THE HOOD RIVER CONSERVATION PROJECT

COOPERATION & COMMUNITY CONSERVATION

JUNE 1987

COMPREHENSIVE REPORT

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COOPERATION AND COMMUNITY CONSERVATION

June 1987

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Preface

This report presents the findings of the Hood River Conservation Project. These exacting, exhaustive, and often surprising materials describe an unprecedented effort to obtain rigorous data on the marketing and performance of residential energy-conservation measures. The investment was both prudent and profitable from the standpoints not only of our regional utility system but also of its counterparts on this continent and beyond. We are proud that the Project has secured an international audience, and we look forward to a full and rich discussion of its technical implications for electric power policy.

But the technical issues do not capture all that Hood River has meant and can mean. This project represents a new way of resolving disputes about North America's most environmentally and economically significant sector. Historically, electric utilities have been wellsprings of controversy because they matter so much in so many different debates. Whether the issue is acid rain, global climate change, disposal of radioactive waste, or the allocation of scarce private investment capital, utilities loom larger than any other industry. At the same time, of course, the heat, cooling, light, and mechanical drive that utilities provide are among the most basic and highly valued services in contemporary society.

Hood River is part of the search for ways to provide these energy services at the lowest possible economic and environmental cost. It took place far from the rhetorical battlefields of adversarial proceedings. The Project was an arrestingly successful attempt to introduce collegial processes among individuals who had never before functioned as colleagues. Traditional adversaries found a way to reframe one of their most fundamental disputes in terms that permitted cooperative solutions. In that metamorphosis is one of the great success stories of Hood River, along with the participation of more than 90 percent of the eligible population and the lowest climate-adjusted space-heating consumption ever recorded following a retrofit program.

Along all these dimensions, we are confident that the Hood River experience will prove instructive wherever electricity grids are found. Utilities, regulators, ratepayers and environmentalists will be among the winners. We salute our many colleagues and friends who showed the way and the Oregon community that helped them do it.

Ralph C. Cavanagh,
Natural Resources
Defense Council

Steven G. Hickok,
Bonneville Power
Administration

James F. Pienovi,
Pacific Power &
Light Company

Summary

The Hood River Conservation Project (HRCP) was intended to test the reasonable upper limits of a residential weatherization program. It was proposed by the Natural Resources Defense Council, funded by the Bonneville Power Administration, and operated by Pacific Power & Light Company in Hood River, Oregon. This five-year, $20 million research and demonstration project installed as many cost-justified energy-conservation measures in as many electrically heated homes in Hood River as possible. The measures were aimed at the building shell to reduce electricity use for space heating and at water-heating efficiency; no heating or water heating equipment was replaced.

The Project had two parts. One was the weatherization of Hood River homes. Energy audits were performed and measures were installed between fall 1983 and the end of 1985. The other was the research and supporting data collection, which began a year before field activity started and continued for more than a year after measures were installed. This research was critical to the Project's success because HRCP was designed to provide information on the appropriate role of Pacific Northwest utilities in securing "conservation resources."

This report summarizes both elements. Topics discussed include the background and objectives of HRCP, the Project's design and data resources, implementation and marketing efforts, household participation in the Project, weatherization measures installed, levels and changes in electricity use, Project cost-effectiveness, and several supplemental studies that used HRCP data to address issues beyond the scope of the original Project.

PROJECT DESIGN

HRCP was envisioned as a major research and demonstration project to provide information on residential weatherization programs. Therefore, before field activities began, substantial effort was devoted to planning the data collection and analysis needed to address the critical issues facing the region's utilities about such programs. The five key Project objectives were to determine:

- The effects of weatherization measures on annual electricity use and on peak demands
- The maximum penetration of the program and of the recommended measures
- The effectiveness of different marketing approaches
- The social dynamics related to the Project within the community
- The costs of the Project

A detailed evaluation plan was prepared in late 1982 to address these five objectives. The plan called for collection of extensive and detailed data on the operation and effects of HRCP. Data collection began several months before the Project officially started, with a community assessment and baseline survey being conducted in early 1983.

A Regional Advisory Group, composed of regional energy experts representing diverse interests, was established to guide the Project and to help maintain its research integrity. A Community Advisory Committee, made up of residents from different groups within Hood River, helped educate residents about HRCP and provided valuable feedback about community concerns with the Project. Both groups were established before the energy audits began.

