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ELECTRICITY SAVINGS ONE AND TWO YEARS AFTER WEATHERIZATION: A STUDY OF 1986 PARTICIPANTS IN BONNEVILLE'S RESIDENTIAL WEATHERIZATION PROGRAM

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Martin Schweitzer
Marilyn A. Brown
Dennis L. White

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ABSTRACT

This study is the latest in a series of evaluations of the Bonneville Power Administration's Residential Weatherization Program (RWP). Data were collected from households weatherized in 1986 under Bonneville's Long Term RWP and from a control group of non-participants. The households selected come from eight different utilities throughout Bonneville's service area.

In 1986, 83% of audit-recommended measures were installed by program participants, approximately the same percentage as in previous years. Also as in previous years, the installation rate was higher for recommended measures with greater estimated energy savings. While Bonneville's retrofit costs have remained fairly constant over time, total retrofit costs have increased from $1,700 in 1982 to $2,400 in 1986 (in 1986-$), with the additional costs absorbed by participating households and utilities. Similarly *Bonneville's* cost per estimated kWh of first-year electricity savings has stayed at about 27 cents/kWh while the average *total* cost has risen from 28 cents/kWh in 1982 to 44 cents/kWh in 1986 (in 1986-$).

For the RWP overall, savings experienced by 1986 participants were substantial. During the first year after weatherization, weighted net savings averaged 2,800 kWh, or 12% of the previous year's energy consumption. In the second post-weatherization year, a weighted average of 2,500 kWh was saved, amounting to 11% of pre-weatherization energy use. Levelized costs were 46 mills per kilowatt hour saved, which is at the low end of the range of cost estimates for a new coal plant.

Since the 1981 Pilot Program, energy savings have declined and costs have risen. Nevertheless, the energy savings and associated costs of the 1986 Long Term RWP indicate that cost-effective savings can still be achieved by this type of conservation program.

EXECUTIVE SUMMARY

To ensure proper assessment of its weatherization activities, the Bonneville Power Administration (Bonneville) has examined several cohorts of participants in various phases of its Residential Weatherization Program (RWP). Beginning in 1980, energy savings one, two, and three years after program participation have been evaluated. This study examines the 1986 RWP, the latest addition to Bonneville's collection of weatherization evaluation activities.

The sample of participants for this study was selected by Bonneville from its Data Gathering Project (DGP) database, which includes 12 utilities from the region's three climate zones and four states. Four of these DGP utilities were excluded from the present analysis because of their participation in Bonneville's Wood Heat Displacement Program or because, in one case, a utility operated a program that deviated from the RWP. Data were collected from 345 participants and 995 non-participants with at least one complete year of post-retrofit billings. Two complete years of post-retrofit data were available for 315 of these participants and 855 of the non-participants.

Electricity bills were weather-adjusted using the Princeton Scorekeeping Method (PRISM). Normalized Annual Consumption (NAC) was calculated for each participant and control household for which data were available. Gross energy savings were calculated by subtracting a household's NAC for each post-retrofit year (1986-87 and 1987-88) from its pre-retrofit NAC (1985-86). Household level data were aggregated and examined at the utility level, allowing the calculation of average net savings, the difference between gross savings by non-participants and participants. Utility-level data were then weighted, based on the extent of each utility's participation in the RWP, to allow the identification of overall program savings.

Findings are summarized below:

- In 1986, 83% of audit-recommended measures were installed by program participants, approximately the same percentage as in previous years. The installation rate was higher for recommended measures with greater estimated energy-savings -- a pattern that was found in evaluations of previous program participants. Consistent with this conclusion, ceiling, floor, wall, and duct insulation was installed in almost all of the homes that needed it, and each of these insulation measures offered significant estimated savings. In contrast, caulking and weatherstripping were the two measures with the greatest disparity between rates of recommendation and installation, and they both offered only modest energy savings.

- For the RWP overall, savings experienced by 1986 participants were substantial. During the first year after weatherization, weighted net savings averaged 2,811 kWh, or 11.8% of the previous year's energy consumption. In the second post-weatherization year, a weighted average of 2,515 kWh was saved, amounting to 10.6% of pre-weatherization energy use. The nature of the energy-saving measures installed under the RWP suggests that most of these savings were from reductions in energy used for space heating. PRISM estimates of the space heating component of total energy use support this contention. Levelized costs were 46 mills per kilowatt hour saved, which is at the low end of the range of cost estimates for a new coal plant.

- The actual amount of energy saved by participating households varied widely and was not closely related to audit-estimated savings. Relatively little of the variation in household performance was explained by pre-weatherization energy use, total weatherization costs, climate, and the installation of various energy conservation measures. This indicates that *other* factors, such as family composition and income, structural characteristics, changes in thermostat settings, and changes in the use of supplemental heat sources over time, may be important in determining the outcomes of residential energy conservation programs.

- At the utility level, average gross savings for the 1986 cohort were positive for participants and negative for non-participants in the majority of cases. While substantial differences were observed among utilities in the amount of energy saved, these could not be explained by differences in average per capita income, recent changes in electricity rates, and climatic conditions (represented by long-run heating degree days). In addition to differences *between* utilities, substantial differences were also identified *within* utilities in terms of the amount of energy saved from one year to the next.

- Audit-estimated savings for both recommended and installed measures declined between 1982 and 1985, but increased in 1986. While Bonneville retrofit costs have remained fairly constant over time, total retrofit costs have increased from $1,747 in 1982 to $2,388 in 1986 (in 1986-$), with the extra costs absorbed by participating households and utilities. The *Bonneville* cost per estimated kWh of first-year electricity savings averaged about 27 cents/kWh between 1982 and 1986, but the average *total* cost per estimated first-year of kWh saved rose from 28 cents/kWh in 1982 to 44 cents/kWh in 1986 (in 1986-$).

- The amount of energy saved program-wide and associated levelized costs were similar for both 1985 and 1986 participants in the Long Term RWP. However, compared to the first year of savings and levelized costs for 1981, 1982, and 1983 participants, the 1985 and 1986 cohorts have not performed as well.

- The 1986 sample experienced a decline in program-wide savings between the first and second years following weatherization. This represents a departure from the experience of the 1985 cohort, but is consistent with the levels of conservation decay documented for earlier participants in the Pilot and Interim Programs. Despite the drop in the amount of energy saved from one stage to the next, the energy savings and associated costs identified in this study for the 1986 cohort of the Long Term RWP indicate that cost-effective savings can still be achieved by this type of conservation program.

It is clear from these findings that the Long Term RWP is generating significant savings at comparatively low costs, thereby continuing to provide a valuable service to the region.

1. INTRODUCTION

Over the past decade, most gas and electric utilities in the United States have offered free on-site home energy audits to their residential customers as part of the federal Residential Conservation Service (U.S. Congress, 1978). The audits are often supplemented by financial incentives to encourage households to install recommended retrofit measures. The underlying assumption of these audit and weatherization programs is that installation of retrofit measures will lead to substantial reductions in residential energy use, and that the value of these savings will justify the utility and household costs of implementation.

Tests of this assumption have typically been short-term in nature, examining homes that have participated over a one- or two-year period, and limiting their analysis of energy savings to a single year of post-program consumption. The results therefore do not reflect the influence of various "life cycle" phenomena, including changes in the nature of households that participate in programs over time, and changes in the performance of weatherization measures as they age. When conservation resources are being purchased to offset supply resources over an extended planning period, it is important to analyze the durability of program performance.

To ensure proper assessment of its weatherization program activities, the Bonneville Power Administration (Bonneville) has examined several cohorts of program participants, beginning in 1980, and has looked at energy savings one-, two-, and three-years after participation. This study represents the latest addition to Bonneville's collection of weatherization evaluation studies (Goeltz, Hirst, and Trumble, 1986; Haeri, 1988; Hirst, et al., 1983a; Hirst, White, and Goeltz, 1985; Hirst, et al., 1985; Horowitz, Bronfman, and Lerman, 1987).

1.1 PURPOSE AND OUTLINE OF REPORT

The purpose of this study is to provide an impact evaluation of Bonneville's 1986 Residential Weatherization Program (RWP). The evaluation examines the measures installed by the program, the actual electricity saved by participants, and the cost-effectiveness of the installed measures. The results of prior evaluations of Bonneville's residential weatherization efforts provide a context within which these results are analyzed.

The rest of Chapter 1 provides a history and brief description of Bonneville's Residential Weatherization Program. Chapter 2 describes the research methods used in this study, including the sampling design, data collection and screening techniques, and data analysis methods. Chapter 3 begins the presentation of results, describing the services recommended and delivered by RWP to its 1986 participants and analyzing program costs. Chapter 4 focuses on energy savings, beginning with household-level savings, moving to utility-level savings, and ending with a discussion of overall program costs and savings. The report concludes with a summary and interpretation of findings, and suggestions for further research (Chapter 5).

1.2 BACKGROUND

Bonneville's residential weatherization efforts were initiated in response to a 1980 federal law that greatly expanded Bonneville's responsibilities for energy planning in the Pacific Northwest (U.S. Congress, 1980). The original intent of the program was to retrofit 300,000 homes and generate an annual energy savings of 1.5 million MWh during its 10-year lifetime at a cost of $480 million (Bonneville, 1982a and b).

Bonneville launched its Pilot Program in 1980 (Bonneville, 1980). The Pilot was operated through 11 small public utilities located in Idaho, western Montana, Oregon, and Washington, and was a precursor to the subsequent, larger regionwide programs. During its two and a half years of operation, the Pilot Program provided free home energy audits to 7200 electrically heated households and zero-interest weatherization loans to 4100 of these homes (Hirst et al., 1983a; Bonneville, 1984a).

An Interim Program was offered to the region's private and public utilities in November 1981 and ran until September 1983. By the time the Interim Program was completed, 96 of 135 eligible utilities had signed up (Eissler, 1984), and the Program had retrofitted 104,000 homes at a total cost to Bonneville of $157 million.

The Interim Program encouraged the installation of retrofit measures by offering cash rebates that averaged $1330 (or 85% of the total costs) for installation of recommended retrofit measures. Two sets of retrofit measures were included in the Program. All eligible houses could have the following set of measures installed: ceiling insulation and appropriate ventilation, unfinished exterior wall insulation, cold and hot water pipe insulation, dehumidifiers, clock thermostats and heating duct insulation. Only houses meeting the Program's indoor air quality criteria qualified for installation of "house tightening" measures: storm windows, storm doors, caulking, weatherstripping, and outlet and switchplate gaskets. Although housing types (other than mobile homes) built before 1981 with electric space heat were eligible, the vast majority of the Program's participants lived in single-family homes and were homeowners.

The Interim Program demonstrated that residential weatherization was a significant, steady, and reliable energy resource that could be purchased by Bonneville. As a result, Bonneville designed a long-term weatherization program that was to operate through 1990.

Bonneville offered the Long Term Residential Weatherization Program (Long Term RWP) to its contracting utilities in July 1983. Budget targets were designed to achieve an annual participation rate of 3-5% of homes within participating utilities' service territories.

Incentives to non-low-income consumers were set at $0.292 per kWh of estimated first-year energy savings.

Since 1983 the program has experienced a variety of budgetary and programmatic changes. Program expenditures were $142 million in FY 1983, but have since been reduced to $40 million in FY 1984, $41 million in FY 1985, and $36 million in FY 1986 for non-low-income households. At the beginning of FY 1985, the non-low-income consumer incentive was increased nearly 3 cents to $0.32 per kWh of estimated first-year energy savings, and "house tightening" measures were made available to all program participants, not just those meeting indoor air quality standards.

2. RESEARCH METHODS

2.1 SAMPLING

The sample of participants for this study was selected by Bonneville from its Data Gathering Project (DGP) database. The DGP was developed and implemented in 1985 to facilitate evaluation of Long Term RWP impacts. The DGP is composed of 12 utilities distributed across the region's three climate zones and four states, and is intended to be representative of the entire RWP. Participating utilities are required to complete and submit to Bonneville worksheet forms that contain data on the types and numbers of recommended and installed measures, the actual costs of the installed measures to the consumer, utility, and Bonneville, and the corresponding audit-estimated savings per installed measure. If less than 20 residential customers have retrofit work done in any one month, the utility is required to submit worksheets on each customer. In the event that more than 20 customers participate in any one month, a random sample of 20 of those participants is drawn and worksheets are submitted for those selected. Each utility applies the same random sampling plan (developed by Bonneville) in order to identify a control or non-participating group.

The present analysis does not include four utilities in the DGP. Benton County PUD operated a residential weatherization program in 1986 that was substantially different from the Bonneville RWP and is therefore excluded from the study. Three other utilities (Douglas Electric Co-op, Oregon; Lincoln Electric Co-op, Montana; and Kootenai Electric Co-op, Washington) are also excluded because they participated in Bonneville's Wood Heat Displacement Program (WHDP) during 1987 and 1988. Under the WHDP, Bonneville sold incremental energy to participating utilities at reduced wholesale rates in order to encourage households to use less wood and more electricity for space heating. Significant numbers of residential customers (9% at Douglas, 10% at Lincoln, and 12% at Kootenai) participated in the WHDP and benefitted from the lower electricity rates. It is not known which of the participants and nonparticipants in the RWP also participated in the WHDP. These three utilities were removed from the present analysis because the two program effects could not be isolated.*

2.2 DATA COLLECTION AND SCREENING

The DGP worksheets for program participants were collected directly from Bonneville. Utility billing records were obtained from ERC International (ERCI) which requested the appropriate records from each utility for the period July, 1985 through June, 1988, for participants and non-participants. Average daily temperature data for the same period as the billing records were obtained from the National Oceanic and Atmospheric Administration (NOAA) for weather stations that correspond to the utilities.

