RESULTS OF A DECADE OF WEATHERIZATION

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Introduction

Pacific Power implemented a number of residential weatherization retrofit programs in the period 1978-89. The purpose of this study is to revisit these past efforts and to determine implications for future program development.

Findings of the study show first year annual net savings (actual savings minus the control group reductions) of just under 3,600 kWh per weatherization, for an aggregate cumulative savings of 161,200 mWh. Another key finding is that energy savings are sustainable. In fact, annual savings five years after installation of measures increased to over 4,200 kWh.

Program Descriptions

Pacific has developed and implemented a number of weatherization incentive programs. The 1978-81 loan programs were implemented as a result of projected power shortages and rising costs of power generation. In 1983, when power surpluses in the region and in the Company became apparent, Pacific began changing its emphasis away from conservation and back to "load building." This resulted in declining activity in weatherization programs.

Since then, Pacific has continued to weatherize dwellings at just over 1,000 dwellings per year even though there has been little or no promotion of programs. Recently, the Company has reemphasized conservation as a method of acquiring resources. Descriptions of the programs implemented by Pacific are listed below. Table 1 shows the annual number of participants for the years in which programs were in operation.

Home Energy Analysis (HEA)

The HEA is the cornerstone of all of Pacific's weatherization incentive programs. It is the initial customer contact and the first step in the weatherization process. An HEA is used to provide energy recommendations concerning all aspects of a customer's home energy use, including where energy is being used and where it can be saved. The HEA aids in the determining weatherization cost effectiveness for the incentive programs offered. Free electric water heater wraps also are included.

Zero Interest Program (ZIP)

ZIP provided customers with a loan of up to $5,000 at no interest, payable upon sale of the house. The program was very popular with customers and led directly to a majority of Pacific's weatherization retrofits. Pacific first tariffed the ZIP program in Oregon in April 1978. Soon thereafter, Pacific filed ZIP in California, Washington, Montana, and Idaho. The Wyoming Commission did not allow the program.

When the Company became concerned with the increasing level of expenditure and ability to recover all program costs through rates, the ZIP program was discontinued in favor of a revised ZIP. The revised ZIP consisted of an interest-free, five-year monthly installment loan.

This program was replaced in Oregon in 1987 by an experimental ZIP program that required a test of the "all or nothing" approach stemming from the Montana Stipulation with the National Resources Defense Council. This approach emphasized the need to fully weatherize homes rather than "cream skimming" (installing the most cost effective measures) so that Pacific would not incur "lost opportunities."

6.5% Interest Loan/Cash Payment

In 1979 and again in 1981 the State of Oregon passed laws requiring utilities to offer low interest loans to customers for weatherization. In 1981 a cash payment was also required. The 6.5% loan offered monthly payments over a maximum period of 10 years. Compared to ZIP, it suffered from low activity. The cash payment program consisted of a payment of 25% of the costs of weatherization not to exceed a total payment of $350 per dwelling.

Cash Rebates

In 1982, Pacific offered Oregon customers another option—a rebate of 6.5¢ per kWh saved up to $350—for

the installation of weatherization measures. Additionally, a cash rebate was offered in California at 32.5¢ per kWh saved (on a five-year basis).

BPA Rebate/Low-income

In mid-1982, Pacific took advantage of a one-time opportunity that stemmed from the passage of the Northwest Power Act of 1980. By signing the Short Term Conservation Agreement with the Bonneville Power Administration (BPA), Pacific customers (with the exception of California and Wyoming) were eligible for the BPA Buyback Program. The program provided for rebates based upon 29.2¢ per kWh of energy savings. Program funding ran out in the summer of 1983 and the program was canceled in November 1983. A low-income program feature was also included in the BPA Buyback Program.

Rental Incentive Program

Stemming from the 1985 Throop Agreement, as a result of Oregon legislative hearings, Pacific was allowed to offer rental property owners an additional incentive to weatherize (this incentive could be combined with other programs). This consisted of a pass-through of the state's 35% Business Energy Tax credit. Rental property owners who weatherized through Pacific's 6.5% loan or cash payment programs were eligible to receive a reduction of the loan principle or an additional payment at 29% of the installed cost of weatherization. This program has been very well received in the multi-family sector. Much of the success of this program is due to marketing efforts by the City of Portland Energy Office, Delta-T in Lane County, and the Portland Energy Conservation, Inc., throughout the state.