PROJECT IMPLEMENTATION

Establishment and operation of the Project's field office, delivery of energy audits, installation of measures, and inspection of contractor work can be divided into three phases: startup, expansion, and production. The startup phase, which lasted from October 1983 through May 1984, included development of operating procedures and promotion of the Project throughout the community. Procedures were refined, and the Project's staff was increased during the seven-month expansion phase. More than three-fourths of the weatherization jobs were completed in the final year (1985).

Participants in special projects were recruited during the summer of 1983. These households played a crucial role in marketing the Project by letting their friends and neighbors know about this new activity. This unanticipated word-of-mouth publicity resulted in many requests for participation, more than the Project staff were initially prepared to handle.

Pacific Power & Light Company's (as well as Bonneville Power Administration's) corporate commitment to achieving 100% participation was a key element in the Project's success. This commitment led to substantial autonomy, informality, and flexibility for the Pacific Power & Light Company staff in Hood River. As a consequence, the staff developed a strong "can do" spirit of teamwork. In addition, the Regional Advisory Group provided strong consensus support for the Project throughout its lifetime.

PARTICIPATION

To achieve 100% participation among electrically heated homes, HRCP offered an extensive package of weatherization measures, generally installed at no cost to the household. The Project also offered "one-stop" convenience to participants; one phone call began the entire process.

HRCP was a remarkably popular program. About 91% of the eligible households received at least an energy audit; 85% of the homes had major measures installed by the Project. During the first three months of operation, more than one-fourth of the eligible households signed up to participate (Fig. S.1). This dramatic response is in stark contrast to the participation rates normally obtained in residential weatherization programs. For example, about 9%/year of the eligible households participated in the Bonneville Power Administration's regionwide Residential Weatherization Program during its first two years. The offer of free weatherization and effective marketing explain much of the difference between response rates to HRCP and to other programs.

More than half the participants first learned about the Project from a friend, neighbor, relative, or community leader. Thus, word-of-mouth was the primary information source about the Project, much more important than newspaper articles, radio, TV, or billboards. The local weekly newspaper, cited by 28% of the participants, was the second most important information source. HRCP's use of community involvement and one-on-one communication, coupled with full-cost reimbursement, can be replicated by other utilities to achieve comparable participation rates in other conservation programs.

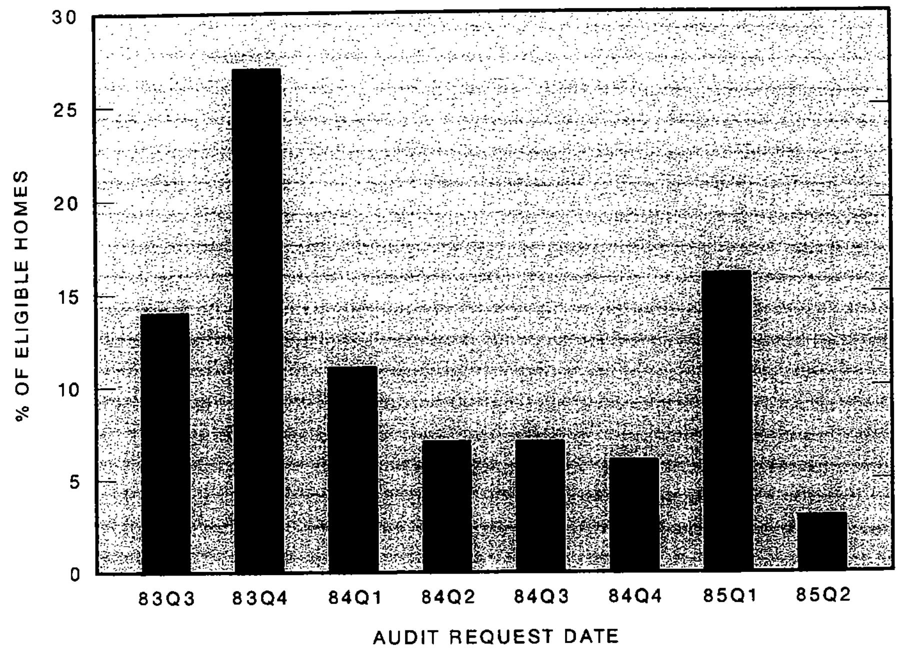

Fig. S.1. Household signups for HRCP from mid-1983 through mid-1985. By the end of 1983, about 40% of the eligible households had asked for energy audits.