Since the present study was designed to focus on single-family, non-low-income residential electricity customers, households not meeting these criteria were removed from the study sample. Furthermore, customers that had been retrofit by other programs or at other times in the RWP were excluded from the study sample. Finally, households were excluded that were retrofit under the 1986 RWP either early (before April 1) or late (after September 30) in 1986. We felt that previously installed measures and retrofit activity outside of a selected time frame would distort the energy savings that could be attributed to the 1986 RWP. Previous research has indicated that no bias is introduced when removing winter retrofits from the analysis (Brandis and Bronfman, 1987). Costs and implementation rates do not significantly

*Idaho Falls was also included in the WHDP. However, only 1% of Idaho Falls customers participated. It is felt that this low participation rate in the WHDP does not confound program effects in the RWP.

vary between summer and winter of the same program year. After removing these households, the resulting sample size for each utility is shown in Column 4 of Table 2.1.

The utility billing records were further screened to identify households that had moved during the study period. For participants, approximately 13% of the households listed in column 4, Table 2.1, either relocated after weatherization or their billing records contained anomalous data that could not be resolved. For instance, a scan of the billing records revealed houses with monthly kWh values as high as 95,000 and as low as -90,000; these records were removed from analysis. The households that survived this cut are shown in Column 5.

Weather-normalization using the Princeton Scorekeeping Method (PRISM, described below) was then applied to the billing records of both participant and control households in order to obtain an estimate of electric energy use under normal weather conditions. Subsequently, another 25% of participant and non-participant households were removed from the analysis of first post-retrofit year savings, due to insufficient or incomplete billing records and negative space heating or baseload estimates from PRISM (indicating a preponderance of multiple-fuels use), or poor-fitting PRISM models (i.e., R-squares of less than 0.25).

Specifically, the screening criteria developed for this analysis consisted of several steps. First, we required that at least two years of billing history (the pre-retrofit year of 1985/86 and the first post-retrofit year of 1986/87) were available for each house to be analyzed. Second, we removed from analysis any house that used less than 3,000 kWh in any one year for whole-house electricity needs including lighting, water heating, and space heating. This second criterion is expected to identify supplemental or multiple fuel users (wood users, among others) and energy users whose energy use patterns are not representative of Bonneville's residential customers. Third, houses whose PRISM estimates of electric space heating were zero or less were not retained in the analysis. These houses probably supplement their electric space

Table 2.1. Data attrition and sample sizes

PARTICIPANTS

UTILITY	Worksheets[a]	Exclusions[b]		Study[c]	Bills[d]	NACs/Worksheets[e]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tacoma	249	67	99	83	72	59	50
Snohomish	243	96	86	61	57	38	36
Elmhurst	123	28	36	59	57	45	45
Richland	240	60	105	75	51	42	42
Eugene	240	58	99	83	62	49	46
Vera	170	55	54	61	69	44	39
Missoula	46	8	22	16	14	10	0
Idaho Falls	191	21	95	75	63	58	57
Sub-Totals	1502	393	596	513	445	345	315

NON-PARTICIPANTS

UTILITY	Bills[d]	NACs[e]	
	(8)	(9)	(10)
Tacoma	283	235	224
Snohomish	166	101	82
Elmhurst	68	45	42
Richland	151	116	107
Eugene	266	189	158
Vera	151	105	63
Missoula	80	71	52
Idaho Falls	174	133	127
Sub-Totals	1339	995	855

[a]Total number of DGP worksheets maintained by Bonneville and provided by the respective utilities under the random sample plan.

[b]Houses in column 2 include low-income households, multifamily structures, houses that had participated in the 1985 RWP, and houses that had two separate installations of retrofit measures as part of the 1986 RWP. Houses in column 3 were retrofit either before 4/1/86 or after 9/30/86.

[c]The study sample: (1) - [(2) + (3)].

[d]Bills collected by ERCI from the utilities for the houses in columns 4 and 8.

[e]Houses in column 6 have worksheets and NACs for the pre-retrofit year (85/86) and the first post-retrofit year (86/87). Houses in column 7 have worksheets and NACs for 85/86, 86/87, and 87/88. Non-participants do not have worksheets.

heating needs with other fuels or the energy use patterns in these houses are more erratic than the present analysis and available data can control. Fourth, we required that each year of billing history span at least 240 consecutive days, two-thirds of a complete year of history. This criterion is expected to identify houses with problems in their electricity accounts, vacations or other periods when the house is not occupied, and changes in occupancy that may have otherwise been overlooked. Finally, we removed houses whose model R-squares from PRISM were less than 0.25, thus excluding from the analysis houses whose energy use patterns are not typical of all-electric residential energy users.

The remaining households are shown in Columns 6 and 9. The total number of participant households for which savings one year after weatherization could be calculated is 345; for non-participants, the number is 995. The number of houses listed in Columns 7 and 10 of Table 2.1 are those for which sufficient data were available to identify savings two years after weatherization. There were 315 participants and 855 non-participants with the necessary data.

2.3 DATA ANALYSIS

Electricity bills were weather-adjusted using the Princeton Scorekeeping Method (see Fels, 1986, for a detailed discussion of PRISM). The basic assumption of PRISM is that residential energy consumption and outdoor temperature are linearly related. PRISM uses average daily consumption and average daily outdoor temperature to fit the following linear model for each housing unit:

$$F_i = a + bH_i(t) + e_i \quad . \qquad (1)$$

where,

F_i = the average daily consumption (kWh) in time interval i,
a = the fixed amount of daily consumption (baseload),
b = the proportional constant amount of daily consumption (space heating),
H_i = the heating-degree days per day computed to reference temperature t in time interval i,
e_i = the random error term.

Normalized Annual Consumption (NAC) is then calculated as follows:

$$NAC = 365a + bH_0(t), \qquad (2)$$

where,

365a = the fixed amount of base load electricity consumed by a household in one year,
$H_0(t)$ = the heating degree-days (base t) in a typical year, so that
$bH_0(t)$ = the proportional amount of heating fuel relative to the outdoor temperature, adjusted for long-term outdoor temperatures.

NACs were calculated for each participant and control household for each of the three household-years that data were available: July 1985 through June 1986, the pre-retrofit year; July 1986 through June 1987, the first post-retrofit year; and July 1987 through June 1988, the second post-retrofit year. Gross energy savings (DNAC or change in NAC) were estimated for each household by subtracting NAC of the first or second post-retrofit year from NAC of the pre-retrofit year, where

$$DNAC = NAC_1 - NAC_{2 \text{ or } 3} \,. \qquad (3)$$

Thus, a positive value for DNAC indicates a reduction in energy use (i.e., an energy savings).

Net energy savings—the portion of the savings that can be attributed to the program—were estimated at the utility and program levels. Average DNACs were calculated for each utility for participant and control groups. The control group average DNACs were then subtracted from the average DNACs for participants. The difference is the average net energy savings per household for the specific utility.

Nearly all of the 27 retrofit measures that could be installed under the 1986 RWP were developed to save weather-sensitive or space heating electricity use, although hot-water pipe wrap and domestic hot water heater (DHWH) insulation were also eligible retrofit measures. Space heating electricity use and savings (gross and net) were therefore estimated using PRISM parameters. The estimate for heating, however, is not as robust as NAC itself (Fels, Rachlin, and Socolow, 1986). It has also been shown that hidden, nonheating factors such as the weather-sensitive portion of water heating and lighting cause PRISM to overestimate space heating (Fels et al., 1986).

A validation of PRISM, sponsored by Bonneville, was conducted at Oak Ridge National Laboratory using submetered data on single family electricity use collected as part of the Hood River Conservation Project. In that study, Hwang (1989) estimates that the heating component of NAC as estimated by PRISM could be overestimated by as much as 19%. Hirst and Goeltz (1986) found that PRISM overestimated space heating by 29% in houses that used multiple fuels for heating and by 6% in houses that used a single fuel. Given the data available for this study, it was not possible to explore further the accuracy of PRISM's estimation of the space heating component, but large, unexplained shifts in reference temperature from year to year for certain utilities would cast some doubt on the validity of program-wide estimates of space heating savings as indicated by the beta coefficient in PRISM.

2.4 UTILITY WEIGHTS

For a variety of reasons, rates of participation in conservation programs typically vary across utilities. Among the 8 utilities studied here, participation rates in the 1986 RWP ranged from 2.6% for the Missoula Electric Co-op to 7.1% for the Eugene Water and Electric Board (Table 2.2).

Furthermore, utilities vary widely in the number of customers they serve. In our sample of 8 utilities, nearly half of the 230,000 households that were eligible to participate in the 1986

RWP were served by one utility, the Snohomish Public Utility District. At the other extreme, Missoula served less than 1% of the eligible households.

Weights were developed for each utility's participant and control groups to reflect the relative contribution of each to energy savings by all 1986 participants and non-participants, respectively, from the eight utilities in this sample. For participants, the weighting factor was calculated for each utility based upon the number of houses retrofit by the utility during calendar year 1986 relative to the total number of houses weatherized by all 8 utilities retained for the present study (See Table 2.2). For the control group, the weighting factor is the utility's share of eligible non-participants relative to the total number of all non-participants in the 8 utilities.

Table 2.2. Utility weights and participation rates for 1986

Utility	Participants: Houses Weatherized[a]	Participants: Utility Weight	Non-participants: Eligible Households	Non-participants: Utility Weight	Participation Rate (%)
Snohomish Public Utility District	3,517	.3710	101,861	.4618	3.3
Eugene Water & Electric Board	3,127	.3299	40,899	.1854	7.1
Tacoma Public Utilities	1,425	.1503	51,304	.2326	2.7
Richland, City of	643	.0678	10,426	.0473	5.8
Idaho Falls, City of	343	.0362	6,584	.0298	5.0
Vera Irrigation District	234	.0247	3,452	.0156	6.4
Elmhurst Mutual Power & Light	144	.0152	4,330	.0196	3.2
Missoula Electric Co-op	46	.0049	1,722	.0078	2.6
Totals	9,479	1.0000	220,578	1.0000	4.1

[a]Total calendar year 1986 weatherizations in RWP. Based upon data obtained from the Bonneville Office of Conservation 1986 Yearbook.

3. AUDIT AND MEASURE IMPLEMENTATION ANALYSIS

This chapter analyzes the retrofit measures that were recommended and installed by Bonneville's 1986 Residential Weatherization Program. It also looks at weatherization costs in aggregate, by measure, and by utility.

Where possible, the 1986 RWP findings are presented alongside those reported in prior evaluations of Bonneville's weatherization efforts. When comparisons are being made with the findings from previous evaluation research, dollars are inflated to 1986 values using 1981 through 1986 Consumer Price Indexes for the Seattle-Everett, Washington area. Measures are also aggregated into the broad categories used in earlier evaluations to facilitate comparison.

3.1 MEASURES RECOMMENDED AND INSTALLED

The retrofit measures that were recommended and installed in homes of participating RWP households are examined here primarily as a means of understanding levels of program savings. As a result, we focus on the same sample of households that is studied in Chapter 4--those 345 RWP participants with sufficient pre- and post-retrofit billing data to enable analysis of energy savings.

A total of 1,945 measures were recommended for installation in these 345 homes, representing 27 different types of measures. More than three-quarters (83%) or 1,611 of these recommended measures were installed. In 1982 and 1983, 70% of the recommended measures were installed by the Bonneville program (Hirst, et al., 1985) and in 1985 the measure installation rate was 78% (Horowitz, et al., 1987). Thus, there appears to be a slight increase over time in the percentage of recommended measures that were actually installed.

There was considerable variation in installation rates across retrofit measures (Table 3.1). At the low end, four types of measures were never installed: cold-water pipe insulation, interior

Table 3.1. Measures installed[1]

	Percent Recommended	Percent Installed	Cost per Installation (in 1986-$)	Audit Estimated Savings (kWh/year)	Cost per kWh of Estimated Savings (in 1986-$)
Ceiling insulation (attic)	85.0	76.8	636	1,727	.37
Weatherstripping	71.1	44.4	58	44	1.32
Caulking	68.6	38.0	74	127	0.58
Floor insulation (over crawl space)	67.7	60.5	788	2,243	0.35
Multi-glazed windows	56.2	47.5	1,326	1,514	0.88
Storm windows	37.1	31.9	885	1,466	0.60
Duct insulation	29.9	27.3	272	1,408	0.19
Sliding glass doors	28.9	27.6	415	578	0.72
Clock thermostat	26.3	13.6	150	263	0.57
Wall insulation (exterior cavity)	26.2	22.6	478	2,207	0.22
Wall insulation (unfinished)	14.0	13.4	250	1,639	0.15
Crawlspace (exterior)	12.6	0.8	530	998	0.53
Windows (sash mounted)	11.5	7.4	204	185	1.10
Basement wall insulation (interior)	7.2	3.8	429	1,858	0.23
Floor insulation (basement)	4.8	4.8	263	853	0.31
Windows (vent conversion)	4.6	4.0	1,151	1,555	0.74
Water heater wrap	2.8	2.6	36	n/a	n/a
Floor insulation (exposed)	2.7	0.7	748	63	11.87
Doors (French and sliding)	1.5	0.7	571	304	1.88
Crawlspace (interior)	1.0	0.1	563	1,073	0.52
Water heater pipe insulation	0.6	0.6	117	n/a	n/a
Wall insulation (exterior surface)	0.1	0.1	88	1,133	0.07

[1]No interior or exterior surface roof insulation, cold-water pipe wrap, air-to-air heat exchangers, or dehumidifiers were installed.

and exterior surface roof insulation, and dehumidifiers. Another six types of measures were installed in no more than 1% of the homes: interior and exterior crawlspace insulation, exposed floor insulation, exterior surface wall insulation, water heater pipe insulation, and sliding glass doors and French doors.