Low-Income Programs

Also as a result of the Throop Agreement, Pacific's weatherization focus began to shift to the low-income sector. Concerns existed that participation by low-income customers was disproportionately lower than non-low-income customers.

Pacific has worked with Community Action Program Agencies (CAPs) to oversee the entire process of the low-income weatherization programs. CAPs are responsible for outreach, income qualification, energy audits, installation, and post inspection. Incentives have grown over time to the present per home contribution of $1,350 plus $150 in Washington, $1,000 plus $150 in Oregon, $500 in Montana, an average of $800 in Idaho, and $900 in California.

Program Profile

Residential weatherization implementation was occurring rapidly in the early 1980s and has dropped off significantly in the last half of the decade, primarily due to a change in the Company's focus and lower promotional levels. Table 1 shows the distribution of customers that have installed weatherization measures, by program and in total.

Listed in Table 2 are the number of participants that installed selected weatherization measures. The most popular measures installed were ceiling insulation, floor

Table 1. Number of Weatherizations by Year (Thousands of Participants)

	78	79	80	81	82	83	84	85	86	87	88	89
ZIP	.2	5.1	7.5	4.5	2.4	.2	.2	.2	.2	a	a	a
OR 6 .5% Loan		a	.3	.3	.2	.4	.1	.2	.2	.1	.1	.1
Cash Rebate				.2	.2	.2	a	a	a	a		
OR Cash Payment						a	.1	.1	.5	.4	.6	.7
BPA Rebate					.4	4.9						
BPA Low-income Rebate						.5						
Revised ZIP						[a]	.5	.5	.2	.2	.1	a
Low-income Direct								.1	.3	.5	.9	.5
Total [b]	.2	5.2	7.8	5.3	3.5	6.8	1.0	1.2	1.5	1.3	1.8	1.4

[a] Less than 50 participants.
[b] Includes those participating in multiple programs.

Table 2. Measures Installed

ECMs	Number of Participants	% of Total Participants
Total Participants	37,064	100.0
Ceiling Insulation	28,337	76.5
Floor Insulation	25,992	70.1
Storm Windows	22,671	61.2
Storm Doors	11,911	32.1
Pipe Insulation	8,058	21.7
Duct Insulation	5,305	14.3
Weather Strip Doors	4,445	12.0
Caulk Windows	3,037	8.2
Caulk Doors	2,207	6.0
Wall Insulation	1,424	3.8

insulation, and storm windows. Customers installed ceiling insulation in over three-quarters of the weatherized homes. Over two-thirds installed floor insulation.

Methodology

In order to develop energy savings estimates, a quasi-experimental design using pre- and post-measurements was utilized. Net savings due to the programs are estimated using the difference between the change in consumption of the participant group and of an equivalent control group.

Customer records with obvious problems were deleted from the analysis. Reasons for data deletion included:

- The absence of pre- or post-billing data.
- Prolonged vacancies.
- Obvious billing problems.
- Outliers.

Thirty percent of the homes were deleted from the analysis due to having one or more of the above mentioned characteristics. Outliers accounted for only 2% of the deletions.

An extraneous variable that could drastically affect the analysis is the weather. In order to factor out the effect of weather, usage data was weather normalized utilizing the Princeton Scorekeeping Method (PRISM). PRISM is a standard package used by many utilities in weather adjusting residential usage data.

During the time when most of the weatherization was occurring, per customer consumption was declining in Pacific's service territory. To factor out the affects of extraneous factors occurring in the service territory during the time when measures were being installed (*e.g.*, economic factors), a control group was employed. The control group is a randomly selected group that is similar to participants by dwelling type and service territory area, with the exception that they had not participated in any of Pacific's programs and had not received an HEA.

Results

This section of the report provides not only an energy savings analysis, but also information related to program participants, their housing characteristics and the type of measures installed through the programs. This analysis can only attempt to isolate conservation from other factors, such as customer behavioral changes such as wood heat use and "take-back," which impact changes in consumption over time.