The few households that were eligible but did not participate (about 250 of the 3500 eligible homes) differed somewhat from those that participated. Nonparticipants were more likely to live in single-family homes and to own their homes. Nonparticipants also had higher incomes and newer homes than did participants. Thus, in contrast to most other conservation programs, HRCP attracted larger fractions of low-income households, occupants of multifamily units, and renters.

The key factors leading to the Project's enormous success in achieving high participation levels include:

- The offer of free weatherization
- Determination on the part of HRCP staff to enlist every eligible household
- The use of community-based marketing approaches
- The reliance on extensive word-of-mouth communication among Hood River residents (begun by the Project's solicitation of households to participate in the special studies a few months before HRCP officially began)
- The early 1985 personal solicitations to the remaining nonparticipants by HRCP staff

INSTALLATION OF MEASURES

The Project paid for installation of measures up to an allowable limit based on the avoided cost of a new coal plant, roughly four times the limit in other Northwest residential weatherization programs.

Eighty-three percent of the measures recommended in the energy audits were installed. These installed measures were expected to save 6140 kWh/year (93% of the saving expected if all the recommended measures had been installed; Fig. S.2).

Ceiling insulation, storm windows, caulking, door weatherstripping, and outlet gaskets were installed in more than two-thirds of the homes. On the other hand, duct insulation and thermal doors were recommended and installed in less than 15% of the homes.

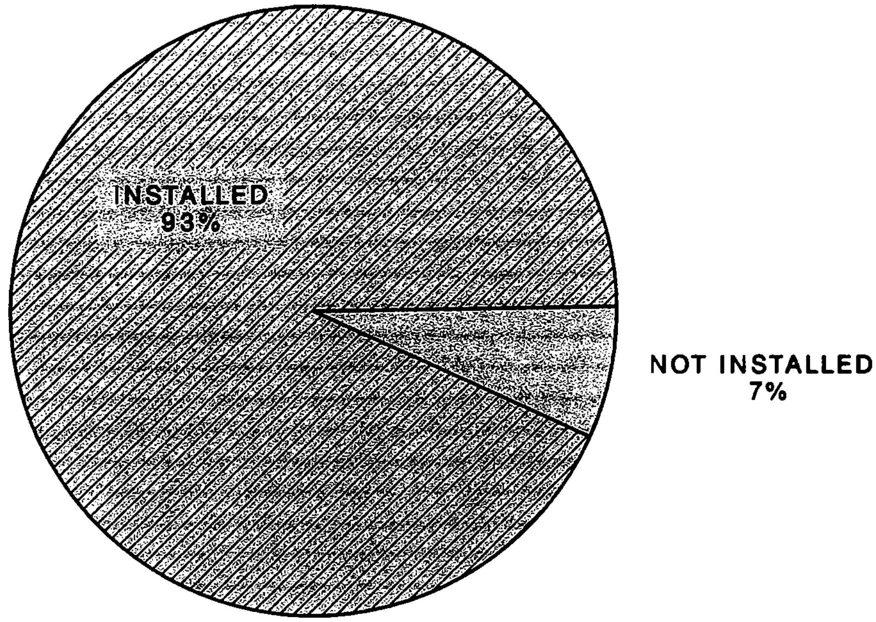

Fig. S.2. Electricity savings estimated by the energy audits for recommended measures, installed and not installed.

Overall, 46% of the 15 measures theoretically available in the HRCP package were installed, 45% of the measures were neither recommended nor installed, and only 9% were recommended but not installed (Fig. S.3). Almost half (45%) of the barriers that prevented installation arose because the measure was already partially or fully in place, which rendered further installation cost-ineffective. Physical barriers accounted for 31% of the noninstallations, noncompatible conditions for 19%, customer concerns for 4%, and other barriers for the remaining 2%.

ELECTRICITY USE AND SAVINGS

HRCP performance was assessed in two ways with respect to electricity use (Fig. S.4). One computed the actual electricity savings caused by the Project's measures. The second approach examined post-HRCP levels of electricity use.

Postweatherization electricity use (1985/86) among participants was remarkably low, averaging 16,000 kWh/year, of which space heating accounted for less than 5000 kWh. Even in single-family homes that used electricity as their primary heating fuel (i.e., used little wood), total and space-heating electricity uses averaged only 20,000 and 7000 kWh, respectively. This space-heating use is equivalent to 4.2 kWh/ft^2 (2.6 Btu/ft^2 per heating-degree day), which is less than the 5.6 kWh/ft^2 observed in recently constructed electrically heated single-family homes in the same climate zone. The low levels of post-HRCP electricity use were caused by a combination of low levels of pre-HRCP electricity use and the HRCP measures. After weatherization, the HRCP homes used less electricity for space heating than did the participants in other weatherization programs in the U.S. on a climate-adjusted basis.