At the other extreme, ceiling insulation was recommended to 85% of the RWP participants and was installed in 77% of the homes, representing the measure that was installed most often. The next four most recommended and installed measures were weatherstripping, caulking, floor insulation (over the crawlspace), and multi-glazed windows.

Some measures are installed in almost all of the homes which need them, based on audit results. Ceiling, floor, wall, and duct insulation are examples. Other measures are installed in a much smaller proportion of the recommended homes. Weatherstripping and caulking are the two measures with the greatest disparity between rates of recommendation and installation. In both cases, the measure is installed in only about 60% of the recommended homes. While these two infiltration measures are inexpensive, their estimated energy savings are also modest, resulting in a high ratio of costs to savings. This may account for their low penetration levels. These measures are also easily installed by the homeowner, and thus may have been installed by program participants without assistance from the RWP. In any event, the same pattern of relatively low installation rates for these two measures was identified in the 1982, 1983, and 1985 RWP evaluations (Hirst, et al., 1985; Horowitz, et al., 1987).

Installation rates and predicted savings for recommended and installed measures are shown in Table 3.2, by utility. Mean values are also presented for the program as a whole, both unweighted and weighted; the latter best represents the region-wide program. The average number of recommendations per house for the program as a whole was 5.6 and the average number of measures installed was 4.7.

Table 3.2. Audit estimated savings

Utility (No. of RWP households)	Number of Measures Installed	Audit Estimated Savings from Installed Measures in kWh/yr (A)	Audit Estimated Savings from Recommended Measures in kWh/yr (B)	Percent of Potential Audit Estimated Savings[1]
Tacoma (N=59)	4.6	4,589	4,999	91.8
Idaho Falls (N=58)	6.8	7,607	7,907	96.2
Eugene (N=49)	5.5	5,438	6,096	89.2
Elmhurst (N=45)	5.4	5,531	5,884	94.0
Vera (N=44)	2.8	4,439	4,910	90.4
Richland (N=42)	3.0	3,498	3,940	91.1
Snohomish (N=38)	4.1	6,112	7,268	84.1
Missoula (N=10)	2.8	2,954	3,139	94.1
Program (unweighted)	4.7	5,308	5,807	91.4
Summary (weighted)	4.7	5,435	6,127	88.7

[1]Defined as (A/B)*100
Source: 345 participant homes weatherized in 1986.

Overall, the average audit-estimated energy savings per house for all recommended measures was 6,127 kWh/year, and estimated savings for installed measures was 5,435 kWh/year. One way of summarizing this information is to compute the percent of potential audit estimated savings that are actually captured by dividing the audit estimated savings from installed measures by the audit estimated savings from recommended measures, and multiplying by 100. The result

(89%) indicates that households are more likely to install measures that are estimated to be more energy-conserving, since overall only 83% of the recommended measures were installed.

Table 3.3 presents the average weatherization costs for the program as a whole based on the sample of 345 participants, and for each of the eight utilities. For the entire sample, the average, regionally weighted job cost (excluding administrative costs) was $2,388 (in 1986-$). The 1986 costs increased to $2,788 when the $400 average administrative costs were included. This exceeds the cost of the average job in each of the three previous evaluation years: 1982, 1983, and 1985. Of the total job cost in 1986, 63% was reimbursed by Bonneville and the customer contribution averaged $743 or 31%. In previous years the customer contribution was less: it was 26% of the total cost of the job in 1985, 20% in 1983, and only 6% in 1982.

Total retrofit costs vary greatly across the eight utilities, as does the distribution of costs across the three contributors: Bonneville, the utility, and the customer. For Vera and Missoula, for instance, the total retrofit costs were $997 and $1,160, respectively for the average consumer. For Snohomish and Elmhurst, on the other hand, the total costs typically exceeded $2,500. Only 3 of the 8 utilities contributed to the expense of installing measures (Tacoma, Snohomish, and Eugene), and their reimbursements were less than 10% in each case.

It is interesting to note that there is little correspondence between the average customer contribution in a utility and that utility's rate of participation in the 1986 RWP. For example, among the 4 utilities with the highest participation level, the levels of customer contribution as a percent of the total job cost range from 18% to 40%. Thus, high levels of customer cost-sharing do not appear to deter participation.

Table 3.3. Weatherization costs

	Total Retrofit Cost (in 1986-$)[a]	Distribution of Costs (in percents) Customer	Utility	Bonneville
Tacoma	2,384	41.8	8.7	49.5
Idaho Falls	2,484	19.2	0	80.6
Eugene	2,398	27.7	6.4	65.9
Elmhurst	2,599	33.8	0	66.2
Vera	997	18.3	0	81.7
Richland	1,913	40.3	0	59.7
Snohomish	2,560	28.5	7.0	64.5
Missoula	1,160	27.5	0	72.5
Program (unweighted)	2,181	29.9	3.2	66.9
Summary (weighted)	2,388	30.9	6.1	63.0

[a]Excludes administrative costs which average $400.
Source: 345 participant homes weatherized in 1986.

3.2 COSTS AND ESTIMATED SAVINGS FOR MEASURES OVER TIME

To track the progress of Bonneville's RWP over time, audit data for the 1982, 1983, and 1985 participants were compared to 1986 participant data. Table 3.4 displays mean values for savings and costs for each of the four samples, using 1986 dollars. Several trends are noteworthy. First, the audit-estimated savings for both recommended and installed measures declined between 1982 and 1985, but increased slightly in 1986 to above the 1983 and 1985

Table 3.4. Comparative costs and estimated savings for RWP[1]

Mean Values	1982	1983	1985	1986
Number of Houses in Sample	612	660	760	345
Estimated Savings (kWh/yr)				
Recommended	7,630	5,790	5,400	6,127
Installed	6,180	5,170	4,980	5,435
	(81%)	(89%)	(92%)	(89%)
Actual Costs (1986-$)[2]				
Bonneville	$1,638	$1,562[4]	$1,283	$1,365[5]
Customer	$109	$385	$475	$743
Total	$1,747	$1,947	$1,757	$2,388
Actual Cost/Estimated Savings for Installed Measures (1986-$)[3]				
Bonneville	$0.27	$0.30	$0.26	$0.25
Total	$0.28	$0.38	$0.35	$0.44

[1]Source for 1982-83 data is Hirst, et al. (1985) Table 5 and footnote (a), Table 11. Source for 1985 data is Horowitz, et al. (1987).

[2]Inflated to 1986 dollars using CPI-U (all items) for the Seattle-Everett, Washington area. Index stood at 297.8 for 1982, 304.0 for 1983, 321.9 for 1985, and 325.2 for 1986. Inflating 1982 costs to 1986 level uses the calculation: $(Cost_{82} / CPI_{82}) \times CPI_{86}$. Administrative costs are not included.

[3]Represents the ratio of the two mean values.

[4]This includes an average payment of $289 by one utility, in addition to the financial incentive provided by Bonneville.

[5]The average utility contribution of $280 (in 1986-$) is not included here.

levels. Although this pattern may be an artifact of evolving audit techniques and eligible measures, it does suggest that a considerable savings potential still exists within eligible homes.

Second, while the Bonneville costs have remained fairly constant over time, the total retrofit costs have increased significantly from $1,747 in 1982 to $2,388 in 1986 (in 1986-$). The increased costs have been absorbed by participating households and utilities, and not by Bonneville.

Finally, the Bonneville cost per estimated kWh of electricity savings in the first year after retrofit averaged about 27 cents/kWh between 1982 and 1986, but the average total cost per kWh of estimated first year savings increased significantly from 28 cents/kWh in 1982 to 44 cents/kWh in 1986. (Each of these figures is based on 1986-$.)

Disaggregation of audit savings and cost data into eight major measure groups offers more specific insights into program trends. As shown in Table 3.5, outside wall and heating duct insulation have consistently been estimated to be extremely cost-effective measures on a cents per kWh basis. Conversely, storm doors, storm windows, caulking, and weatherstripping, collectively known as "infiltration" measures, have generally proven to be least cost-effective. Audit-estimated savings attributable to floor insulation, storm windows, caulking and weatherstripping, and setback thermostats have significantly declined over time. Storm doors, on the other hand, have improved over time in terms of the savings they are predicted to deliver. Some of this decrease may be attributable to revisions in the audit heat-loss methodology, particularly to new assumptions about thermostat setback effects (Pratt, 1984).

Costs for most categories of retrofit measures have increased slightly over time, although they have increased markedly for storm doors and decreased for setback thermostats. The result of these trends in estimated savings and actual costs is that the cost effectiveness of most types of retrofit measures has declined somewhat over time.

Table 3.5. Comparative costs and audit-estimated savings for RWP measures (weighted)

Measures	Audit-Estimated Savings (kWh/yr)				Retrofit Cost[1] (1986-$)				Cost/Savings (cents/kWh)			
	1982	1983	1985	1986	1982	1983	1985	1986	1982	1983	1985	1986
Insulation												
Outside Wall[2]	2,630	3,000	3,430	2,384	415	482	545	485	16	16	16	20
Roof/Ceiling[3]	2,120	1,860	1,640	1,727	579	599	576	636	27	32	35	37
Floor[4]	3,040	2,640	2,240	2,189	863	867	687	785	28	33	31	36
Heating Ducts	1,590	1,090	1,460	1,408	262	257	283	271	16	24	19	19
Storm												
Windows[5]	3,170	2,280	1,660	1,760	1,245	1,487	1,071	1,359	39	65	65	77
Doors[6]	190	140	520	571	218	246	364	419	115	176	70	73
Caulking/ Weatherstripping	210	220	180	130	98	54	81	105	47	25	45	81
Setback Thermostat	1,300	1,150	300	263	186	182	121	150	14	16	40	57

[1]Inflated to 1986 dollars using CPI-U (all items) for the Seattle-Everett, Washington area.
[2]Includes crawlspace perimeter (interior and exterior), basement wall, unfinished wall, exterior wall and exterior wall cavities insulation.
[3]Includes ceiling and roof (interior and exterior) insulation.
[4]Includes crawlspace, basement and exposed floor insulation.
[5]Includes storm windows, sash-mounted storms and multiple glazing.
[6]Includes sliding glass doors and French doors.
Source for 1982-83 data is Hirst, et al. (1985), Table 12. Source for 1985 data is Horowitz, et al. (1987)

Table 3.6 shows household recommendation and installation rates for each of the eight measure groups and four participant cohorts. There are few clear and consistent trends over time among the four types of insulation. Storm windows, storm doors, caulking and weatherstripping, on the other hand, have been recommended and installed with increasing frequency over time, reflecting the removal of an indoor air quality criterion that was used to qualify participants for these measures in the 1982 and 1983 Interim Program. Setback thermostats, in contrast, have been recommended and installed with decreasing frequency over time. This is consistent with their increase in cost per estimated kWh of savings (Table 3.5).

In summary, there appear to be a number of important shifts in estimated savings, costs, recommended measures, and installation rates from 1982 through 1986. In part, these are caused by technical refinements in the audit procedures and changes in the program. However, they also reflect changes in the type, mix, and prior conditions of the residential buildings entering the RWP.

Table 3.6. Implementation rates for RWP measures[1] (weighted)

Measures	Not Recommended				Recommended But Not Installed				Installed			
	1982	1983	1985	1986	1982	1983	1985	1986	1982	1983	1985	1986
Insulation												
Outside Wall	71%	84%	46%	54%	13%	7%	9%	12%	16%	9%	46%	34%
Roof/Ceiling	5	10	33	14	5	10	6	9	90	80	61	77
Floor	24	22	57	28	3	5	5	8	73	73	39	64
Heating Ducts	80	82	85	70	3	3	1	3	17	15	15	27
Storm												
Windows	45	34	29	21	18	20	7	11	37	46	63	68
Doors	62	72	84	70	23	21	2	2	15	7	15	28
Caulking/ Weatherstripping	47	60	30	14	33	23	19	34	20	17	51	52
Setback Thermostat	62	82	78	74	9	4	6	12	29	14	16	14

[1]Source for 1982-83 data is Hirst, et al. (1985), Table 13. Source for 1985 data is Horowitz, et al. (1987). Rows may not add to 100% due to rounding.

4. ENERGY SAVINGS

Based on billing histories provided by the eight utilities described in Chapter 2, annual energy use and savings were calculated for all sample households. There were 345 participant households for which at least two complete years of data were available, allowing the calculation of energy use for one year prior to weatherization and at least one year afterwards. Two years or more of complete data also were available for 995 non-participants. Changes of occupancy and anomalous data caused the sample to shrink to 315 participants and 855 non-participants with three complete years of data. For this slightly reduced sample, energy use could be calculated for the second year following weatherization.

Once household energy use and savings were calculated for the sample of participants and non-participants described above, these data were then aggregated and examined at the utility level. Finally, utility savings were weighted, using the weights shown in Table 2.2, to allow the identification of *overall* program savings. Each of these different levels of analysis will be discussed in the following sections, beginning with energy use and savings by individual households.

4.1 HOUSEHOLD SAVINGS

We begin by comparing the average weather-adjusted annual energy consumption of RWP participants and non-participants, for the year prior to their weatherization. We found that those households that participated in the program in 1986 used significantly more energy prior to weatherization than did the non-participants. Table 4.1 shows that the sample of 1986 participants used nearly 2,400 kWh more than the sample of non-participants, and that the two groups are different at the 0.000 significance level. This finding is consistent with the results

Table 4.1. Comparison of pre-retrofit normalized annual consumption for program participants and non-participants[1,2]

	Participants' Mean Pre-Retrofit NAC	Non-Participants' Mean Pre-Retrofit NAC	Participants' Pre-Retrofit NAC Minus Non-Participants' Pre-Retrofit NAC	Significance of Difference Between Participants' and Non-Participants' Pre-Retrofit NAC
Normalized Annual Consumption (NAC)	25,546 kWh (9,436)	23,157 kWh (10,141)	2,389 kWh ---	$p = .000$ ---
Reference Temp. (°F)	59	62	---	---
Model R^2	0.89	0.87	---	---
Number of Households in Sample	345	995	---	---

[1]Participants and non-participants shown here are all those households for which at least two complete years of billing data were obtained.

