EVALUATION OF A RESIDENTIAL APPLIANCE REBATE PROGRAM USING BILLING RECORD ANALYSES

Eric A. Rogers, P.E.
Wisconsin Electric Power
Company
Milwaukee, Wisconsin

Abstract

Wisconsin Electric Power Company is providing financial incentives to customers who install energy-efficient appliances or turn in old, inefficient appliances. The purpose of the evaluation of the Smart Money program is to determine whether the specific components are cost-effective. The basic question asked by the utility management is "Are customers who participated in the program using less energy than they would have used if there had not been a rebate program?" One method that is used to evaluate the energy effects of the residential rebate components is billing record analysis.

Background

Wisconsin Electric Power Company is conducting the Smart Money energy conservation program, through which customers in all classes are provided financial incentives to install energy efficient appliances or equipment or to turn in old, inefficient appliances. In the first two years of the program, over 10,000 commercial and industrial projects were completed, over 120,000 rebates or loans were provided to residential customers purchasing new appliances, and over 90,000 old appliances were turned in and exchanged for savings bonds.

The evaluation of the Smart Money program is divided between two major emphases. The Market Research Group of the Consumer Relations Department conducts extensive surveys of program participants and nonparticipants to determine the impact the program has on the customers' purchase decisions. The Demand-Side Evaluation Group of the Corporate Planning Department conducts various analyses to determine the energy and demand effects the program has on the system's loads. This paper will focus on one such analysis: the billing record analysis of the residential appliance rebate program.

Why Billing Record Analysis?

The utility's primary interest in conservation programs is to reduce energy production at power plants, thereby saving fuel costs and delaying the need to build additional capacity. It would seem most appropriate, therefore, to measure the effects of conservation programs at the power plant. Unfortunately, it is generally not very practical to do so because the effects of energy conservation programs are generally quite small relative to the other factors that affect energy consumption. The effects of these other factors—notably weather and economic conditions — cannot easily be controlled for when the only data one has to analyze is total system energy production before and after the program.

Billing record analysis provides a means for controlling these extraneous factors. Indeed, billing records are the only comprehensive source of energy consumption data for both program participants and nonparticipants before and after the program. Furthermore, billing record analysis is incredibly inexpensive, compared to end-use metering; the incremental cost to the utility of collecting billing data is essentially zero (it's collected for another purpose, anyway), while the incremental cost to identify and submeter a representative sample of program participants and nonparticipants would be prohibitively expensive.

The Experimental Design

An ideal experimental design would compare the before and after energy consumption of a test group of program participants with that of a control group of nonparticipants who were identical to the participants in every respect except exposure to the conservation program. There would be an identical distribution of energy consumption for both groups before the program started. A hypothetical distribution of energy usage for an existing appliance before the program is represented in Figure 1. For the purposes of this hypothetical example, it is assumed that the differences in energy consumption are due to differences in appliance models rather than due to any demographic or psychographic phenomena.

Each customer in the ideal control group would replace his or her existing appliance with a new appliance. The energy consumption of each customer's new appliance may be less than that of the respective existing appliance because, in general, appliance manufacturers have im-

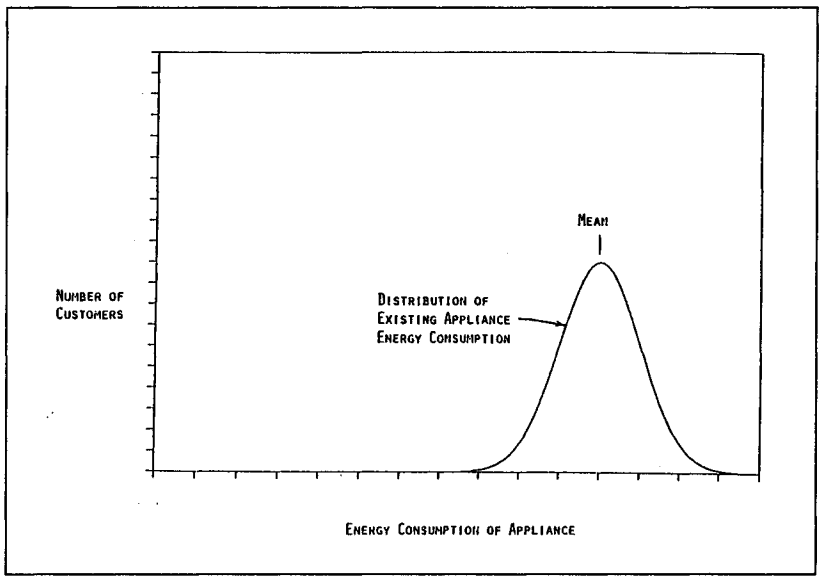

Figure 1. Wisconsin Electric Power Company Distribution of Existing Appliance Energy Consumption