Electricity use among HRCP participants before the Project began (1982/83) was less than 19,000 kWh/year, below levels expected in Hood River and below typical levels observed throughout the Pacific Northwest at that time. For example, single-family homes used about 20,000 kWh/year in Hood River, compared with almost 25,000 kWh

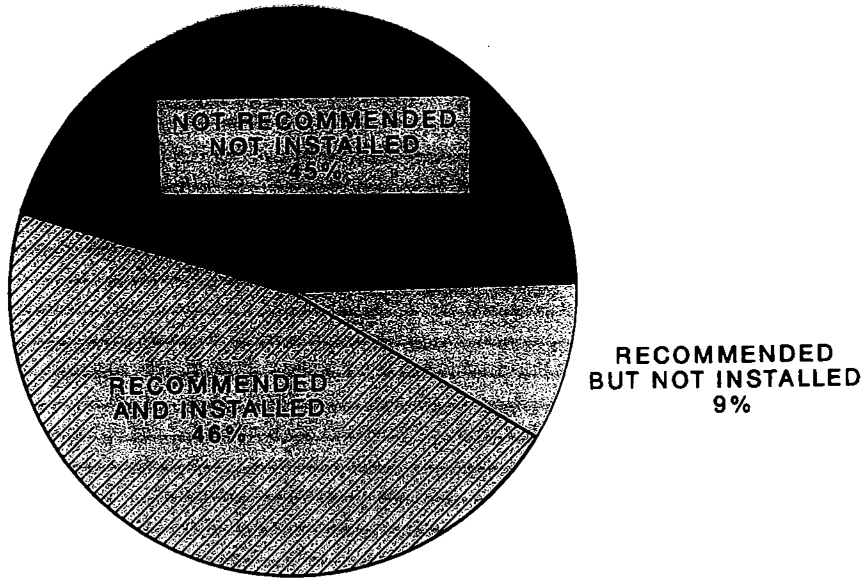

Fig. S.3. Percentages of HRCP measures recommended and installed. Slightly less than half the measures theoretically available in the Project's "package" were installed; on the other hand, 83% of the measures recommended during energy audits were installed.

throughout the region. Similarly, Hood River homes used less than 8,000 kWh/year for space heating, far below the almost 13,000 kWh observed throughout the region.

These low levels of electricity use were associated with convenient access to and use of wood, high unemployment, and dramatic increases in electricity prices; during the two years preceding HRCP, real (corrected for inflation) electricity prices rose by 40% in Hood River. Almost two-thirds of the participants used wood as their primary or supplemental heating fuel, probably because of increases in electricity prices and unemployment. Use of wood reduced annual space-heating electricity use by as much as 6000 kWh per wood-burning home. In addition, participation in prior conservation programs and growing public knowledge of how to save energy contributed to lower electricity use. Some of the lower usage reflects behavioral changes that, unlike the HRCP measures, are reversible. If electricity prices remain stable, households may relax their conservation behaviors, which will effectively increase the HRCP-induced savings.

The reduction in electricity use (pre-HRCP minus post-HRCP; 1982/83 minus 1985/86) in weatherized homes averaged 2600 kWh/year (15% of preweatherization use), almost entirely because of reductions in space heating. Multifamily homes, mobile homes, and single-family homes that used electricity as their secondary heating fuel saved less than the average (Table S.1). On the other hand, single-family homes that had not participated in earlier weatherization programs saved 3050 kWh, much more than that saved by the 1985 participants in the Bonneville Power Administration's regionwide weatherization program (2000 kWh). However, HRCP spent an average of $5400/house on measures and program administration, compared with $2300 for the Bonneville Power Administration program.

The actual savings averaged only 43% of those predicted during energy audits of these homes. Differences between actual and predicted savings can be attributed to typical discrepancies between actual savings and audit estimates, to pre-HRCP reductions in electricity use, and to post-HRCP changes in energy-related behaviors (e.g., higher indoor temperatures and less use of wood).