[2]Pre-retrofit NAC is Normalized (weather-adjusted) Annual Consumption for July 1985-June 1986. Numbers in parentheses are standard deviations.

of previous studies of residential conservation programs in the Pacific Northwest and elsewhere (Hirst et al., 1983b; Goldberg, 1986; Brown and White, 1988). Participants generally consume more energy prior to weatherization than households that choose not to participate in weatherization programs.

Gross energy savings achieved by participating households one year after weatherization are shown in Figure 4.1. The distribution of savings for the second year following weatherization is not shown because it is similar to the distribution of first year savings. Gross savings are calculated by subtracting post-retrofit normalized annual consumption (NAC) from pre-retrofit NAC. If the amount of energy consumed after a home is weatherized is less than was used before, gross savings are positive; if energy use goes up following weatherization, gross

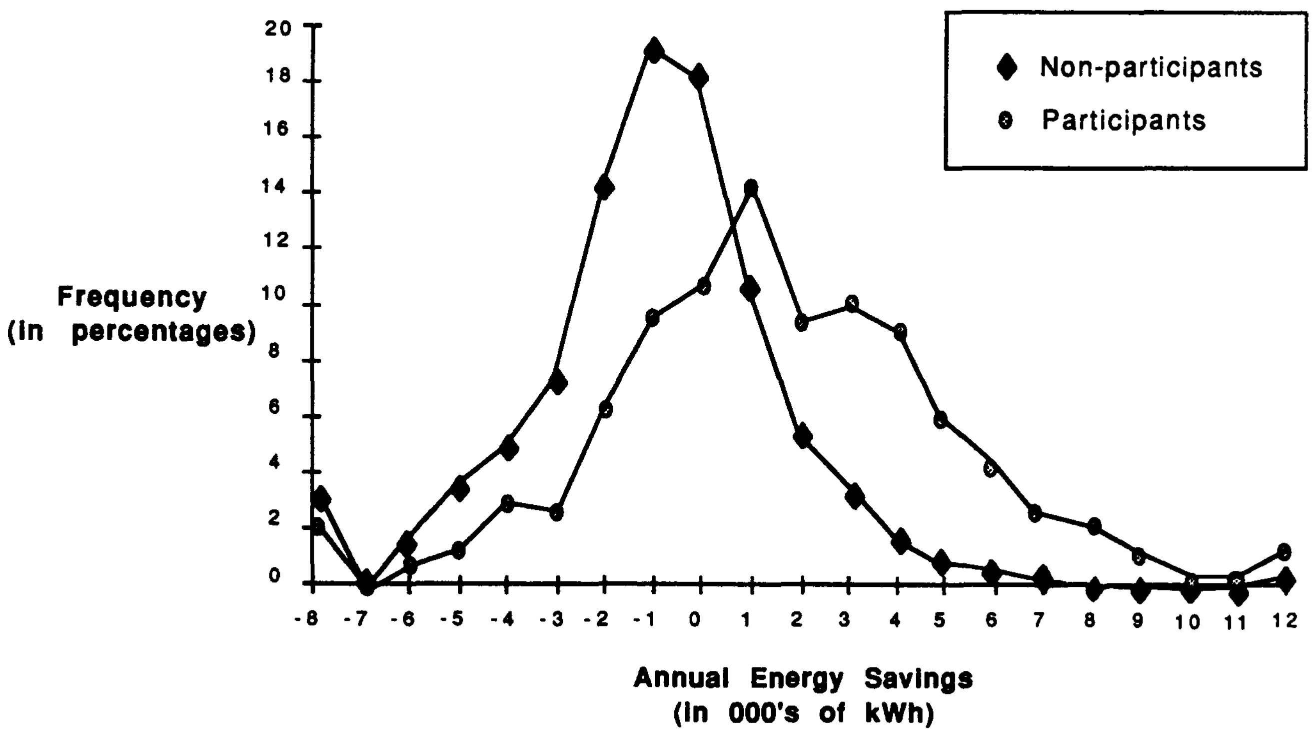

Fig. 4.1. Gross energy savings[1] for program participants, one year after weatherization.

[1]Gross energy savings one year after weatherization = 1985-86 NAC minus 1986-87 NAC.

savings are negative. Participants' gross savings for the first year following weatherization have a mean of 1,936 kWh and a standard deviation of 5,185 kWh. These numbers and the accompanying figure indicate that there was a broad range of savings and that many program participants used more energy following weatherization than they did previously. This finding is common to many other studies of conservation programs, including earlier assessments of the RWP (Hirst, et al., 1983a).

As shown in Figure 4.1, non-participants also experienced a broad range of energy savings, even in the absence of participation in the RWP. In this case, however, the mean amount saved was a *negative* 613 kWh, meaning that the average control household used 613 kWh more during 1986-87 than in 1985-86. Still, the standard deviation was 3,538 kWh, indicating that many households experienced substantial savings, even without being weatherized through this program.

While there is a widespread distribution of energy savings for both participants and non participants, there is also a distinct difference in their means: participants have clearly saved more energy than non-participants. A t-test of the difference between these means confirms this conclusion, at a significance level of 0.01.

Household energy savings are difficult to predict using audit estimates, as shown by Figures 4.2 and 4.3. Each point on these scatter plots represents an estimate of savings made during a pre-retrofit energy audit and the actual energy savings achieved one or two years after the same home was weatherized. In general, audit-estimated savings were much higher than the savings actually realized. Again, this is frequently found in other conservation programs as well (Hirst, Goeltz, and Trumble, 1989). In this study, average audit-estimated savings were approximately 5,300 kWh for both the group with at least two complete years of data and for the three-year group. Mean gross savings, however, were only 1,936 kWh for the first year

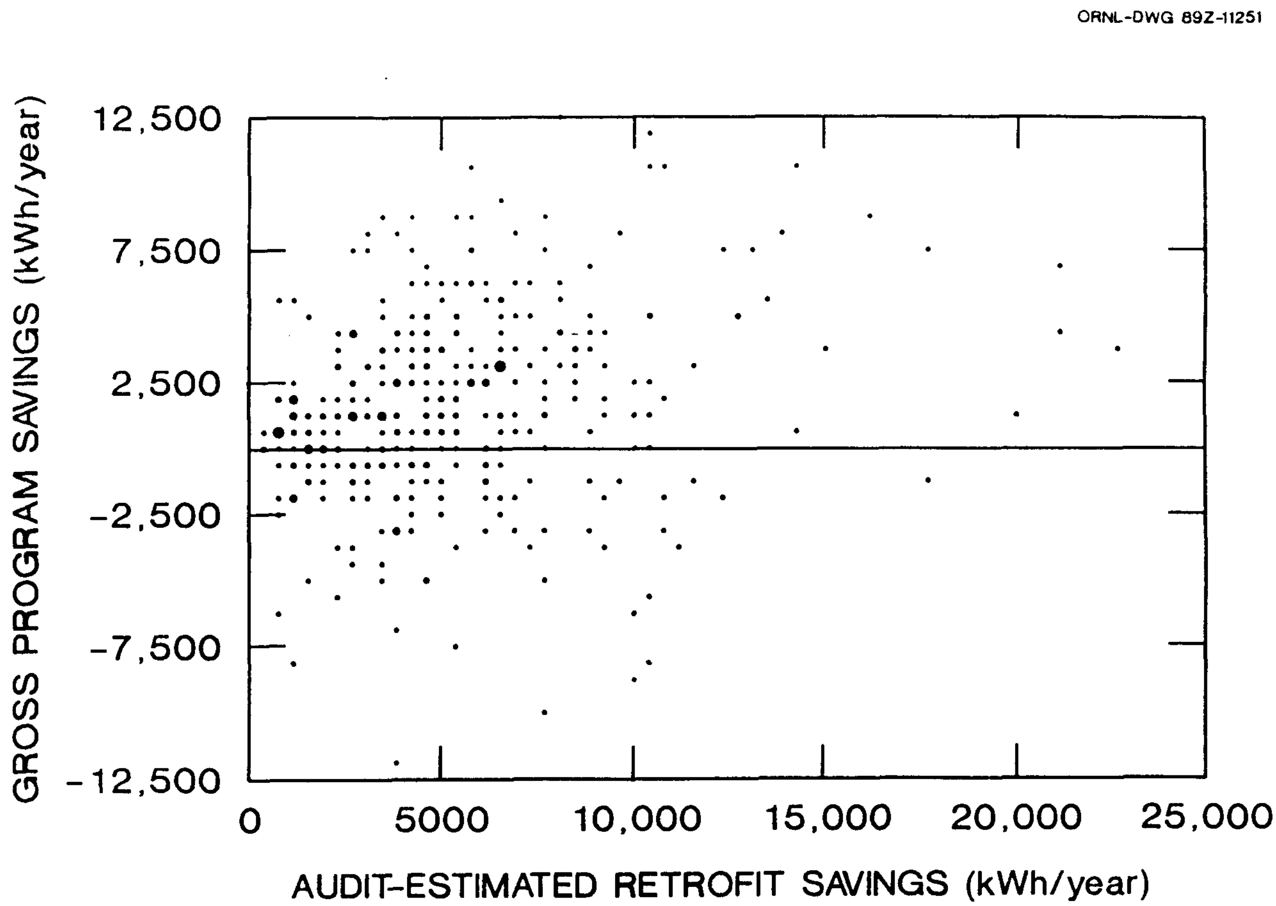

Fig. 4.2. Comparison of audit-estimated savings[1] with actual savings,[2] one year after weatherization.

[1]Audit-estimated savings (labelled "Retrofit Savings") are gross savings.

[2]Actual savings (labelled "Program Savings") are gross savings one year after weatherization (1985-86 NAC minus 1986-87 NAC).

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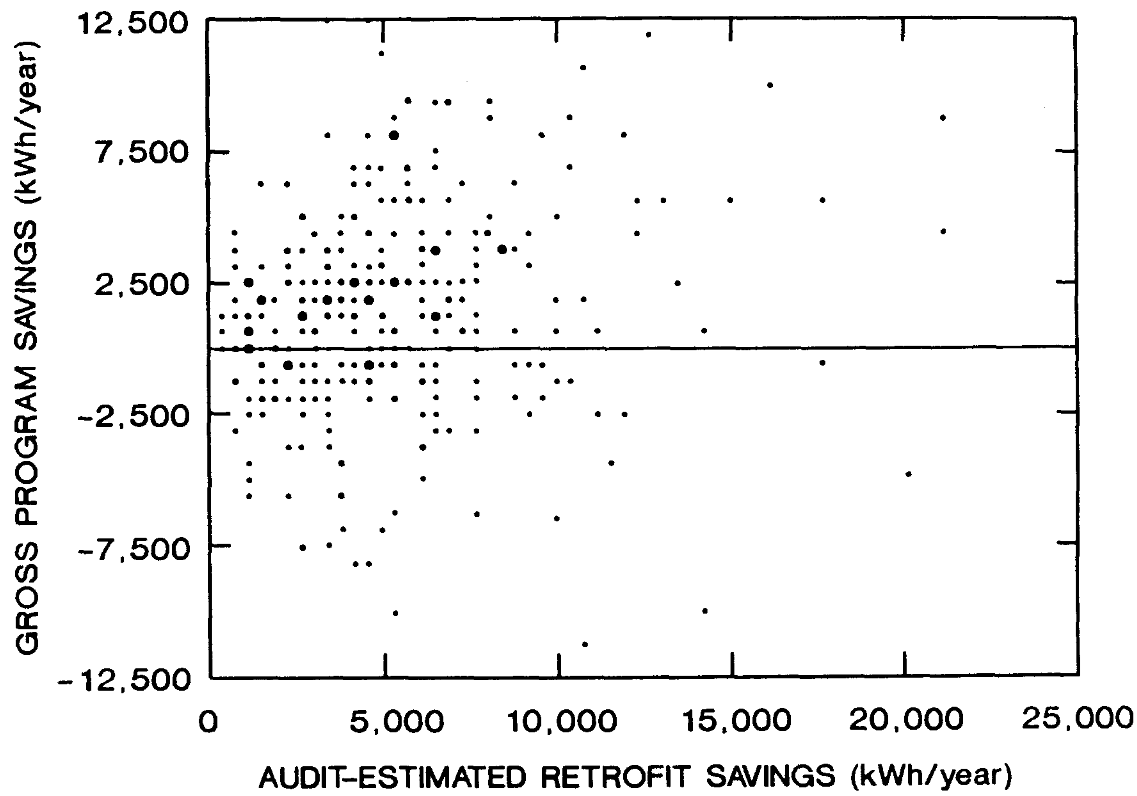

Fig. 4.3. Comparison of audit-estimated savings[1] with actual savings,[2] two years after weatherization.

[1]Audit-estimated savings (labelled "Retrofit Savings") are gross savings.

[2]Actual savings (labelled "Program Savings") are gross savings in 2nd year following weatherization (1985-86 NAC minus 1987-88 NAC). Gross energy savings NAC.

after weatherization and 1,567 for the following year. Thus, only 37% of the estimated savings was realized during the first post-retrofit year. The correlation between audit-estimated and actual savings was very low, with a correlation coefficient of 0.143 for the first post-retrofit year ($p = .008$) and 0.160 for the following year ($p = .005$).