Average savings for customers participating in the programs was 4,234 kWh in the first year. This is statistically significant at $\alpha = 0.01$. A randomly selected control group, mirroring the participant characteristics saved, on average, 652 kWh per year (statistically significant at $\alpha = 0.01$). Control group savings were subtracted from participant savings, yielding an *average net savings of nearly 3,600 kWh per year.*

Future savings gained from residential weatherization will be influenced by the types of measures installed, the climatic location where the measures are installed, customer behavior, and changes in residential building codes.

Table 3 shows average first year annual savings by state. Estimated savings were calculated utilizing engineering models. Net savings, which are somewhat lower than estimated savings (averaging about 80%), are based upon actual savings minus the control group savings. Note that there are no programs in the State of Wyoming, and programs administered by the Utah Division are excluded from the analysis.

This translates to a cumulative aggregate savings of 161,200 MWh in 1989, attained through residential weatherization programs in the Pacific Division. This is equivalent to almost 18 MW saved—about the size of the Pacific

Table 3. First Year Savings by State

State	Participants		Savings				
	Number	Percent	Estimated kWh	Actual kWh	Control Group kWh	Net kWh	Net as a Percentage of Estimated
Oregon	28,836	77.8	4,271	4,043	518	3,525	82.5
Washington	6,037	16.3	5,330	4,977	1,016	3,961	74.3
Idaho	463	1.2	5,793	3,297	1,168	2,129	36.8
Montana	878	2.4	4,486	4,982	808	4,174	93.0
California	850	2.3	3,972	4,573	1,164	3,409	85.8
Total	37,064	100.0	4,460	4,234	652	3,582	80.3

Division's Idaho service territory. This aggregate estimate includes only those customers who installed weatherization measures through Company programs. It does not include savings from those customers who received only energy audits and water heater wraps. Customers who had audits received educational value and theoretically have incorporated this knowledge into decreases in energy usage. They also may have installed measures on their own, outside of the programs.

Savings are also understated due to the "take-back" effect. This phenomenon is due to customers increasing their comfort levels and is difficult to measure. Experiences from the Hood River Conservation Project suggest that "take-back" of about 300 kWh may have occurred, due to decreased use of wood for space heating.

Table 4 shows average annual kWh savings of customers five years after weatherization measure(s) were installed. It can be concluded that *savings are sustainable* over the long run. In fact, savings increased over the five year period to, on average, over 4,200 kWh ($\alpha = 0.01$). This is over 600 kWh greater than first year savings.

Table 5 shows actual and estimated first year savings by program. These savings are gross savings; they have not been adjusted, as in Table 3 and Table 4, for control group savings.

Over one-half of the homes had participated in the Zero Interest Program (ZIP), with relatively high energy savings (slightly higher savings than estimated). The rest of the programs, however, did not save as much as estimated by the engineering models.

The Low Income Program appears to have significantly lower savings than were expected. A reasonable explanation may be that these customers may not have been using much space heat before measures were installed. The measures installed allowed them to increase their comfort levels through "take-back" leading to lower savings than expected. These programs have subsequently been improved to include an educational component.

Table 4. Annual (Five-year Post) Savings by State

State	Savings				Net as a Percentage of Estimated	First-year Savings (Net kWh)[a]
	Estimated kWh	Actual kWh	Control Group kWh	Net kWh		
Oregon	4,271	5,423	1,405	4,018	94.1	3,525
Washington	5,330	7,136	2,218	4,918	92.3	3,961
Idaho	5,793	6,201	2,736	3,465	59.8	2,129
Montana	4,487	7,703	1,918	5,785	128.9	4,174
California	3,972	7,038	2,096	4,942	124.4	3,409
Total	4,460	5,821	1,597	4,224	94.7	3,582

[a] From Table 3 (r epeated for convenience).