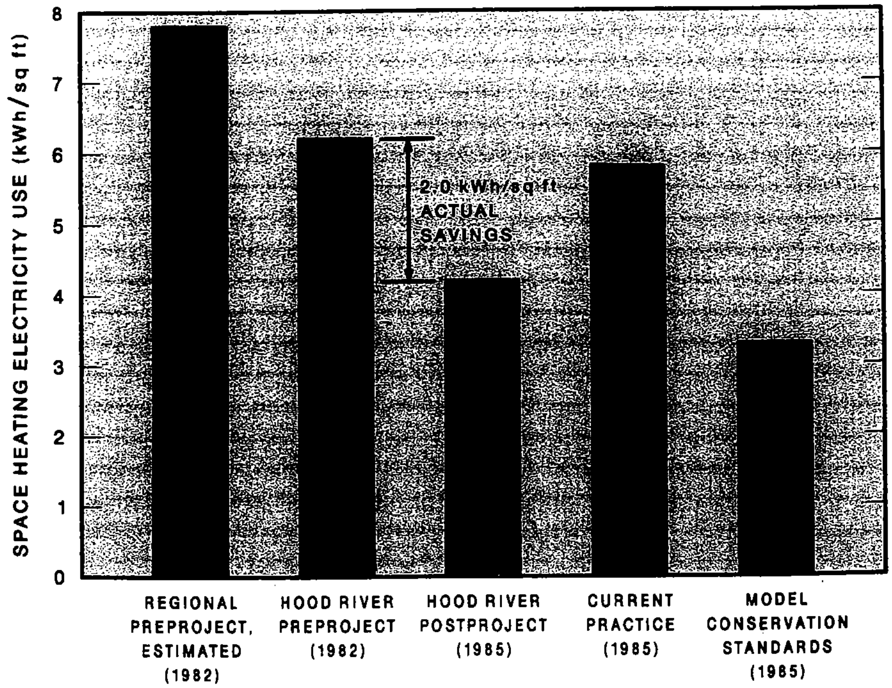

Fig. S.4. Comparison of annual electricity use for space heating in single-family homes.

The most important reason for HRCP's small savings was probably the low level of pre-HRCP electricity use. Had electricity use averaged 25,000 kWh in 1982/83 rather than 19,000 kWh, the savings would have been about 4,000 kWh. Other factors also contributed to the modest electricity savings. Households took the efficiency improvements provided by HRCP measures in terms of both reduced electricity bills and increases in comfort and convenience. For example, reductions in wood use (pre- vs post-weatherization) increased electricity use, thereby cutting electricity savings by roughly 300 kWh. This 300 kWh reduction in wood use is attributable to behavioral changes and is in addition to a roughly 1500 kWh reduction associated with proportional savings in wood and electricity uses for space heating. Also, indoor temperatures increased slightly by an average of 0.6°F after weatherization, which cut electricity savings by an additional 300 kWh/year.

LOAD REDUCTIONS

HRCP measures affected peak demands (kW) as well as annual electricity use (kWh). Reductions in demand at the time of system peak can reduce capital costs associated with the construction of power plants intended to meet peaks, transmission lines, and distribution systems. The reduction in demand at the time of Pacific Power & Light Company's system peak averaged 0.5 kW/house (about 10%). Load reductions increase as outdoor temperatures drop. The reduction for all-electric single-family homes was about double the average reduction.

COSTS

The HRCP budget was $20 million, split between implementation and research. Implementation costs totaled $14 million, of which almost 80% was spent on installation of weatherization measures. Energy audits cost $171,000, air-to-air heat exchangers and

Table S.1. Electricity savings for homes weatherized by HRCP

House type	Electricity savings (kWh/year)	Percentage of weatherized homes
Single-family	2900	65
Primary electric	(4000)	(15)
Other	(2600)	(50)
Multifamily	1600	17
Mobile home	2500	18
Average	2600	
Total		100

other air-quality activities cost $1.3 million, and administration (including marketing and computer costs) totaled $1.6 million. Thus, administrative costs amounted to about 14% of the costs of weatherization materials and installation.

The average cost of HRCP-installed measures, including administrative expenses, was $4400/house (exclusive of the air-to-air heat exchangers), of which the Project paid 99%. Only 10% of the households paid anything for measures; their average payment was $430.

Weatherization costs increased with house age because improvements in construction practices, stimulated by higher fuel prices and new construction standards, reduced the need for and cost of measures in newer homes. For example, the costs were roughly three times higher for homes constructed before 1945 than for homes built after 1979.