The broad range of savings experienced by participants and non-participants and the low correlation between audit-estimated and actual savings underscore the fact that other factors influence household energy performance in addition to the package of weatherization measures installed. In an effort to identify some of these determinants of energy savings and to see which specific measures were most strongly associated with energy savings, a multiple regression analysis was performed using independent variables for which data were available at the household level. Due to considerations of cost and intrusiveness, some potentially important characteristics of household members and their energy consumption practices (such as family size, ages of family members, income, wood use, and actual thermostat settings) were not examined. Those variables selected include pre-retrofit NAC, total weatherization costs, long-run average heating degree days (HDD), and location of household (East or West of Cascade Mountains), as well as a number of specific weatherization measures. Unfortunately, the entire set of variables used in the regression analysis explained less than 10% of the total variance in gross energy savings. For this reason, the results of that analysis will not be discussed in more detail.

4.2 UTILITY-LEVEL SAVINGS

Following the household-level analysis discussed above, energy use and savings were aggregated by utility. Table 4.2 shows pre-retrofit NAC, NAC for the first year following

Table 4.2. Average weather-adjusted energy consumption and gross energy savings one year after weatherization,[1] by utility

Utility (No. of Households)	Pre-Retrofit NAC	First Year Post-Retrofit NAC	First Year Post-Retrofit Gross Energy Savings[2]
Tacoma Partic. (59)	25,219	22,277	2,942
Tacoma Non-Partic. (235)	24,605	25,700	-1,095
Idaho Falls Partic. (58)	29,187	26,446	2,741
Idaho Falls Non-Partic. (133)	27,754	28,045	-290
Eugene Partic. (49)	20,896	18,094	2,802
Eugene Non-Partic. (189)	17,341	18,211	-870
Elmhurst Partic. (45)	27,225	26,390	835
Elmhurst Non-Partic. (45)	24,600	25,929	-1,329
Vera Partic. (44)	25,541	24,472	1,069
Vera Non-Partic. (105)	26,278	26,185	93
Richland Partic. (42)	26,541	25,136	1,405
Richland Non-Partic. (116)	26,075	26,774	-700
Snohomish Partic. (38)	24,981	23,606	1,375
Snohomish Non-Partic. (101)	20,899	20,686	214
Missoula Partic. (10)	19,575	19,337	237
Missoula Non-Partic. (71)	18,156	18,716	-561

[1]Energy use and savings are in kilowatt hours (kWh).

[2]First Year Post-Retrofit Gross Energy Savings = Pre-Retrofit NAC minus First Year Post-Retrofit NAC.

weatherization for each of the eight utilities in our sample. The utilities are listed in order of the number of participant households from each that provided at least two complete years of billing data. This table shows that, for all utilities except one, participants used more energy prior to weatherization than did non-participants. The table also shows substantial differences among utilities in average pre-retrofit consumption for participants and non-participants alike.

Turning to savings, all participating utilities experienced positive gross savings in the first year and all non-participants but two experienced negative savings (i.e., greater energy use). Despite these basic similarities, there was substantial variation among utilities in the magnitude of savings achieved.

Table 4.3 provides pre-retrofit NAC plus NAC and gross savings for the *second* year following weatherization, by utility. Savings were calculated by subtracting second year post-retrofit NAC from pre-retrofit NAC. During this second post-retrofit year, average savings by participants were positive for all utilities, while savings by non-participants were negative for four utilities and positive, but small, for the other four. Once more, there was considerable variation in pre-retrofit NAC and in savings among utilities.

Net energy savings are calculated by subtracting gross savings experienced by non-participants from gross savings achieved by participants. Taking the difference between gross savings by these two groups is intended to control for any exogenous influences (such as higher energy prices) that might influence energy behavior by all customers, in order to isolate the effect of the Residential Weatherization Program on participants' energy use. Net savings by utility for the first post-retrofit year, along with the size of these savings in relation to pre-retrofit NAC, are given in Table 4.4. All eight utilities experienced net savings during this

Table 4.3. Average weather-adjusted energy consumption and gross energy savings two years after weatherization,[1] by utility

Utility (No. of Households)	Pre-Retrofit NAC[2]	Second Year Post-Retrofit NAC	Second Year Post-Retrofit Gross Energy Savings[3]
Tacoma Partic. (50)	25,369	23,052	2,317
Tacoma Non-Partic. (224)	24,868	27,436	-2,568
Idaho Falls Partic. (57)	29,280	26,574	2,706
Idaho Falls Non-Partic. (127)	28,029	27,485	544
Eugene Partic. (46)	21,210	19,919	1,291
Eugene Non-Partic. (158)	18,024	19,101	-1,077
Elmhurst Partic. (45)	27,225	26,493	732
Elmhurst Non-Partic. (42)	24,779	25,963	-1,184
Vera Partic. (39)	25,674	24,364	1,310
Vera Non-Partic. (63)	27,269	30,501	-3,232
Richland Partic. (42)	26,541	25,695	846
Richland Non-Partic. (107)	25,294	25,163	131
Snohomish Partic. (36)	24,206	22,969	1,237
Snohomish Non-Partic. (82)	20,937	20,079	858
Missoula Partic.[4] (0)	-	-	-
Missoula Non-Partic. (52)	18,821	18,552	269

[1]Energy use and savings are in kilowatt hours (kWh).

[2]Pre-retrofit NAC shown in this table differs from that in Table 4.4 because it is not taken from an identical sample, due to attrition from the first post-retrofit year to the second.

[3]Second Year Post-Retrofit Gross Energy Savings = Pre-Retrofit NAC minus Second Year Post-Retrofit NAC.

[4]All Missoula participants were dropped from the study during this time period due to problems of data quality and availability.

Table 4.4. Average net energy savings one year after weatherization, by utility

Utility (No. of Participating Households)	Pre-Retrofit NAC	1st Year Post-Retrofit Net Energy Savings	Savings as % of Pre-Retrofit NAC	Test of Research Hypo.[2] That Net Savings >0
Tacoma (59)	25,219	4,037	16.0%	$p < .000$
Idaho Falls (58)	29,187	3,031	10.4	$p < .000$
Eugene (49)	20,896	3,672	17.6	$p < .000$
Elmhurst (45)	27,225	2,164	7.9	$p = .037$
Vera (44)	25,541	976	3.8	$p = .182$
Richland (42)	26,541	2,105	7.9	$p = .003$
Snohomish (38)	24,981	1,161	4.7	$p = .137$
Missoula (10)	19,575	798	4.1	$p = .447$

[1]Net energy savings = participants' first year post-retrofit gross savings minus non-participants' first year post-retrofit gross savings, in kWh.

[2]Using two-sample t-test comparing gross savings for participants and non-participants.

period. In five cases, the finding of a net savings was significant at the .05 level or less (often much less); in the other three cases, the findings were not found to be significant. For these utilities where savings were found to be significant, they ranged from 2,105 kWh (7.9% of previous energy use) to 4,037 kWh (16.0% of prior use).

Savings for the second post-retrofit year are shown in Table 4.5. It should be noted that the savings shown here for many of the utilities are substantially different from the first year savings shown in Table 4.4. A comparison of savings for the two years is shown in Figure 4.4. For the second year following weatherization, all utilities again showed a net savings. Once more, this finding is not significant for three utilities in the table. For those utilities with significant net savings, the range was from 11.1% to 19.3% of pre-retrofit NAC.

Table 4.6 represents an attempt to explain some of the large differences in savings observed among the utilities studied. First and second year net savings are listed for each utility, along with three potentially important characteristics of each service area that might help explain the variance in savings achieved by utility customers. These characteristics are the average per capita income in the county served by each utility, the magnitude of any recent increases in electricity rates, and the severity of the local climate as represented by long-run average heating degree days.

An examination of the data presented in Table 4.6 shows no obvious relationship between first or second year net savings and any of the independent variables. In both years, for example, Tacoma had much higher savings levels than Elmhurst, but both had virtually identical climates and income levels. Those utilities with the highest and lowest statistically significant net savings in the first post-retrofit year showed no recent changes in their electricity rates, while the utility with the largest rate change had among the smallest savings in both years. This finding of no clear relationship between these utility-level characteristics and average savings

Table 4.5. Average net energy savings two years after weatherization, by utility

Utility (No. of Participating Households)	Pre-Retrofit NAC	Second Year Post-Retrofit Net Energy Savings[1]	Savings as % of Pre-Retrofit NAC	Test of Research Hypo.[2] That Net Savings >0
Tacoma (50)	25,369	4,886	19.3%	$p = .014$
Idaho Falls (57)	29,280	2,162	7.4	$p = .004$
Eugene (46)	21,210	2,368	11.2	$p = .001$
Elmhurst (45)	27,225	1,916	7.0	$p = .076$
Vera (39)	25,674	4,542	17.7	$p < .000$
Richland (42)	26,541	715	2.7	$p = .464$
Snohomish (36)	24,206	379	1.6	$p = .712$
Missoula (0)	-	-	-	-

[1]Net energy savings = participants' second year post-retrofit gross savings minus non-participants' second year post-retrofit gross savings, in kWh.

[2]Using two-sample t-test comparing gross savings for participants and non-participants.

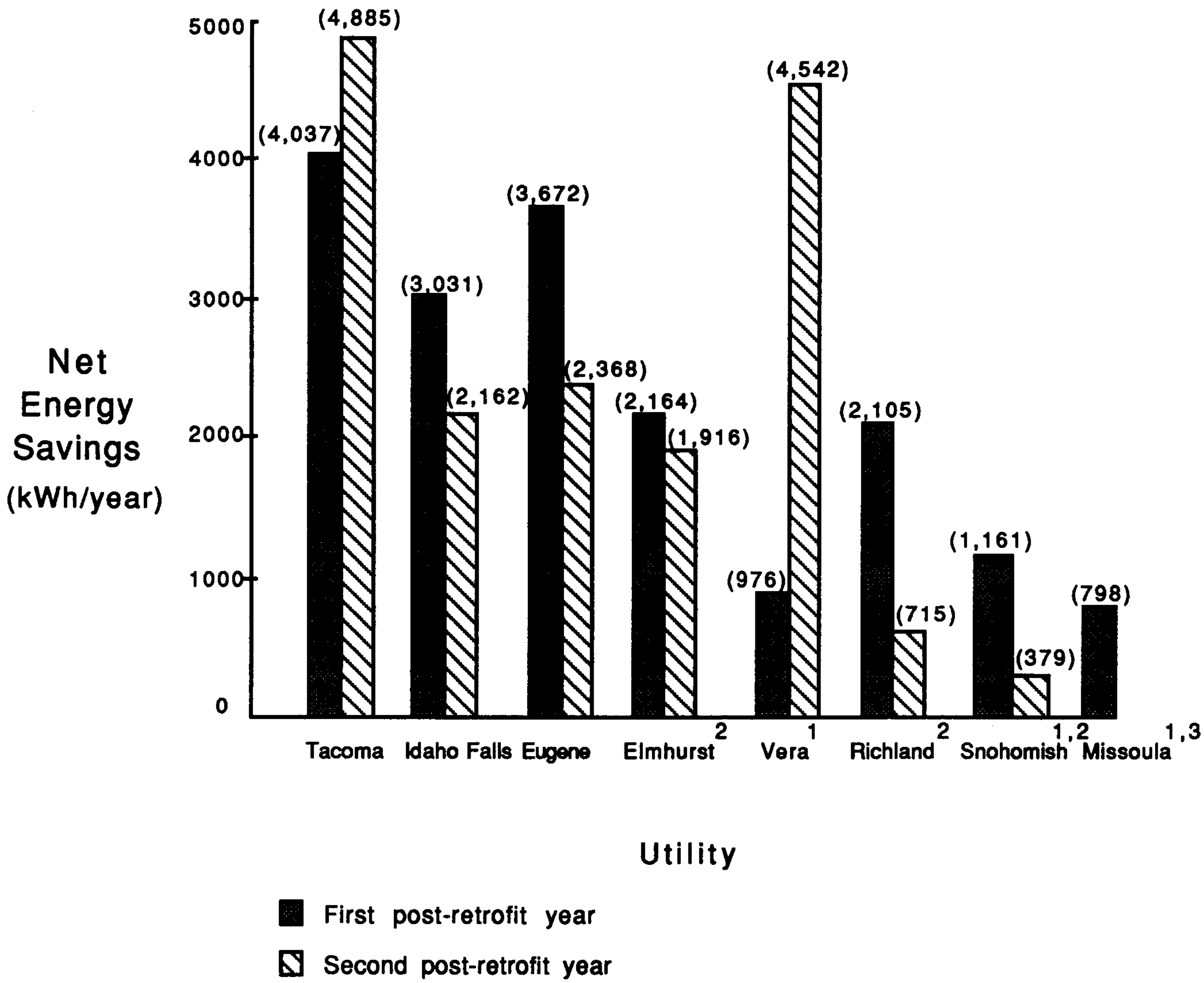

Fig. 4.4. Average net energy savings one and two years after weatherization, by utility.

[1]First year savings for these utilities are not significant at the 0.5 level.
[2]Second year savings for these utilities are not significant at the .05 level.
[3]Data were not available for Missoula participants for the second post-retrofit year.

