the high CFL removal rate seen in the second process evaluation.

2. As a primary input into the engineering algorithms, hours of use is probably a large source of error without even considering program operation. Residential customers simply do not estimate their hours of lighting use very accurately. Customer estimates of hours of use are also very susceptible to being skewed by the data collection process. At one point it was discovered that field staff were receiving incentives for the number of CFLs installed per household. However, vendors had also been given guidelines for

Table 3.

PROGRAM: EF (ACEEE 1990) 08-Jun-92

	Single Sample Statistics						Two Sample Statistics	
	Column A	Column B	Column C	Column D	Column E	Column F		Column G
Sample →	Participant Pre Installation Annual Usage	Participant Post Installation Annual Usage	Participant Pre – Post Annual Usage	Comparison Pre Installation Annual Usage	Comparison Post Installation Annual Usage	Comparison Pre – Post Annual Usage	Difference Between Means	Participant Mean (Pre – Post) Minus Comp. Mean (Pre – Post)
Sample Size	983	983	983	1,205	1,205	1,205	Sample Size = n1+n2	2,188
Sample Mean	4,711	4,534	178	4,760	4,877	(117	Mean(1) – Mean(2)	295
Sample Variance							Sample Size = n1	983
Sample Standard Deviation	2,551	2,641	1,661	2,525	2,693	1,635	Sample Sixe = n2	1205
CALCULATIONS								
DF = v = n – 1	982	982	982	1,204	1,204	1,204	DF = v1 + v2	2,186
Sample Sum of Squares	6,390,464,182	6,849,333,142	2,709,260,422	7,676,252,500	8,731,707,796	3,218,562,900		
Sample Variance	6,507,601	6,974,881	2,758,921	6,375,625	7,252,249	2,673,225	Pooled Variance	2,711,722
Sample Standard Deviation	2,551	2,641	1,661	2,525	2,693	1,635	Var of Dif Btn Means	5,009
Standard Error	81	84	53	73	78	47	Std Error of Dif Btn Means	71
Std Error / Mean	1.7%	1.9%	29.8%	1.5%	1.6%	40.3%	t	4
90 % CONFIDENCE INTERVAL AROUND THE MEAN								
t value = t 0.10(2),v	1.645	1.645	1.645	1.645	1.645	1.645	t = t0.20(2),(2186)	1.645
1/2 90% Confidence Interval	133.836	138.558	87.143	119.649	127.609	77.475	1/2 90% Conf Interval	116.417
Lower End of Interval	4,577.164	4,395.442	90.857	4,640.351	4,749.391	(194.475)	Lower End of Interval	178.583
Upper End of Interval	4,844.836	4,672.558	265.143	4,879.649	5,004.609	(39.525)	Upper End of Interval	411.417
Precision = (1/2 Int)/Mean	0.028	0.031	0.490	0.025	0.026	0.662	Precision = (1/2 Int)/Mean	0.395

PROGRAM: EF (ACEEE 1991)

	Single Sample Statistics						Two Sample Statistics	
	Column A	Column B	Column C	Column D	Column E	Column F		Column G
Sample →	Participant Pre Installation Annual Usage	Participant Post Installation Annual Usage	Participant Pre – Post Annual Usage	Comparison Pre Installation Annual Usage	Comparison Post Installation Annual Usage	Comparison Pre – Post Annual Usage	Difference Between Means	Participant Mean (Pre – Post) Minus Comp. Mean (Pre – Post)
Sample Size	2,234	2,234	2,234	1,308	1,308	1,308	Sample Size = n1+n2	3,542
Sample Mean	4,806	4,594	212	5,023	4,954	69	Mean(1) – Mean(2)	143
Sample Variance							Sample Size = n1	2234
Sample Standard Deviation	2,640	2,544	1,073	2,702	2,683	1,253	Sample Sixe = n2	1,308
CALCULATIONS								
DF = v = n – 1	2,233	2,233	2,233	1,307	1,307	1,307	DF = v1 + v2	3,540
Sample Sum of Squares	15,563,116,800	14,451,833,088	2,570,917,657	9,542,150,828	9,408,425,123	2,052,001,763		
Sample Variance	6,969,600	6,471,936	1,151,329	7,300,804	7,198,489	1,570,009	Pooled Variance	1,305,909
Sample Standard Deviation	2,640	2,544	1,073	2,702	2,683	1,253	Var of Dif Btn Means	1,583
Standard Error	56	54	23	75	74	35	Std Error of Dif Btn Means	40
Std Error / Mean	0	0	0	0	0	1	t	4
90 % CONFIDENCE INTERVAL AROUND THE MEAN								
t value = t 0.10(2),v	1.645	1.645	1.645	1.645	1.645	1.645	t = t0.20(2),(3540)	1.645
1/2 90% Confidence Interval	92	89	37	123	122	57	1/2 90% Conf Interval	65
Lower End of Interval	4714	4505	175	4900	4832	12	Lower End of Interval	78
Upper End of Interval	4898	4683	249	5146	5076	126	Upper End of Interval	208
Precision = (1/2 Int)/Mean	0.019	0.019	0.176	0.024	0.025	0.826	Precision = (1/2 Int)/Mean	46%

*These formulas are based on the standard deviation being the square root of the sum of squares divided by n–1.

* Indicate whether total usage reflects annual usage, average monthly usage, or seasonal usage. If none of these ategories fit, plase provide a description appropriate for your analysis.

