A COMPARISON OF METHODOLOGIES AND THEIR IMPACT ON RESULTS FROM TWO WEATHERIZATION PROGRAMS: THE PACIFIC NORTHWEST AND WISCONSIN

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ABSTRACT

This paper describes the approaches taken in two residential program evaluations that were recently completed by ERC International for the Wisconsin Utilities Association and the Bonneville Power Administration. Both programs shared common features, yet each was also unique. For example, both programs involved estimating weather-normalized annual energy consumption for households sampled in ten different utilities. On the other hand, household socio-economic data was available for analysis in the Wisconsin evaluation but not in the Bonneville evaluation. These parallel evaluation efforts demonstrate how program research designs can be adapted both to the needs of program managers and the availability of relevant data.

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INTRODUCTION

Evaluations of residential weatherization programs generally consist of three parts: an energy savings analysis, behavioral modeling of household energy use, and a cost-effectiveness analysis. Because no two residential energy conservation programs are alike, critical features such as implementation guidelines, participant selection and data collection tend to vary widely among programs. As a result, although the goals of most residential program evaluations are similar, the methods employed in doing the evaluations must be carefully chosen and adapted to the needs and individuality of each program.

This paper describes the approaches taken in two residential program evaluations that were recently completed by ERC International (ERCI) for the Wisconsin Utilities Association (WUA) and the Bonneville Power Administration (Horowitz et al. 1987; Horowitz and Degens, 1987). Both residential weatherization programs shared common features. For example, both programs involved ten different utilities. In Bonneville's program the utilities were dispersed throughout the Pacific Northwest region; for WUA the utilities were situated throughout the state of Wisconsin. This permitted similarity in certain features of the research design. Yet, each program was also unique, necessitating that some research design features be specific to the programs.

BACKGROUND

During 1985 the Bonneville Power Administration operated the Long-Term Residential Weatherization Program (RWP) in which utilities offered energy audits and weatherization reimbursements to qualified homes in their service territories. At the same time, ten utilities were also involved in the Data Gathering Project (DGP). The purpose of the DGP was to gather energy audit information in a standard reporting format for evaluation and information purposes.

ERCI was contracted by Oak Ridge National Laboratory (ORNL) to conduct an outcomes evaluation of the Residential Weatherization Program. This evaluation differs from previous evaluations of Bonneville programs (e.g. Hirst et al., 1985) in its use of the DGP forms and because no household surveys were conducted. Also, utility-level data was collected for use in statistically modeling energy savings to control for effects other than weather, such as electricity prices and geographic location.

ERCI collected DGP forms and energy use data (bills) for over 700 program participants in the ten DGP utilities. Billing histories were also collected for over 1500 randomly selected eligible non-participants. Daily temperature readings for 12 weather stations were gathered from NOAA to weather-adjust energy consumption for households across years. Finally, information on utility area characteristics such as average income, energy prices and local unemployment rates was gathered from the individual utilities and published sources.

In the state of Wisconsin, the Utility Weatherization Assistance Program (UWAP) is an energy conservation program for qualified low-income households which has been ongoing since the early 1980s. It involves all the major privately-owned (Class A) gas and electric utilities in the state. The program arranges and pays for the installation of all weatherization and conservation measures projected to have a simple payback of five years or less.

The houses studied for this statewide evaluation are those which were weatherized under UWAP in the period from April 1984 to April 1985; a prior evaluation examined houses weatherized in 1983 (Banerjee and Goldberg, 1985). This evaluation was contracted for by the WUA, which directed and coordinated the data collection effort among the utilities.

Data requested from each utility included audit information, monthly utility bills and selected socio-economic information for each household. Daily temperature readings for weather stations throughout the state were received from NOAA. The participant sample was selected by WUA to be representative of the proportion of total participants in each utility. A non-participant or control household sample was drawn on a "one-for-two" basis -- for every two treated homes selected by a utility, one non-treated home was drawn from a waiting list of households applying for weatherization assistance.

ENERGY SAVINGS ANALYSIS

Preparation for the energy savings analyses for each evaluation began with careful screening of billing histories. The screening protocol was designed to detect problems such as:

- Multiple identification numbers in the same file.
- Missing billing periods or estimated bills.
- Occupancy changes or other service interruptions.
- Inconsistent billing dates or too few billing dates.
- Outliers or "zero" readings.