Table 4.6. Average net savings and possible explanatory factors, by utility[1]

Utility	1st Year Net Savings as % of Pre-Retrofit NAC	1st Year Net Savings in kWh	2nd Year Net Savings as % of Pre-Retrofit NAC	2nd Year Net Savings in kWh	Average Per Capita Income[2]	Recent Rate Change[3]	Long-Run Average HDD[4]
Eugene	17.6%	3,672	11.2%	2,368	$7,819	0	3,484
Tacoma	16.0	4,037	19.3	4,886	$7,417	$ .0052	3,684
Idaho Falls	10.4	3,031	7.4	2,162	$7,170	0	6,693
Elmhurst	7.9	2,164	7.0	1,916	$7,409	$ .0008	3,684
Richland	7.9	2,105	2.7[5]	715[5]	$9,837	0	3,651
Snohomish	4.7	1,161	2.7[5]	379[5]	$8,243	$ .016	3,884
Missoula	4.1	798	-	-	$7,256	0	6,710
Vera	3.8	976	17.7	4,452	$6,932	0	5,599

[1]Utilities are arranged in descending order by first year net savings as percent of prior energy use.
[2]Per capita income is taken from the 1980 census of population.
[3]Recent rate changes are increases that took place between June 1984 and December 1985.
[4]HDD are based on a reference temperature of 60°F.
[5]Net savings not significantly different from zero at .05 level.

differ from the results of a recent study of 1985 participants and non-participants in the RWP (Horowitz, Bronfman, and Lerman, 1987). In that case, a regression analysis of both participants and non-participants found higher savings by utilities with higher average income and by utilities located in the colder region east of the Cascade Mountains and, surprisingly, found lower savings for those utilities that had experienced recent rate increases. It may be that these participants had already reduced their pre-retrofit electricity consumption.

4.3 OVERALL PROGRAM SAVINGS

After household energy use was aggregated by utility and net savings were calculated, utility-level data were further aggregated to allow the calculation of program-wide savings. *Unweighted* and *weighted* calculations of savings were made, yielding substantially different results. Unweighted savings were calculated by averaging the mean savings achieved by each utility, which gave the smallest and largest utilities equal weight. In contrast, weighted savings (as explained in Section 2.4) were calculated by attaching a different weight to the savings achieved by each utility, based on the proportion of total program participants (from all eight utilities combined) contributed by each utility. By weighting the savings of each utility in this manner, a more accurate representation of program-wide savings can be made.

Table 4.7 shows unweighted energy savings achieved by participants and non-participants one and two years after weatherization. As explained earlier, gross savings by non-participants were subtracted from participants' gross savings to yield net savings due to program participation. Unweighted net savings one and two years after weatherization were 2,549 kWh and 2,539 kWh, respectively, representing 10.0% and 9.8% of pre-retrofit energy use. The finding of a positive net savings was significant at the .000 level in both years. While estimates of space-heat energy use are shown in this table, we place little trust in their accuracy.

A more representative picture of overall program accomplishments is provided by showing weighted energy savings. Figure 4.5 graphically illustrates weighted gross savings by participants and non-participants one and two years after weatherization. In Table 4.8, both gross savings *and* net savings for both post-retrofit years are shown. Program-wide total net savings were 2,811 kWh and 2,515 kWh, respectively, one and two years following weatherization. For the first year, these savings represent 11.8% of pre-retrofit energy use (Table 4.7). Average net savings two years after weatherization were 10.6% of prior use. As

Table 4.7. Average energy savings for program participants and non-participants (unweighted)

		Pre-Retrofit NAC	Total Gross Savings[1]	Total Net Savings[2]	Total net Savings as % of Pre-Retrofit NAC	Test of Research Hypothesis That Total Net Savings > 0
One Year after weatherization	Participants	25,546	1,936 (1,472)	2,549 (1,362)	10.0%	p < .000
	Non-Participants	23,157	-613 (110)	--	--	
Two Years after weatherization	Participants	25,796	1,567 (1,523)	2,539 (1,847)	9.8	p < .000
	Non-Participants	23,554	-972 (-324)	--	--	

[1]Numbers in parentheses are estimates of gross *space-heating* savings, in kWh.
[2]Numbers in parentheses are estimates of net *space-heating* savings, in kWh.

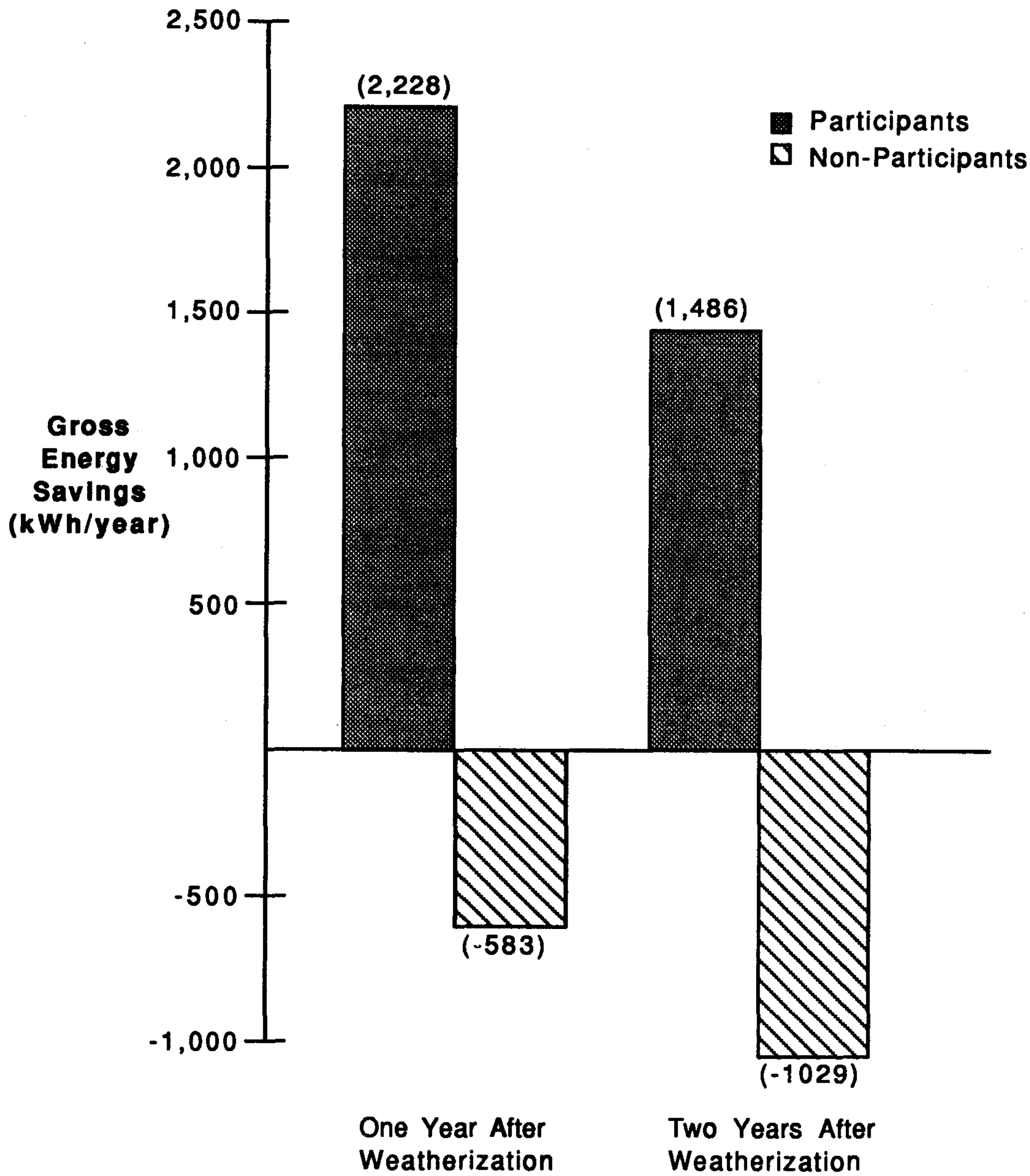

Fig. 4.5. Average program-wide gross energy savings for program participants and non-participants (weighted)

Table 4.8. Average program-wide energy savings (weighted)

		Pre-Weatherization Energy Use	Total Gross Savings[1]	Total Net Savings[2]	Total net Savings as % of Pre-weatherization energy use	Test of Research Hypothesis That Total Net Savings > 0
One Year after weatherization	Participants	23,919	2,228 (1,448)	2,811 (1,207)	11.8%	p = .000
	Non-Participants	21,866	-583 (241)	--	--	
Two Years after weatherization	Participants	23,827	1,486 (1,422)	2,515 (1,272)	10.6	p = .000
	Non-Participants	22,294	-1,029 (150)	--	--	

[1]Numbers in parentheses are estimates of gross *space-heating* savings, in kWh.
[2]Numbers in parentheses are estimates of net *space-heating* savings, in kWh.

with unweighted savings, the finding of a positive net savings in both years was significant at the .000 level.

As shown in Tables 4.7 and 4.8 and in the text, there is some difference between weighted and unweighted total net savings one year after weatherization but almost no difference in the second post-retrofit year. When weighted and unweighted savings do differ from each other, the weighted numbers present a more representative picture of overall program-wide savings.

A sense of the magnitude of energy savings achieved by 1986 RWP participants can be attained by comparing the amount of energy saved by this group with the savings experienced by previous participants in this and similar Bonneville conservation programs. Tables 4.9 and 4.10 and Figure 4.6 show net savings for participants in the RWP Pilot, Interim, and Long Term programs, whose homes were weatherized between 1981 and 1986. For the Pilot Program, the savings presented are for the first three years following weatherization. For 1982 and 1983 participants in the Interim Program, savings estimates are available for 3 and 2 years after participation, respectively. For the Long Term program, the savings experienced by 1985 and 1986 participants are tracked for three and two post-weatherization years, respectively.

There had been a fairly distinct downward trend over the years in the savings achieved in the first post-retrofit year by each successive cohort of participants, ranging from 4,500 kWh in 1981 to 2,610 kWh in 1985. Contrary to this trend, the 1986 group had higher savings than the 1985 group in its first post-retrofit year. Recall that the audit-estimated savings for 1986 participants were also greater than for the 1985 or 1983 participants.

Four of the five cohorts discussed above exhibit marked decay in savings over time, including the 1986 cohort. Net savings by the 1985 cohort remained relatively constant for three years after retrofit. In contrast, the amount of energy saved by the 1986 group fell by

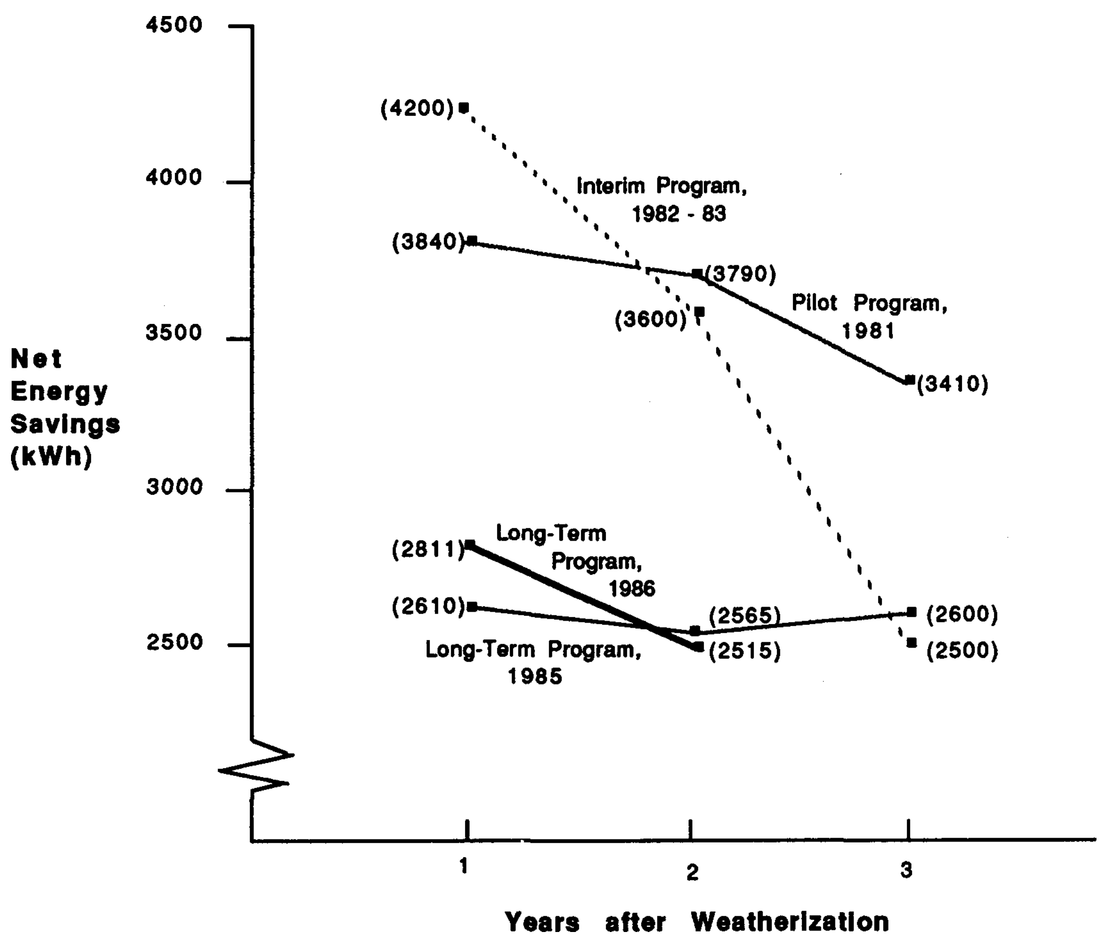

Fig. 4.6. Comparison of savings by participants in Long Term RWP and earlier Bonneville Programs[1].

[1]The phase of the RWP and year in which households were weatherized are indicated for each post-weatherization year for which data are available.

Table 4.9. Comparison of savings and costs for 1986 Long Term RWP participants with savings and costs for earlier participants in this and other Bonneville Programs

Program	Net Savings in kWh/year[1]	Regional Costs/unit[2]	Regional Levelized Costs (mills/kWh)[3]
Pilot 1981	3,840	2,630	32
Interim (1982-83)	4,200 (4,620)	2,100	23
Long Term (1985)	2,610 (2,870)	2,280	40
Long Term (1986)	2,811 (3,090)	2,790	46

[1]Savings numbers are for first post retrofit year. Numbers in parentheses include a 10% credit for reduced transmission and distribution losses.