CFL installation that required that a light be used a minimum of three hours per day before retrofitting. This combination probably lead to participants being encouraged to overestimate hours of use, in order to increase the number of CFLs installed per participant, a conclusion supported by anecdotal information from field auditors.

3. Finally, the engineering estimate ignored changes to participant behavior caused by the installation of CFLs. These are usually referred to as "snapback" effects.

One of the most disturbing findings from the process evaluation was that program participants removed large numbers of CFLs. There is evidence of a trend towards removals increasing with age, but it should be noted that the mix of CFLs shifted substantially towards higher wattages over the three years. Because inadequate brightness was listed most frequently as the reason for removals, installations made in 1990 and 1991 may not experience the same degree of removals as those made in 1989.

The Energy Fitness program was discontinued in the form described in this paper at the end of 1991. Reasons for cancellation included the above evaluation results and the effects of the economic recession on the long term avoided cost of energy which is used to value NEES DSM programs, which combined to make the Program no longer cost-effective.

Vendor to Vendor Comparison

In addition to the two billing analyses described above, which were variations of studies prepared for regulatory filings, a third billing analysis was prepared specifically for this paper that looks at kWh savings by vendor. Fortunately for the sake of program evaluation, there were differences in style between the vendors who provided services under Energy Fitness. Therefore, it becomes possible to compare savings and techniques between them. Table 2 presents the results of this comparative analysis. The last row in the Table shows the results of billing analyses performed *without a control group* that provides a relative measure of vendor effectiveness.

The analyses for the five vendors were performed using participants who received installations from May 1, 1990 through January 1, 1991. The most prevalent reason, by far, for exclusion from the participant sample was incomplete billing data. The participant sample was compared to a group of 1,205 customers who participated in the program after October of 1990. Concurrent participant and comparison group pre- and post-participation periods were chosen to run April 1, 1988 through June 1, 1989, and September 1, 1989 through November 1, 1990 respectively (pre- and post-periods contained 14 months to allow truing of monthly billing data to the beginning and end of calendar months, as opposed to billing cycle months).

No strong correlations appear between measured savings and number of CFLs installed, or between measured savings and engineering estimates of savings. Displaced watts per participant is an alternative engineering estimate of savings that avoids the error inherent in customer estimated hours of use. There does not appear to be a correlation between displaced watts and measured savings either, however.

Perhaps the most interesting part of Table 2 is the difference in the removal rates between vendors (These rates reflect 1990 and 1991 installations only to provide a more balanced comparison). The vendor with the lowest removal rate installed more CFLs per participant than the vendor with the highest removal rate. This suggests that there is little correlation between penetration and customer dissatisfaction with CFLs. There appears to be also no correlation between measured savings and CFL removal rates, at least in this type of single year analysis.

Conclusions

The above findings suggest that CFLs do indeed produce identifiable and statistically significant savings in residential customers. However, the magnitude of those savings is not at all certain, and the engineering algorithms used did a poor job of predicting single year savings.

The vendor-by-vendor analysis showed that sizeable differences existed between the quality of installations, as measured by the subsequent rate of removal of CFLs. However, these differences were not tied to easily measured factors, such as the number of CFLs installed per participant, and may be due to more intangible qualities such as field staff experience and training.

Anybody who can unscrew a light bulb can remove a CFL, and incandescent light bulbs are inexpensive. Therefore, program designers must be careful to structure all aspects of Energy Fitness-type programs to insure that installed lights meet customer expectations, or risk large numbers of removals.

Acknowledgments

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Endnotes

1. No means testing, however, was used to screen participants.

2. Margaret Fels from Princeton's Center for Energy and Environmental Studies noted during her tutorial on PRISM at Affordable Comfort IV that there appears to be a kind of constant of 43% for billing to billing/ engineering ratios. Energy Fitness ratios were 60% and 48% for the 1990 and 1991 evaluations, respectively.

3. Non-lighting measure savings estimates were provided by EnerCon Systems, Inc. of Eden Prairie MN, and other sources including staff engineering estimates.

4. Free-ridership was estimated for Energy Fitness for the 1991 evaluation based on the portion of customers who already had CFLs at the time of the installation visit. Nine percent of the respondents to a telephone survey claimed they had such lights in place. However, with further probing, it was determined that only 31% of the 9%, or 2.8% of the total sample (9% x 31% = 2.8%) actually had CFLs; the rest were referring to "Watt-Misers" or other lower wattage incandescents. Furthermore, it is unlikely that these customers had as many pre-existing CFLs per home as were installed by the program. It was decided to use half of the percentage who previously had lamps, or 1.4% as the free-ridership estimate for the program.

References

Applied Management Sciences for New England Power Service Company. 1990. *The 1989 Residential Energy Fitness Program in Worcester Massachusetts: An Evaluation of Program Effectiveness*. Westborough, MA

New England Power Service Company. 1992. *1991 DSM Performance Measurement Report*. Westborough, MA

New England Power Service Company. 1991. *1990 DSM Performance Measurement Report*. Westborough, MA

Pileggi, D.J., T.J. Gentile, A.E. Emanuel. *The Effect of Modern Compact Fluorescent Lights on Voltage Distortion*. to be presented at the Summer 1992 IEEE PES Meeting in Seattle, July, 1992.

Synergic Resources Co. for New England Power Service Company. 1992. *Implementation Experiences with NEPSCO'S Energy Fitness Program*. Westborough, MA