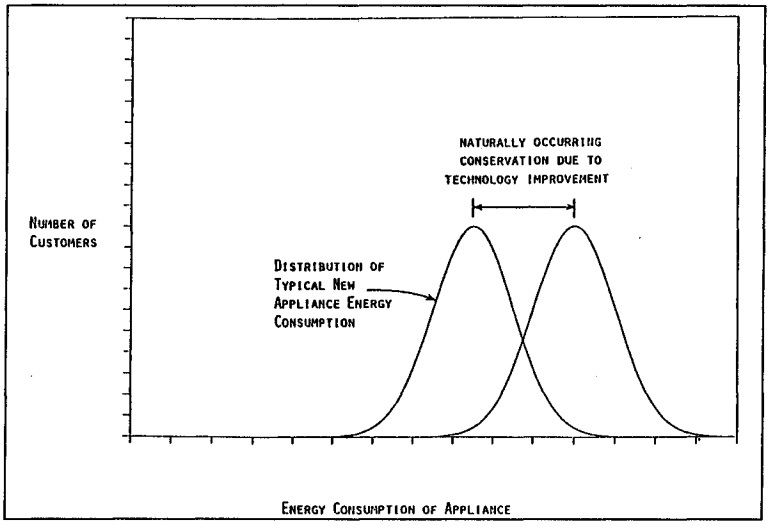

Figure 2. Wisconsin Electric Power Company Distributions of Existing Appliance and Typical New Appliance Energy Consumption

proved the efficiency of their products in recent years. The distribution of energy consumption of the new appliance is shown in Figure 2 next to that of the existing appliance, which was shown in Figure 1. The difference between the means of these two distributions is the naturally occurring conservation due to technology improvements.

Each customer in the ideal test group would replace his or her existing appliance with a new appliance that qualifies for the rebate. The distribution in energy consumption therefore is not a normal distribution; rather, it has an abrupt upper constraint (the program standard), as shown in Figure 3. The difference between the mean of the control group's new appliance energy consumption distribution and the mean of the test group's new appliance energy consumption distribution is the net program-induced effect. The difference between the mean of the existing appliance distribution and the mean of the test group's new appliance distribution is called the gross conservation effect of the program.

Practical Experiments to Identify Gross and Net Effects

The purpose of this hypothetical example is to delineate what can and cannot be measured. Unfortunately, the ideal control group cannot be identified because all the customers in the service territory are exposed to the program. A control group can be defined that is similar to the ideal control group, however. The difference is that, while it would be known that every member of the ideal control group purchased a new appliance, it cannot be determined whether any member of the practical control group purchased a new appliance. Indeed, it is assumed that practical control group members did not purchase new appliances. This experiment, therefore, measures the gross conservation effects rather than the net effects.

A separate experiment could be devised to identify the naturally occurring conservation due to technology improvements if a group of customers who purchased new appliances without exposure to the Smart Money program could be identified. Wisconsin Electric's residential appliance saturation survey, conducted in September 1986, provides such a group. A representative sample of residential customers was asked, among other things, how many of each type of various appliances they owned, whether they had purchased new appliances within the last year and, if so, whether the appliances were replacements or additions. The before and after energy consumption of customers who reported purchasing new appliances as replacements was compared to the before and after energy consumption of a control group.