Since large attrition rates are common when working with household billing histories, cases were only dropped when problems with the data appeared too serious to overcome. In many instances, retention of houses was made possible by aggregating billing periods or by truncating the billing series.

For the actual energy savings analysis, individual household energy billing histories were used to construct weather-adjusted energy consumption values (Normalized Annual Consumption or "NAC") for program participants and non-participants in both the pre- and post-weatherization periods. NAC values were derived using the Princeton Scorekeeping Method (Fels, 1984). This approach estimates regression models for individual households and uses them to reconstruct annual household consumption based on long-run average annual temperatures for local areas. The main purpose of estimating these household level energy use statistics is to determine the change in annual energy use for each household, while controlling for year to year differences in the temperatures each household experiences. The household PRISM models themselves are also used to screen houses with anomalous energy consumption behavior from the data sets.

Sample-Weighted Program Savings

Summary statistics for each evaluation are derived by pooling the regionwide sample of electrically-heated houses for the Bonneville program and the statewide sample of natural gas heated households for the WUA sample, respectively. Implicitly, this pooling procedure weights the means by the number of cases in the sample provided by each utility. To the extent that these numbers accurately reflect statewide proportions of utility participation and eligibility, the summary mean will be a realistic measure of program impact.

As indicated in Table I, for the WUA sample average natural gas consumption in the pre-weatherization period was almost identical for each study group. However, treated houses reveal an average savings of 233 therm/years or a 13.8% decrease in energy use after weatherization, while average gas use for the control houses increased by 3.0%. On average, the net estimated program impact was energy savings of 274 therms/year.

A parallel analysis for Bonneville's electrically heated houses is reported in Table I. For these houses, the net savings in electricity use attributable to the program is estimated to be 2,200 kWh/year. This is comprised of no change in consumption for the control group and a 9% decrease in consumption for the treatment group.

Although the percentage change in electricity savings was relatively small compared to the natural gas heated homes, it must be remembered that households use gas primarily for heating, whereas electricity is used for most appliances and air conditioning in addition to heating. With heating being a smaller fraction of the total use of electricity, the change in use is not as easily attributable to weatherization. Differential behavior related to other seasonal electricity uses could also play a important role in changes in annual use.

Table I. Sample-weighted energy use.

	Bonneville RWP (kWh/yr)	Wisconsin UWAP (therms/yr)
N		
Treatment	393	483
Control	1192	265
NAC1 (pre-program)		
Treatment	23900	1392
Control	22100	1370
NAC2 (post-program)		
Treatment	21700	1159
Control	22100	1141
DNAC (change from pre- to post-program)		
Treatment	-2200	-233
Control	0	41

Program-Weighted Savings

To generalize the energy savings analysis to the region or state as a whole, it is necessary to adjust the findings so that each utility's averages are represented in proportion to their importance to the overall program both for the participants and the non-participants. For the treatment groups the adjustment is relatively straightforward. Weights for each utility are computed by dividing the total number of residences weatherized in a given utility by the total number of residences weatherized in all the utilities studied. This procedure is necessary as a check even when the entire population of weatherized homes makes up the study sample. This is because differential attrition rates for the utilities in the data screening and cleaning stages can cause the sample proportions to change.

The weighting issue is more complex for the control group because sample proportions must represent the proportion of eligible but non-participating houses in each utility. To create the appropriate weights requires additional information about the distribution of eligible households among the utilities. For these evaluations, this information was gathered via published reports and information from utility staff and program managers.

To estimate program weighted energy savings, DNAC for the treatment and control groups for each utility was multiplied by the respective weight. The results for UWAP indicate that net savings was approximately 243 therms/year. This agrees very closely with the sample-weighted results. The exercise confirms that the sample-weighted results for WUA are generalizable to the statewide program as a whole. Comparison of the existing sample proportions with the true program proportions reveals that the samples from each utility roughly matches each utility's actual importance to the program.

However, this is not the case for utility samples in Bonneville's program. The composite savings, presented in Table II, indicate that program-weighted net savings is approximately 2782 kWh/year. Reliance on the sample-weighted mean value of 2200 kWh/year would thus have led to a general underestimate of energy savings on the order of 20%.