[2]Costs are figured with nominal dollars and include administrative costs.

[3]Uses 1987 financing assumptions, including a 3 percent real discount rate and a 31-year measure lifetime.

<u>Sources of Data for Pre-1986 Participants</u>

Pilot Program - (Hirst, White, and Goeltz, 1985, Table 2, p. 18; and Hirst et al., 1983, Ch. 8, assuming $360 in administration costs)

Interim Program - (Goeltz, Hirst, and Trumble, 1986, Table 3, p, 14; and Hirst, et al., 1985, Table 19, p. 72, and Ch. 7)

Long Term Program, 1985 Cohort - (Haeri, 1988, Table 10 and p. 23, assuming $400 in administrative costs)

Table 4.10. Average annual energy savings during post retrofit years

Program	Net Energy Savings (kWh/Year)[1]		
	Year 1	Year 2	Year 3
Pilot	3,840	3,790	3,410
Interim (1982-83)	4,200	3,600	2,500
Long Term (1985)	2,610	2,565	2,600
Long Term (1986)	2,811	2,515	NA

[1]Does not include 10% credit for reduced transmission and distribution losses.

[2]Net energy savings of the Interim Program is the weighted average of the 1982 and 1983 cohort savings. In particular:

Year 1 = .483 (4,100) +.517 (4,300) = 4,200

Year 2 = .483 (3,300) +.517 (3,800) = 3,600

The 1982 cohort is the only cohort with a third year of savings (2,500).

nearly 300 kWh from the first to the second post-retrofit year. In fact, *gross* savings by the participants fell by almost 750 kWh during this time, but net savings did not decrease by this much because the control group of non-participants *decreased* their energy consumption by nearly 450 kWh during this same period. It is too early to tell whether this drop in savings for the 1986 participants represents a stable downward trend in Long Term RWP performance or is merely a short-term aberration.

While the causes of conservation decay are still unclear, there is a growing body of empirical evidence documenting the magnitude of the decay. Longitudinal evaluations of Seattle City Light's Home Energy Loan Program (HELP) and Utah's Institutional Conservation Program (ICP) are particularly noteworthy.

Sumi and Coates (1988) examined HELP to determine the persistence of energy savings over the 1982-87 period. The analysis was restricted to 1,030 single-family households who had received a loan, performed a home weatherization, and who had lived in the same home for the duration of the study period. A non-participant sample of 229 homes was studied for comparison purposes. All energy consumption data were weather normalized using PRISM. On average it was found that the energy saved by participating households declined 5.9% per year, or 27% over the six-year period.

The analysis of Utah's Institutional Conservation Program examined 40 buildings that were retrofitted in the early 1980's. Energy use for each building was normalized using building area and weather factors, but no comparison group of buildings was studied. It was estimated that the energy savings realized immediately after retrofit were declining at an average rate of 6.9% per year (Utah Energy Office 1989).

The overall experience with Bonneville's weatherization efforts suggests a larger conservation decay than for the two programs discussed above. The average decline in net savings for the eight one-year segments shown in Figure 4.6 is 9.5%.

In addition to identifying energy savings over time, we also calculated levelized costs for the 1986 cohort and earlier RWP participants. Cost levelization is a technique that puts costs on a common basis, allowing comparisons across different retrofits, different markets, and different supply options. Consistent with Bonneville procedures, the following equation was used to calculate the levelized costs of the program to the Bonneville region:

Levelized costs (mills/kwh) = [1000 x (first costs)
x (composite multiplier)]
/ [(line loss credit)
x (annual energy savings)]

where,
composite multiplier = [(financing factor)
x (real levelizing factor)]
/ (nominal discount factor),
annual energy savings = first year net savings.

First costs for 1986 RWP participants are assumed to be the weighted average cost of the weatherization ($2,388) plus $400 in program administration costs. The lifetime of the measures is assumed to be 31 years, to be consistent with prior RWP evaluations. The discount rate is assumed to be 3 percent, the inflation rate is assumed to be 5 percent, the long-term financing rate is assumed to be 8.35 percent, and levelizing rate is assumed to be 3 percent. The annual energy savings are the net savings (2,811 kWh) achieved one year after weatherization. This savings is multiplied by a line loss credit of 1.1, which reflects a credit given to conservation programs due to electricity transmission and distribution savings.

The result is a regional levelized cost estimate of 46 mills/kWh. This is at the low end of the range of estimates for new coal plant levelized costs for the Pacific Northwest or

California, which generally range from 40 to 80 mills/kwh (Amir and Ringer, 1987). As shown in Table 4.9, these levelized program costs are similar to the costs calculated for the 1985 participants in the Long Term program, but exceed the costs of earlier RWP efforts.

The trend in regional levelized costs over time is slightly flatter when the results of previous studies are inflated to 1986 dollars (Fig. 4.7). It should be noted that only a single levelized cost figure is shown for each group of participants, even if savings are available for multiple years, because the formula used to calculate costs is based on the assumption that annual energy savings remain constant over time and are equal to the first year of savings. Should subsequent years' savings by the 1986 cohort continue to fall below first year savings, actual levelized costs would be higher than shown here.

In addition to calculating total savings, an estimate was made, using the PRISM model, of the portion of total savings that came from reductions in energy used for space-heating. The outcomes of this analysis are open to question because of known biases in the space-heating estimates from PRISM (Hwang, 1989), and several large, inexplicable shifts from year to year in the reference temperature used to estimate space heat energy use. The results are displayed in Fig. 4.8. Slightly under two-thirds of the first-year gross energy savings of program participants resulted from reductions in space heat electricity usage. In the second year, space heat savings accounted for virtually all of the gross savings, as anticipated. For non-participants, the PRISM results suggest that all of their increased usage came from increased baseload consumption while their space-heat energy use decreased slightly in both post-retrofit years.

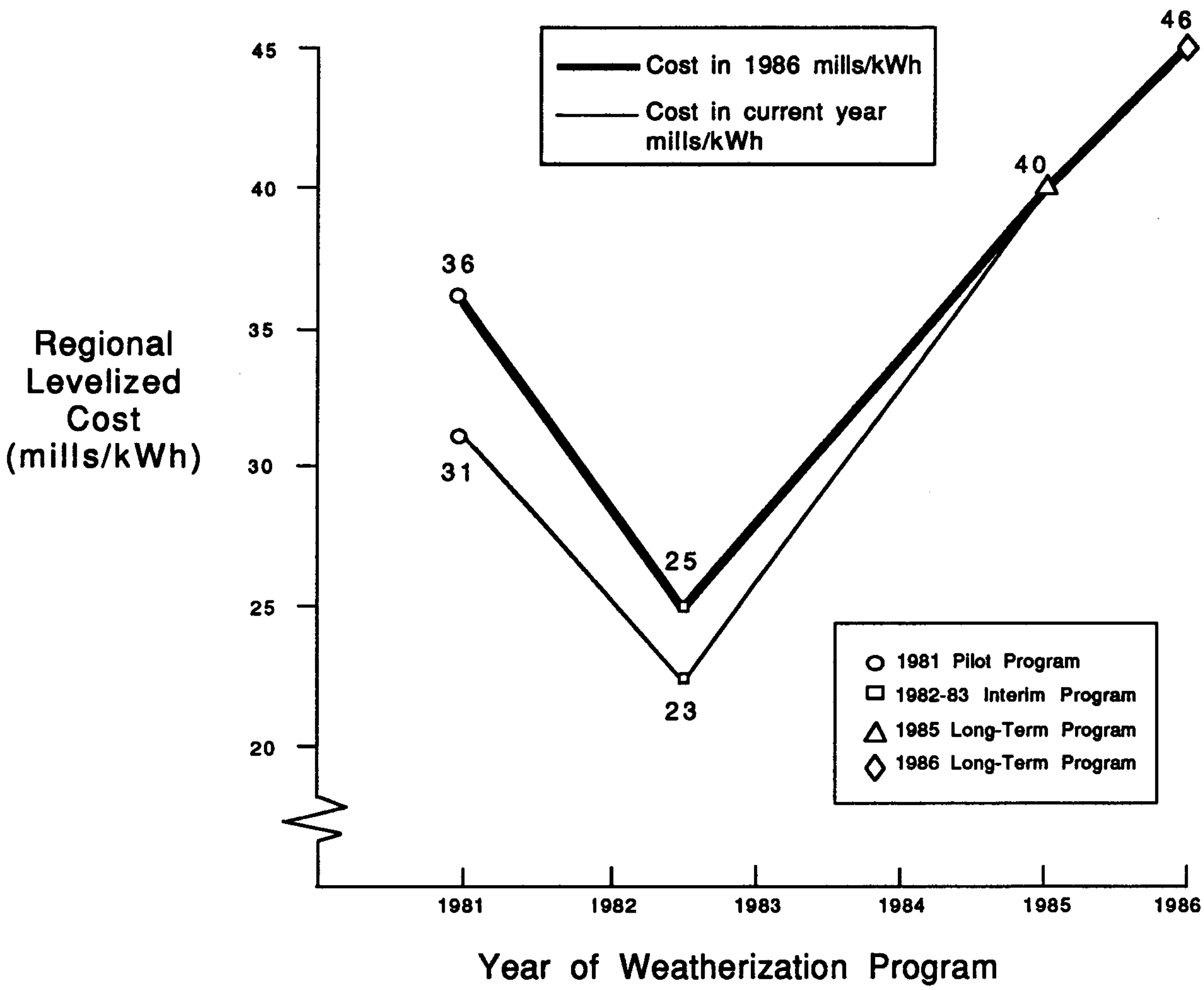

Fig. 4.7. Regional levelized costs of the Long Term RWP and earlier Bonneville Programs.

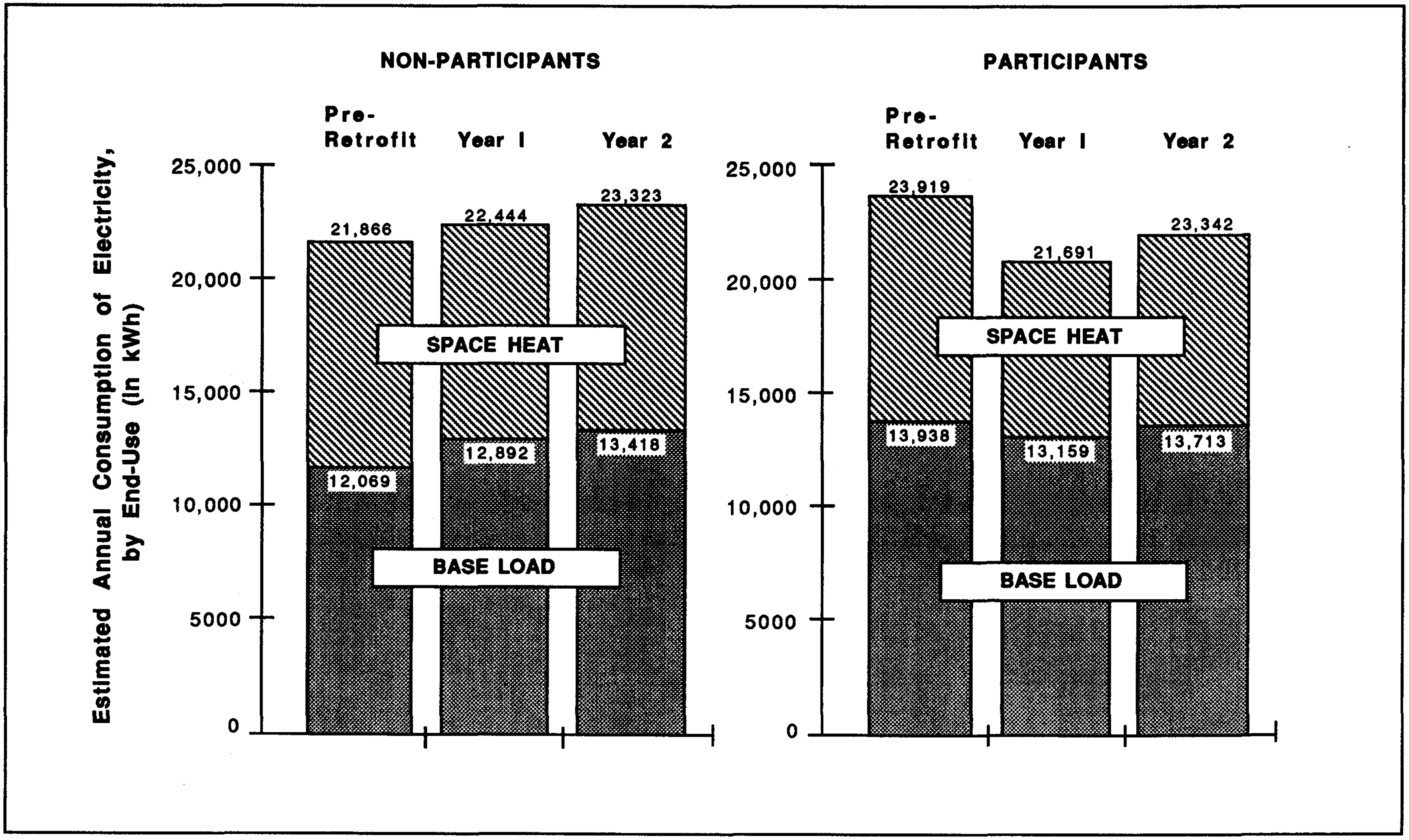

Fig. 4.8. NAC components for program participants and non-participants.