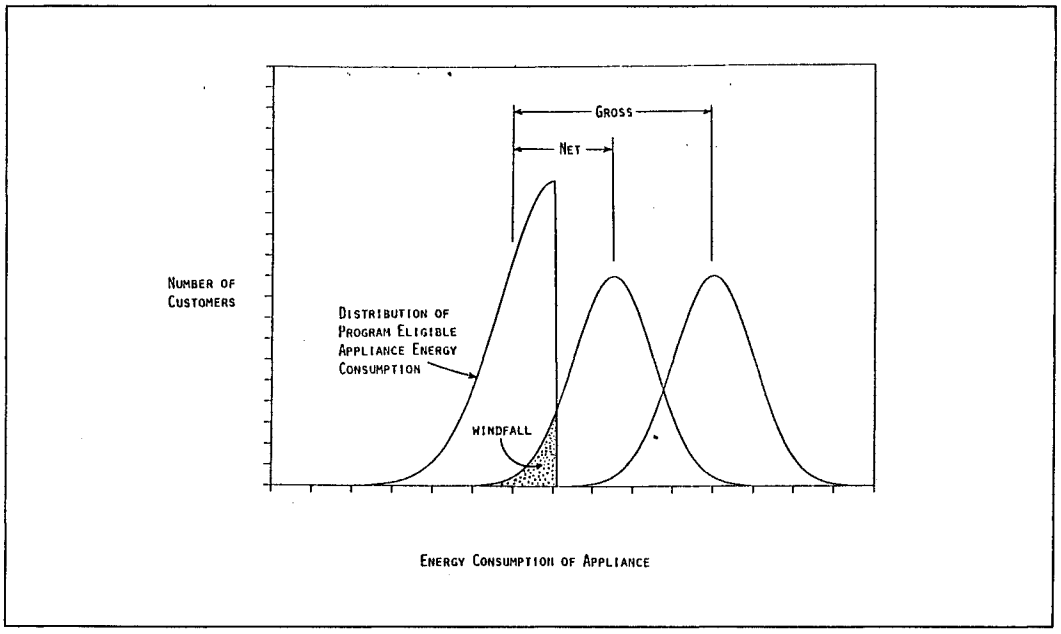

Figure 3. Wisconsin Electric Power Company Distributions of Existing Appliance, Typical New Appliance, and Program Eligible Appliance Energy Consumption

Methodology

In order to derive meaningful results from a billing record analysis, the participant group must be properly segmented and the control groups must be carefully selected. Participants are segmented by program component and by whether they had replaced existing units or purchased original or additional units. The control groups are formed by matching each participant in a given test group with a nonparticipant from the same political district with similar energy usage. The mean energy use before the program for the test group and for the control group are, therefore, virtually identical.

Nonweather-sensitive appliances (refrigerators, freezers, and water heaters) are analyzed by comparing the total customer usage (on a kWh per day basis) in a base month prior to the program (or, in the case of survey respondents, prior to their purchase of new appliances) with the total customer usage in the same month one year later. Air conditioners are analyzed by comparing the weather-sensitive usage (on a kWh per cooling degree day basis) in the base month with that of the same month one year later. The weather-sensitive load is calculated by subtracting each customer's base load, as defined by the average kWh/day in the May 1987 billing month, from the total customer usage in the July or August billing month of the appropriate year. The analyses are based on the comparison of two months of consumption data rather than two years, so as to minimize the number of participants that are rejected from the analysis for billing irregularities, such as estimated or adjusted bills.

The months that were analyzed for the various analyses are in Table 1. The November 1985 and 1986 billing months were selected for the analysis of the nonweather-sensitive survey respondents because the survey was conducted in September 1986 and, presumably, the respondents who reported replacing old appliances still had their old appliances in November 1985. November is a good month for analyzing nonweather-sensitive appliances because is has low weather-sensitive loads. (The November billing month represents energy consumed from mid-September through mid-November, depending on each customer's billing cycle.) Similarly, the May 1987 and 1988 billing months were selected for the analysis of the 1987 nonweather-sensitive participants because May also has low weather-sensitive loads and most of the 1987 program activity occurred after the May 1987 billing month. The 1988 nonweather-sensitive participants will be analyzed with the May 1988 and May 1989 billing month when the later data becomes available. Presumably, the same results will be observed as are seen with the analysis using data from November 1987 and 1988.

Table 1. Analyses Performed for Each Survey and Participant Group

Analysis	Before Month	After Month
Nonweather-sensitive Survey Respondents	November 1985	November 1986
Weather-sensitive Survey Respondents	August 1985	August 1986
1987 Nonweather-sensitive Smart Money Participants	May 1987	May 1988
1988 Nonweather-sensitive Smart Money Participants	November 1987	November 1988
1988 Air-conditioning Smart Money Participants	August 1987	August 1988

A comparison of the changes in energy use between the base month (which was before the program) and the same month one year later for the test group and control group is then made. A *t*-test is performed to determine whether the difference between the mean changes is significantly different than zero.

The Smart Money participants and survey respondents are screened through a number of filters before the billing record analysis is performed. These filters are:

Multiple Participation Filter. The first filter separates the Smart Money participants into groups by program component and eliminates customers who participated with more than one appliance.