Table II. Bonneville RWP utility-weighted savings.

	kWh/yr
NAC1 (pre)	
Treatment	23896
Control	20141
NAC2 (post)	
Treatment	21902
Control	20930
DNAC (change pre-post)	
Treatment	-1993
Control	789
NET SAVINGS	-2782

BEHAVIORAL MODELS OF HOUSEHOLD ENERGY USE

To gain an understanding of the determinants of household energy consumption behavior, multiple linear regression models were developed for each evaluation. These models are similar in the sense that they provide estimates of the impact of energy prices, geographic and/or household characteristics, and program participation on the level of post-retrofit energy use. The dependent variables of these models are close substitutes; one model employs DNAC or estimated energy savings as the dependent variable, while the other uses NAC2 or total estimated energy use in the post-retrofit year.

Table III. Regression results for two programs.

WISCONSIN UWAP: Dependent Variable = NAC2

Adjusted R^2 = .68
Standard Error = 217.01

VARIABLE	COEFFICIENT	T-STATISTIC
PRICE2	-0.01	-0.002
NORTH	-81.47	-2.524*
WEST	-93.44	-1.425
NAC1	0.71	35.726*
TREAT	-284.40	-13.895*
CONSTANT	422.30	2.652*

*Statistically significant for $p < .05$

BONNEVILLE RWP: Dependent Variable = DNAC

Adjusted R^2 = .93
Standard Error = 433.6

VARIABLE	COEFFICIENT	T-STATISTIC
INC1	-0.337	-2.29*
DRATE	87580	3.85*
EAST	-831.5	-2.81*
DTREAT	-2739	-14.00*
CONSTANT	3144	2.74*

*Statistically significant for $p < .05$

For the WUA evaluation the dependent variable was NAC2 and the independent variables in the model represented the utilities in northern Wisconsin (NORTH) and in western Wisconsin (WEST), and whether a house was in the treatment or control group (TREAT). Also included was NAC1 and average prices per therm charged by each utility in the post-program period (PRICE2).

As shown in Table III, the adjusted R^2 for this model was .68. NAC_1 was the best predictor of annual household usage in the post-program period.[1] It indicated that a marginal change (i.e. an increase of 1 therm) in household gas usage in the pre-program period results, on average, in .71 therms higher household gas usage in the post-program period. Gas prices took on the expected negative sign -- higher prices were associated with declining consumption for that portion of energy use in the post-weatherization period not explained by pre- period consumption.

Locational variables indicated that spatial demographics play an important role in household energy consumption. Houses in northern utility service areas used approximately 81 therms/year less than other houses. The point estimate for western utility service areas, although not statistically significant, indicates that households in western Wisconsin consumed an average of 93 therms/year less than the remaining households in the state. These are the least urbanized areas of the state. Finally, treatment houses were estimated to use an average of 248 therms/year less than control houses. This agrees with the finding of the prior energy savings analysis.

Rather than developing a disaggregated household-level model for Bonneville's electrically heated houses, a utility-level model was estimated in which the dependent variable was average DNAC per utility. A utility-level model was required for several reasons. First, no data was collected on individual households. Second, sample representation was inadequate -- for three of ten utilities less than 30 houses were present in the treatment samples. Third, the energy savings analysis pointed to the importance of weighting the overall findings by each utility's proportional importance in the regional program.

For these reasons a "weighted least squares" model was estimated using the aggregated data where the dependent variable was DNAC, the change in energy use from the pre to post-program period. In this model each utility-level observation was given the weight developed earlier for the energy savings analysis. This procedure ensured that the estimator accurately mirrored regional representation of each utility in the program. The major finding of the model was that, when controlling for geographic location, county income levels and electricity prices, the treatment homes saved approximately 2,739 kWh/year.[2] This conforms to the findings of the energy savings analysis. The adjusted R^2 for the model was .93, and the standard error of the estimate was approximately 16% of the weighted mean.

COST-EFFECTIVENESS ANALYSIS

Overall program cost-effectiveness can be calculated once household energy savings estimates are available. A number of financial methods are widely used, e.g. payback and levelized cost, depending mostly on the approach preferred by the utility or its regulatory agency. For Bonneville, where least-cost planning is practiced, the levelized cost method is required.

Calculating the cost-effectiveness of specific weatherization measures is a more formidable task than calculating overall cost-effectiveness, since energy savings estimates for individual or groups of measures are harder to come by. For the Bonneville evaluation statistical estimates of measure savings were unattainable, hence audit-predicted energy savings were used for the cost-effectiveness analysis of individual measures (see the Horowitz et al., 1987, for details of cost-effectiveness analysis based on audit-predicted savings, and for the levelized-cost analysis of the program).