5. SUMMARY AND CONCLUSIONS

Chapter 3 identified a number of important trends in estimated savings, costs, recommended measures and installation rates between 1982 and 1986. Audit-estimated savings for 1986 participants were not substantially different from those of previous program cohorts, but the average total cost per retrofit increased significantly over the same five-year period. As a result, the average total cost per kWh of estimated savings has increased markedly. In contrast, Bonneville's costs per kWh of audit-estimated savings have remained fairly stable because of greater cost sharing by utilities and participating households in recent years.

In 1986, 83% of the recommended measures were installed by the program, approximately the same percentage as in previous years. A somewhat greater proportion (89%) of the potential audit-estimated savings is associated with installed measures. Thus, 1986 participants were more likely to install measures that are estimated to be more energy-conserving--a pattern that was found in evaluations of previous program participants. Consistent with this conclusion, ceiling, floor, wall, and duct insulation are installed in almost all of the homes that need it, and each of these insulation measures offers significant estimated savings. In contrast, caulking and weatherstripping are the two measures with the greatest disparity between rates of recommendation and installation, and they both offer only modest savings.

For the Residential Weatherization Program overall, savings experienced by 1986 participants were substantial. During the first post-retrofit year, weighted net savings averaged 2,811 kWh, or 11.8% of the previous year's energy consumption. In the second post-retrofit year, a weighted average of 2,515 kWh was saved, amounting to 10.6% of pre-retrofit energy use. Levelized costs were 46 mills per kWh saved, which is at the low end of the range of cost estimates for a new coal plant. It is clear from these findings that the Long Term RWP is generating significant savings at comparatively low costs, thereby continuing to provide a valuable service to the region.

As shown in Chapter 4, the average amount of energy saved at the household level was positive for 1986 participants and negative for non-participants. Despite this general relationship between program participation and savings, the actual amount of energy saved by participating households varied widely and was not closely related to audit-estimated savings. Relatively little of the variation in household performance was explained by pre-retrofit energy use, total weatherization costs, climate, and the installation of various energy conservation measures. This indicates that *other* factors, such as family composition and income, structural characteristics, changes in thermostat settings, and changes in the use of supplemental heat sources over time, may be important in determining the outcomes of residential energy conservation programs. Further study of participants in the Residential Weatherization Program, incorporating these additional variables and focusing on households with marked deviations between predicted and actual savings, could yield interesting results.

At the utility level, average gross savings for the 1986 cohort were always positive for participants and mostly negative for non-participants. Statistically significant net savings were achieved by over half of the utilities studied during both years. While substantial differences were observed among utilities in the amount of energy saved, these could not be explained by differences in average per capita income, recent changes in electricity rates, or climatic conditions (represented by long-run heating degree days). In addition to differences *between* utilities, substantial differences were also identified *within* utilities in terms of the amount of energy saved from one year to the next. The magnitude of net savings fluctuated by more than 30% from the first to the second post-retrofit years for four of the seven utilities in our sample for which data were available on participants for this entire period. To help explain between-utility variation, additional research could examine differences among utilities in their administration of the RWP as well as in the populations they serve. Within-utility variations over time could be addressed by the same type of study of household characteristics, structural conditions, and occupant behavior suggested earlier.

The amount of energy saved program-wide was similar for both 1986 and 1985 participants in the Long Term RWP. However, compared to the first year of savings and levelized costs for 1981, 1982, and 1983 participants, the 1985 and 1986 cohorts have not performed as well.

The decline experienced by the 1986 group in program-wide savings from the first to the second post-retrofit year represents a departure from the experience of the 1985 cohort. However, it is consistent with the levels of conservation decay documented for earlier participants in the Pilot and Interim Programs. This drop in savings could indicate an increase in "take-back" behavior, whereby participants in a conservation program take advantage of the improved energy-efficiency of their structures by raising thermostat settings or otherwise increasing occupant comfort. Whether or not the observed decline in savings is a durable trend in Long Term RWP performance or a short-term aberration cannot be determined from the available data. Because of the importance that such a downward trend would represent for program planners, energy savings for the 1986 cohort should be tracked for at least one additional year. It might also be useful to extend the evaluation of savings to 4 and 5 years after retrofit. At the same time, research should be undertaken to explain the observed levels of conservation decay. This would require home inspections as well as interviews with participants. If subsequent savings appear to be consistently lower than first year savings, Bonneville's current formula for calculating levelized costs (which assumes constant savings over time) should be modified.

Since 1981, energy savings have declined and costs have risen for each subsequent stage (Pilot, Interim, and Long Term) of the Residential Weatherization Program. An earlier analysis of changes in the RWP over time (Hirst and Keating, 1987) suggests that this reduction in savings is the result of a number of factors, including fuel prices, changes in the region's economy, public awareness of energy issues, and increasing adoption of conservation measures prior to participation in the Bonneville program. The degradation of weatherization materials over time and poor maintenance practices may also contribute to conservation decay. Despite the drop in the amount of energy saved from one year to the next, the energy savings and associated costs identified in this study for the 1986 cohort of the Long Term RWP indicate that cost-effective savings can still be achieved by this type of conservation program.

APPENDIX A

BIAS TESTS

As indicated in Chapter 2, data were processed and screened in accordance with predetermined criteria. Households were removed from analysis when any of the following conditions were true:

1. The occupant was defined as a low-income participant, the housing type was either multifamily or attached, or the house had previously been included in another weatherization program; or
2. The retrofit work performed under the 1986 DGP was conducted before April 1 or after September 30; or
3. Either the utility's weatherization worksheet or NAC was unavailable for a participant, or the NAC was not available for a non-participant (e.g., households moved).

Table A.1 shows the distribution of participating and non-participating houses across the above conditions.

Table A.1. Data attrition and sample sizes (program summary)

	UNIVERSE	CONDITIONS[a]			
		1	2	3	
				(1 year after weatherization)	(2 years after weatherization)
A. Participants	1502	393 (1109)	596 (513)	168 (345)	30 (315)
B. Non-participants	1339	-	-	344 (995)	140 (855)

[a]The top number of each pair is the number of houses that were removed from analysis. The bottom number (in parentheses) refers to the houses that were retained.

A series of tests was conducted to determine whether the data screening method introduced bias into the analysis results reported in Chapter 4. Comparisons of means were conducted on all available data. Factors like climate and distribution of households across utilities at different screening stages were also examined. The potential bias associated with condition 1 was not assessed. Since the houses removed from analysis under condition 1 did not fit the description of the sampling frame for this study, there is no conceptual bias.

In the bias test for condition 2, the 596 participant households removed from the sample were compared to the 513 that remained (see Table A.1). Climate zones and utilities were similarly represented in both groups. It was found that the two groups of households were not significantly different in terms of utility and Bonneville retrofit costs and retrofit activity, but that the 513 households remaining in the sample contributed 10% more to their respective retrofit costs than the 596 households that were dropped. Thus, our estimate of the average level of customer contribution to the total retrofit costs may be slightly high.

In the bias test for condition 3 for participants, 345 participant households were compared to the 513 households from the previous step and to the 168 households dropped at this stage. In terms of utility and Bonneville retrofit costs and retrofit activity, these three groups were not different.

This bias test was replicated for the 315 households with sufficient data to allow identification of savings two years after weatherization. In terms of customer and total retrofit costs, and the number of retrofit measures installed, the 315 households retained in the two-years-after analyses were more active in the 1986 program than the 198 households that were eliminated by our screening criteria.

Customer costs for the houses retained in the two-years-after analyses were approximately 23% higher than the customer costs of the houses for which NACs were not available and which were dropped from the analysis. Total retrofit costs were approximately 10% higher. The impacts of this bias on our estimates of energy savings, if any, are unclear. However, the difference in customer costs suggests that those households that may have been planning to move made smaller personal investments in the retrofits than those who remained in their residences.

Households dropped from year two to year three are not different from those retained in terms of pre-retrofit energy use, retrofit cost, and distribution across weather zone and utility.

For the non-participants, the bias test on condition 3 revealed that the climate zones and utilities were similarly represented before and after removing houses due to the screening criteria.

Two additional potential biases were uncovered during data processing of the utility bills. First, in Snohomish, the first month of billing records for non-participants was usually August or September, 1985. Consequently, the pre-retrofit year for Snohomish non-participants spanned approximately 330 days on average rather than 365 days for the participants and other utilities whose first month was July, 1985. This shorter year did not prevent weather or temporal adjustments with PRISM. Nonetheless, the overall NAC based upon 330 days of history is probably underestimated. Thus, the gross energy savings of Snohomish non-participants is also underestimated.

Second, the billing records for Eugene participants contained a 4-month gap in the late Fall and early Winter of 1986/87. The effect of this gap is the underestimation of NAC in the first post-retrofit year and an overestimation of gross energy savings.

REFERENCES

Amir, E. and M. Ringer, 1987, Relative Cost of Electricity Production, California Energy Commission, Sacramento, California.

Bonneville Power Administration, 1980, Residential Weatherization Pilot Program, Portland, Oregon.

Bonneville Power Administration, 1982a, BPA Home Energy Efficiency Program, Residential Weatherization, Portland, Oregon, January.

Bonneville Power Administration, 1982b, Conservation Program Fact Sheet Residential Weatherization, Portland, Oregon, October.

Bonneville Power Administration, 1984a, Results of the BPA Residential Weatherization Pilot Program Evaluation, Office of Conservation, DE-2, Portland, Oregon, August.

Bonneville Power Administration, 1986, Office of Conservation 1986 Yearbook, Portland, Oregon.

Brandis, P. and B. Bronfman, 1987, "Captured Conservation: One Year of a Decade," Proceedings of the 1987 Conference, Energy Conservation Program Evaluation: Practical Methods, Useful Results, Volume 2, Argonne, Illinois: Argonne National Laboratory, pp. 435-444.

Brown, M. A. and D. L. White, 1988, "Stimulating Energy Conservation by Sharing the Savings: A Community-Based Approach, Environment and Planning A, 20, pp. 517-534.

Eissler, A., 1984, personal communication, Bonneville Power Administration, Office of Conservation, Portland, Oregon, January.

Fels, M. F., 1986, "PRISM: An Introduction," Energy and Buildings, 9, pp. 5-18.

Fels, M. F., J. Rachlin, and R. H. Socolow, 1986, "Seasonability of Non-heating Consumption and Its Effect on PRISM Results," Energy and Buildings, 9, pp. 139-148.

Goeltz, R., E. Hirst, and D. Trumble, 1986, Electricity Savings One to Three Years After Participation in the BPA Residential Weatherization Program, ORNL/CON-194, Oak Ridge National Laboratory, Oak Ridge, Tennessee, April.

Goldberg, M. L., 1986, "A Midwest Low-Income Weatherization Program Seen Through PRISM," Energy and Buildings, 9, pp. 37-44.

Haeri, M. Hossein, 1988, Electricity Savings Three Years After Participation in the Bonneville Power Administration Regionwide Weatherization Program, ERC/PO-34, ERC International, Portland, Oregon.

Hirst, E., B. Bronfman, R. Goeltz, J. Trimble, and D. Lerman, 1983a, Evaluation of the BPA Residential Weatherization Pilot Program, ORNL/CON-124, Oak Ridge National Laboratory, Oak Ridge, Tennessee, June.

Hirst, E., R. Goeltz, M. Thornsjo, and D. Sundin, 1983, Evaluation of the Home Energy Audit Retrofit Loan Programs in Minnesota: the Northern States Power Experience, ORNL/CON-136, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Hirst, E., D. White, and R. Goeltz, 1985, Three Years After Participation: Electricity Savings Due to the BPA Residential Weatherization Program, ORNL/CON-166, Oak Ridge National Laboratory, Oak Ridge, Tennessee, January.

Hirst, E., R. Goeltz, D. White, B.Bronfman, D. Lerman, and K.Keating, 1985a, Evaluation of the BPA Residential Weatherization Program, ORNL/CON-180, Oak Ridge National Laboratory, Oak Ridge, Tennessee, June.

Hirst, E. and R. Goeltz, 1986, Electricity Use for Residential Space Heating: Comparison of the Princeton Scorekeeping Method with End-Use Load Data, ORNL/CON-203, Oak Ridge National Laboratory, Oak Ridge, Tennessee, April.

Hirst, E. and K. Keating, 1987, "Dynamics of Energy Savings Due to Conservation Programs," Energy Systems and Policy, 10(3), pp. 257-273.

Hirst, E., R. Goeltz, and D. Trumble, 1989, "Effects of the Hood River Conservation Project on Electricity Use," Energy and Buildings 13 (1), pp. 19-30.

Horowitz, M. J., B. H. Bronfman, and D. I. Lerman, 1987, Evaluation of the Bonneville Power Administration Long-Term Residential Weatherization Program: The Data Gathering Report, IEAL/PO-16, International Energy Associates Limited, Portland, Oregon.

Hwang, H. L., 1989, Analysis of the Princeton Scorekeeping Method Using End-Use Data From the Hood River Conservation Project Submetered Houses, ORNL/CON-270, Oak Ridge National Laboratory, Oak Ridge, Tennessee, March.

Pratt, F., 1984, "Standard Heat Loss Methodology Energy Savings Estimates," Bonneville Power Administration White Paper, April.

Sumi, D. and B. Coates, 1988, Longitudinal Evaluation of Energy Savings from Seattle City Light's Home Energy Loan Program, Seattle, Washington: Seattle City Light.

U.S. Congress, 1978, National Energy Conservation Policy Act, Public Law 95-619, November 9.

U.S. Congress, 1980, Pacific Northwest Electric Power Planning and Conservation Act, Public Law 96-501, December.

Utah Energy Office, 1989, Utah Institutional Conservation Program, Fourth Phase Project Tier I Final Report, Unpublished report.