Valid Billing Record Filter. The participants who pass the multiple participation filter are merged with their billing records from Wisconsin Electric's customer information and billing system.

Valid Bill Code Filter. The valid billing record filter checks only to see that the participant's account number appears in the billing record extract. The valid bill code filter checks to see if the billing records in both of the months in question are based on actual meter readings—if an estimated reading was made at the start or end of either of the months the participant is eliminated from the analysis.

Control Group Matching Filter. The participants who pass the valid bill code filter then are matched with a nonparticipant who is from the same political district and had similar energy consumption in the base year. The same political district is used to match the participants with nonparticipants in an attempt to minimize the demographic and psychographic differences between the test group and the control group.

Analyses were also performed in which the control groups was derived from the 1986 residential appliance saturation survey. Demographic characteristics of these customers are known. Unfortunately, the control groups derived from the survey respondents were often quite small and there appeared to be major differences between the participant groups and the survey-derived control groups, particularly with respect to energy consumption. While the survey respondents are representative of all customers, Smart Money participants tend to be larger customers. It was deemed more appropriate to match each participant (whose demographic characteristics are generally unknown anyway) with a similarly sized nonparticipant from the same political district.

The nonweather-sensitive participants are matched with nonparticipants who had similar usage, on a kWh per day basis, in the given month of the first year of the analysis. The air conditioning participants are matched with nonparticipants who had both similar usage in the base month and similar weather-sensitive usage in the summer month. This increases the probability that the control group for the air conditioning analyses will consist largely of customers who have air conditioning or, at least, some other weather-sensitive end use.

Up to 10 nonparticipants are identified for each participant and one of these is selected at random. In some cases matches are not made because there are more participants in a given political district in a given consumption range than respective nonparticipants. The participants who cannot be matched with nonparticipants are eliminated from the analysis.

Customer Groups Used in the Analysis

Billing record analyses were conducted for 13 groups of 1987 Smart Money participants, 19 groups of 1988 Smart Money participants, and seven groups of survey respondents. The groups of Smart Money participants are designed to isolate a specific component of the Smart Money program, and, in general, customers who participated in more than one component of the Smart Money program or who purchased or turned in more than one appliance were excluded from the analysis. The 1988 application form asked whether the customer was replacing an existing unit or purchasing an original or additional unit. This has a large effect on energy consumption, so the 1988 air conditioning refrigerator and freezer participant groups were disaggregated based on this response. For brevity, only the refrigerator and central air conditioning groups are described below.

REF1: Participants who received one refrigerator rebate each and had no other participation except air conditioning, which was allowed because air conditioners would not affect usage in May or November, the months that were analyzed. This group was disaggregated into two groups for the 1988 program.

REF1A: 1988 REF1 participants who reported replacing existing refrigerators.

REF1B: 1988 REF1 participants who reported purchasing original or additional refrigerators.

REF2: Participants who received one refrigerator rebate each and turned in one refrigerator and had no other nonweather-sensitive participation. This group was disaggregated into two groups for the 1988 program.

REF2A: 1988 REF2 participants who each reported replacing an existing refrigerator.

REF2B: 1988 REF2 participants who each reported purchasing an original or additional refrigerator.

REF3: Participants who turned in one refrigerator each and had no other nonweather-sensitive participation.

REF4: 1987 Participants who received one refrigerator loan each and had no other nonweather-sensitive participation. This group was not analyzed in 1988.

NEWREF: Survey respondents who purchased new refrigerators as replacement within a year before the survey and did not purchase any other nonweather-sensitive appliances.

OLDREF1: Survey respondents who have one refrigerator each and did not purchase any nonweather-sensitive appliances within a year before the survey.

OLDREF2: Survey respondents who have two refrigerators each and did not purchase any nonweather-sensitive appliances within a year before the survey.

CAC1A: 1988 Participants who replaced existing central air- conditioning units and had no other participation. This group was not analyzed in 1987.

CAC1B: 1988 Participants who purchased original or additional central air conditioning units and had no other Smart Money participation. This group was not analyzed in 1987.

NEWCAC1: Survey respondents who reported purchasing new central air-conditioning units as replacements in the previous year and did not purchase any other major appliances in the previous year.

NEWCAC2: Survey respondents who reported purchasing original or additional central air-conditioning units in the previous year and did not purchase any other major appliances in the previous year.

OLDCAC: Survey respondents who reported owning central air- conditioning units and did not purchase any major appliances in the previous year.