For the WUA evaluation a method was developed to estimate measure savings econometrically. A regression model was specified which elaborated on the behavioral model of household energy consumption described earlier. The focus was "savings" or the "negative consumption" resulting from particular weatherization measures or groups of related measures. In implementing this model the variable representing "treatment group" in the NAC2 or energy consumption model was replaced by one or more variables representing categories of weatherization measures.

For this model the values of the measures variables can take on 0 or 1 for each house, depending on whether or not the measure was installed. For households in the control group it was assumed that none of the program weatherization measures were installed; this assumption is reasonable given that the control group was drawn from a waiting list of households applying for weatherization assistance. Using this approach, empirical estimates were derived for the average amount of energy savings experienced due to specific residential energy conservation measures or groups of measures. In a second version of this model, the dichotomous variables are replaced by cost estimates of the installed measures. Unlike the previous model which provides energy savings estimates which must then be input into a financial model, this version provides direct estimates of the relative cost effectiveness of the measures.

The estimated models of NAC2 are shown in Table IV, where the measure group variable takes on a value of 0 if no measures in the group were taken by the household, and 1 if one or more measures in that category were taken. These models indicate that insulation measures saved an average of 122 therms/year; furnace replacement saved 188 therms/year; furnace operations and maintenance measures saved 48 therms/year; and miscellaneous measures saved 20 therms/year. The coefficients for the first three of these measure group variables were all statistically significant at a probability of less than .05. The remaining measure groups -- infiltration, water heater and rehabilitation -- had coefficients with positive signs and were not statistically significantly different from 0.

Table IV. Wisconsin UWAP analysis.

Independent Variable - NAC2

VARIABLE	DICHOTOMOUS APPROACH COEFFICIENT	DICHOTOMOUS APPROACH T-STATISTIC	COST APPROACH COEFFICIENT	COST APPROACH T-STATISTIC
PRICE2	-1.91	-0.682	-2.60	-0.933
NORTH	-36.53	-1.085	-56.22	-1.669
WEST	-63.05	-0.915	9.80	0.14
NAC1	0.73	36.182*	0.75	36.487*
WATER	1.14	0.044	-0.11	-0.934
MISCEL	-19.64	-0.814	0.11	0.533
INSULB	-122.17	-4.191*	-0.11	-6.039*
REHAB	0.11	0.004	-0.02	-0.989
FURN	-188.37	-7.559*	-0.11	-8.009*
FURN2B	-47.61	-2.181*	-0.28	-2.573*
INFIL	32.01	1.289	0.00	-0.028
CONSTANT	437.36	2.617*	433.57	2.619*
N	703		703	
R^2	0.76		0.66	
STANDARD ERROR	223.37		225.02	

*Statistically significant for $p < .05$

To calculate cost-effectiveness for individual measure groups, "simple payback" was computed by dividing average costs per measure by average dollar savings. The findings presented in Table V indicate that the statewide average paybacks for gas-heated houses range from a low of 3.5 years for furnace operations and maintenance measures to a high of 12.3 years for furnace replacements. Note that for the measure groups with positive coefficients, payback could not be computed; it should be recalled that these coefficients were not statistically significant.

A second model of NAC2 used household measure group costs as the value of the measure group variable. As shown in Table IV, this model is similar in many respects to its predecessor. The model indicates that a marginal increase of $100 in costs led to savings of approximately 11 therms/year for insulation measures, 11 therms/year for furnace replacement and 28 therms/year for furnace operations and maintenance measures.

To determine relative cost-effectiveness for individual measures, the measure groups can simply be ranked by their highest marginal rates of return per dollar invested. Using this criterion, furnace operations and maintenance measures provided the highest expected marginal returns of 28 therms/year for an additional investment of $100. This group was followed by insulation measures, furnace replacements and water-related measures, all returning around 11 therms/year per $100 investment. These results are taken directly from the coefficients of the model shown in Table V.

Table V. UWAP payback by measure.

MEASURE GROUP	AVERAGE SIMPLE PAYBACK (years)*
WATER	-
MISCEL	6.2
INSULB	7.8
REHAB	-
FURN	12.3
FURN2B	3.5
INFIL	-

CONCLUSION

This paper highlights the similarities and differences between two residential energy conservation program evaluations designed to measure program impacts. The comparison points up the value and efficiency in developing a standardized yet flexible research design that can be adapted to similar programs. However, the comparison also underlines the need for developing innovative research methods that can make the most out of the unique needs and datasets for each program.

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