Table 5. Annual Savings by Program

Program	Participants		Estimated Savings kWh	Actual Savings kWh	Actual as a Percentage of Estimated
	Number	Percent			
Zero Interest Loan	20,623	55.6	5,000	5,309	106.2
Revised Zero Interest	1,613	4.3	5,247	3,519	67.1
BPA Rebate	5,293	14.3	3,951	3,013	76.3
BPA Low-income Rebate	538	1.5	2,232	2,066	92.6
Oregon Cash Payment	2,626	7.1	2,420	1,739	71.9
Cash Rebate	725	2.0	4,547	4,438	97.6
Low Income	2,221	6.0	4,238	1,896	44.7
Oregon 6.5% Loan	1,995	5.4	2,975	1,464	49.2
Multiple Programs	1,015	2.7	4,996	2,937	58.8
Other	415	1.1	3,724	2,602	69.9

Table 6 shows estimated first year annual savings by measure package. A package can be either a measure installed by itself or in conjunction with a combination of measures. Packages that occurred more than 1,000 times were analyzed. Just under 50% of the selections are lumped together in an "all other combinations" category.

Engineering estimates appear to be fairly accurate estimates of energy savings. Ceiling insulation and storm windows are exceptions, where estimated savings are lower than actual savings. Also, ceiling insulation provides significantly more savings than either floor insulation or storm windows ($\alpha = 0.01$), while floor insulation provides more savings than storm windows ($\alpha = 0.07$).

Homes receiving combinations of measures tended to have less savings than would be expected from summing the savings of homes that received individual measures. This is commonly known as the "stack effect." The combination of ceiling and floor insulation provides significantly lower savings ($\alpha = 0.01$) than the sum of ceiling and floor insulation done individually. This is also the case when storm windows and ceiling insulation are combined.

This does not necessarily imply that the measures physically interact with each other. Energy interactions would contradict the generally accepted theory of heat flow and building physics. Residences with major dif-

Table 6. Annual Savings by Measure Package

ECMs	Participants		Estimated Savings kWh	Actual Savings kWh	Actual Savings as a Percentage of Estimated
	Number	Percent			
Storm Windows	2,077	5.6	1,267	1,680	132.6
Floor Insulation	1,113	3.0	2,063	2,078	100.7
Ceiling Insulation	1,980	5.3	1,669	3,138	188.0
Ceiling and Floor Insulation	3,280	8.9	3,824	3,420	89.4
Storm Windows and Ceiling Insulation	1,220	3.3	2,782	3,048	109.6
Storm Windows, Doors and Ceiling	1,203	3.2	4,607	4,754	103.2
Storm Windows, Ceiling and Floor	2,182	5.9	4,932	4,284	86.9
Ceiling, Floor, and Pipe Insulation	1,213	3.3	3,501	4,167	119.0
Windows, Doors, Ceiling, Floor	3,174	8.6	6,451	5,907	91.6
All of the Above	1,188	3.2	7,762	6,719	86.6
All Other Combinations	18,434	49.7	4,936	4,470	90.6

ferences in needed conservation measures are likely to also differ in other ways that affect energy usage, including differences in residence size, structure type, occupant characteristics, operating conditions, and so on.

Table 7 shows that over 75% of homes participating in the programs were single family residences. These residences saved more than twice as much compared with other types of dwellings. Single family dwellings are generally larger than apartments, so actual savings per square foot (on which there was no data available) may be close to being equivalent. Also shown in the table is savings by whether customers own or rent their homes. Another interesting fact, not shown in the table, is that 60% of the homes that installed weatherization measures were built prior to 1971.

Table 8 shows savings by climate zone. Climate zones were defined by the Northwest Power Planning Council based upon the number of heating degree days (HDDs). Zone 1 has between 4,000-6,000 HDDs; Zone 2, between 6,000-8,000 HDDs; and Zone 3, over 8,000 HDDs.

Measures installed in colder climates appear to bring about higher energy savings. Zones 2 and 3 had significantly higher savings than Zone 1 ($\alpha = 0.01$). However, Zone 3 did not have significantly higher savings than Zone 2 ($\alpha = 0.25$).

Cost Effectiveness

In examining the cost effectiveness of programs, levelized costs (life cycle) were calculated to determine the cost of acquiring conservation resources, so that comparisons with constructing power plants or other resource acquisitions can be made. These costs are based upon both installed costs of measures (1990$—Total Resource Cost [TRC] basis) and on the cost to the Company (utility cost).