Results

The results of these analyses are interesting. The observed gross savings of the refrigerator rebate component is consistent with engineering estimates and no significant naturally occurring conservation due to technology improvements is observed. There are no observed savings for air-conditioning rebate components, however. Indeed, there is a suggestion that air- conditioning participants use more energy than they would use if there had not been a rebate program.

Detailed results for selected analyses are shown in Table 2. The table lists the sample size for each participant group. The next four columns list the average usage of the test group and control group before and after the program. The average usage for the refrigerator groups is total customer usage expressed in kWh per day. The average usage for the air-conditioning groups is summer weather-sensitive usage expressed in kWh per cooling degree day. The next two columns list the average usage change for the test group and control group and the next column lists the difference between the average usage changes. The *t*-statistic and the corresponding significance level are listed in the next two columns. The extrapolation factor is used to convert the unit energy effects to annual values. The refrigerator analyses listed on this table were conducted using November billing months. Analysis of data collected through Wisconsin Electric's Residential End-Use Metering Experiment indicates that daily refrigerator usage in the November billing month is 97% of the annual average daily usage. There are 579 cooling degree days in a normal summer in Wisconsin Electric's service territory. The final column in this table lists the extrapolated annual energy savings.

Results of Analysis of Survey Respondents

The sample sizes of the survey respondents who reported purchasing new appliances as replacements are, in general, quite small, and the differences between the year-to-year changes of the test groups and their respective control groups are not statistically significant. The NEWREF group has a sample size of 156, which should be large enough to identify a difference if it exists. There is no observed naturally occurring conservation due to technology improvements of refrigerators. This conclusion could be due to a trend to purchase larger refrigerators with more energy consuming features, which may be offsetting the trend to improve energy efficiency.

Results of Analyses of Program Participants

Large gross savings are observed for the REF1A, REF-2A, and REF3 groups in the 1988 program analyses. The sample sizes for these analyses range from 2,500 to almost 4,000 and the results are statistically significant at better than the 0.1% level; there is a $< 0.1\%$ chance that such large differences could occur due to random chance.

The observed gross savings for the freezer components are also statistically significant at better than the 5% level, even though the sample sizes for these analyses were considerably smaller than the refrigerator sample sizes.

There are no statistically significant differences between the year-to-year changes of the test group and control group for the electric water heating or heat pump water heater analyses.

The sample size of the CAC1A group, central air conditioning participants who reported replacing an existing unit, was over 1,000, and the result of this analysis shows an increase in annual energy consumption of 57 kWh, which is statistically significant at better than the 5% level. The RAC1A analysis also shows this trend toward increased energy consumption, but the results just miss being statistically significant at the 5% level.

One explanation for this is the possibility that participants of the air-conditioning rebate program tend to operate their new air conditioners more than they otherwise would because they were told the new units are energy efficient. Every time a customer goes to the thermostat to turn on his or her air conditioner it can be considered a discretionary purchase of energy services. A customer who believes his or her new unit is energy efficient may be more inclined to make this discretionary purchase than someone who was not told that the new unit is efficient.

Conclusions

Based on the results of this analysis, it seems that the refrigerator and freezer components of the residential Smart Money program are efficient in reducing the energy consumption of the participants. The air-conditioning components of the program, on the other hand, do not seem to be effective. Indeed there is an indication that the program may be encouraging increased energy consumption by air conditioning participants.

Table 2. Wisconsin Electric Power Company Results of Selected Residential Billing Record Analyses

Analysis and Test Group	REF1A	REF2A	REF3	CAC1A	RAC1A
Sample Size	2508	2750	3998	1016	1070
Average Usage of Groups (kWh/Day or kWh/CDD)					
Test Group After	21.56	20.29	23.48	1.834	1.099
Test Group Before	23.16	22.53	24.04	1.928	1.095
Control After	23.36	22.57	22.09	1.657	1.176
Control Group Before	23.21	22.38	23.90	1.849	1.236
Average Usage Change					
Test Group	-1.597	-2.245	-0.554	-0.0942	0.0042
Control Group	0.148	0.190	0.188	-0.1926	-0.0594
Difference between Average Changes	1.745	2.435	0.742	-0.0984	-0.0636
T-Statistic of Difference	9.51	16.12	5.53	-1.98	-1.85
Significance Level	0.1%	0.1%	0.1%	4.8%	6.5%
Extrapolation Factor	376.3	376.3	376.3	579.0	579.0
Extrapolated Annual Energy Savings (kWh)	657	916	279	-57	-37