Levelized cost calculations include a credit of 10% for line losses and assume 17% administrative costs consistent with assumptions in the Company's Least Cost Plan. In calculating the total resource cost, "customer take back" (assumed to be 300 kWh) is added to the net savings. Utility levelized costs are calculated based upon net savings; these are the savings that the Company actually sees when customers install measures.

Levelized costs were calculated using a method outlined by the Northwest Power Planning Council (listed below). Nominal levelized costs were calculated using

Table 7. Yearly Savings by Residence Type and by Own/Rent

Housing Type	Participants		Estimated Savings kWh	Actual Savings kWh	Savings as a Percentage of Estimated
	Number	Percent			
Residence Type					
Single Family	28,972	78.2	4,972	4,693	94.4
Apartment	7,361	19.8	2,600	2,204	84.8
Mobile Home	731	2.0	2,957	2,450	82.9
Own/Rent					
Home Owner	25,317	68.3	4,792	4,671	97.5
Rental Unit	11,747	31.7	3,745	3,054	81.5

Table 8. Yearly Savings by Climate Zone

Climate Zone	Participants		Estimated Savings kWh	Actual Savings kWh	Actual as a Percentage of Estimated
	Number	Percent			
Zone 1	29,938	80.8	4,350	4,157	95.6
Zone 2	6,420	17.3	4,970	4,545	91.4
Zone 3	706	1.9	4,530	4,920	108.6

the Company's cost of capital of 11.5%. Real levelized costs are calculated using a real interest rate of 6% (the Company's cost of capital with inflation removed). Useful life is determined using a weighted average of each measure's life.

$$LC = \frac{(K \cdot CRF)}{EA}$$

where:

LC = levelized cost,
K = conservation measure's installed cost (1990 dollars),
EA = annual savings of electricity (kWh), and
CRF = capital recovery factor as determined by

$$\frac{i(1+i)^N}{(1+i)^N - 1}$$

where:

N = conservation measure's useful life (years) and
i = discount rate (nominal or real)

Table 9 shows levelized costs for the total effort and by state. It should be noted that the Total Resource Costs are slightly understated. In the early years of the programs, the installed cost was not tracked. The financed amount (in a large number of cases equal to the installed cost) was used as a proxy for installed costs.

Concluding Remark

This evaluation took a comprehensive look at past residential retrofit activities, and was not intended to address all of the issues and answer all of the questions regarding these activities. The study provides some useful insights that should aid in future residential program planning and development in the Company, as well as quantifying the impact of past efforts.

Bibliography

Fels, Margaret. *The Princeton Scorekeeping Method: An Introduction.* Princeton University, Center for Energy and Environmental Studies, Princeton, NJ, March 1984.

Hirst, Eric. *The Hood River Conservation Project—Cooperation and Community Conservation.* Oak Ridge National Laboratory, Oak Ridge, Tennessee, June 1987.

Khawaja, Muhammad, *et al. Cost Effectiveness of Conservation Programs: The Hood River Experiment.* Western Economic Association International, July 1990.

Northwest Power Planning Council. *Northwest Conservation and Electric Power Plan,* Volume II. NPPC, Portland, Oregon, April 1983.

Schoch-McDaniel, Karen. *Third Year Analysis of Electricity Use and Savings for the Hood River Conservation Project.* Pacific Power & Light, Portland, Oregon, October 1990.

Table 9. Levelized Costs: Residential Weatherization

Location	Total Resource Cost Nominal ¢/kWh	Total Resource Cost Real ¢/kWh	Utility Costs Nominal ¢/kWh	Utility Costs Real ¢/kWh	Average Installed Cost (1990$)
Total Company	5.8	3.2	4.6	2.6	1,812
Oregon	5.8	3.3	4.7	2.6	1,805
Washington	5.6	3.2	4.4	2.5	1,937
Idaho	7.8	4.4	6.0	3.4	1,539
Montana	2.9	1.6	2.1	1.2	1,050
California	6.8	3.8	7.5	4.2	2,056