The research and evaluation costs amounted to almost $5 million. The largest cost (almost $2 million) was for equipment to collect end-use load data from 320 Hood River homes.

PROJECT ECONOMICS

Assessments of the costs to achieve HRCP savings (i.e., comparison of benefits and costs) must be approached with caution because of the Project's research focus. These research goals led to tests of the maximum number and extent of measures that were possible candidates for inclusion in future regional conservation programs. As expected, some measures and program-design features were more costly than others, so the total cost represents a meld of measures and design characteristics that include both "winners" and "losers." The data base established by the Project allows energy planners to estimate the cost of saved energy for a range of alternative program designs.

HRCP economics can be considered from two perspectives. One is retrospective, focuses on the measured electricity savings, and probably underestimates the Project's economic benefits in this instance. Averaged over all weatherized homes, the annual savings were 2600 kWh/house. The average cost to achieve these savings was $4400/house, equivalent to $1.70/annual kWh actual saving, substantially higher than the cost-effectiveness limit ($1.15/kWh). Annualizing the $4400 cost (at a 3% real discount rate and a 44-year lifetime) yields a cost of conservation of 7.1¢/kWh, higher than the 5.0¢ used by the Northwest Power Planning Council as the cost limit for conservation programs. These calculations give no credit to HRCP for increases in comfort and convenience associated with less use of wood and warmer homes. Nor do the calculations account for possible savings in transmission and distribution costs because of reductions in load at the time of system peak. Finally, environmental benefits associated with reduced electricity generation are not computed.

The second perspective, which probably overestimates HRCP benefits in this case, is that of a utility planner deciding among alternative strategies to meet long-term power needs. When HRCP was being designed, utility estimates of space-heating electricity use averaged 13,000 kWh/year for single-family homes in the Pacific Northwest; final Hood River figures for single-family homes with little or no wood heat were 6000 kWh lower. Utilities did not predict the decline in electricity use that occurred in Hood River (and other communities) during the early 1980s, and given the reversibility of much of the savings, there will be understandable reluctance to assume that such patterns can be sustained indefinitely without utility intervention. When predicting long-term system needs, utilities cannot count on independent customer actions that result collectively in large reductions in electricity use; this is one reason why utilities invest directly in customer conservation measures.

The ability to plan confidently for post-weatherization loads that are 6000 kWh below forecast estimates would allow a utility to avoid an equivalent commitment to new generating capacity. These planning savings were obtained in Hood River at an average cost of $5600 per single-family house heated primarily with electricity, or 3.7¢/kWh.

SUPPLEMENTAL STUDIES

HRCP's focus on providing high-quality information to support decisions about residential weatherization programs led to development of an extensive data base. These data turned out to be valuable for purposes that went beyond the original HRCP objectives. In fact, several additional studies were conducted that relied on these data:

- A random sample of 75 Hood River participants received the "House Doctor" treatment to reduce infiltration in addition to the usual HRCP measures.
- Results obtained with an engineering model that calculates electricity use for space heating were compared with end-use load data from Hood River homes.
- The data collected from several surveys, both in Hood River and in the Pacific Northwest, were used to assess the extent to which Hood River results could be generalized to the region as a whole. (The primary conclusion is that the lessons learned from HRCP can be applied to regional energy planning.)
- Results obtained with a widely used method to adjust monthly electricity billing data for differences in winter severity were compared with the end-use load data.
- The end-use load data were used to examine electricity use and savings for water heating, changes in indoor temperatures after weatherization, and use of wood for space heating.
- Because these data are so valuable, end-use load data will be collected for at least two more years. Monthly billing and survey data will also be collected to assess the durability of electricity savings produced by HRCP measures.

In summary, HRCP demonstrated the feasibility of gaining nearly 100% participation from eligible households in an aggressive weatherization program. Probably because of the substantial financial incentives and the commitment to achieve high penetration rates, 85% of the electrically heated homes installed most of the recommended measures. The measured reductions in electricity use were substantially below initial expectations, pri-

HRCP Facts, Figures, and Findings

A five-year demonstration (1983-1987), funded by Bonneville Power Administration and run by Pacific Power & Light Company, focused on information needed for regional energy planning about residential weatherization potentials.

Aimed at weatherizing 100% of electric-heat homes in Hood River with an extensive set of measures installed at no cost to the households.

Cooperation was key element of Project, included participation from Bonneville Power Administration, Pacific Power & Light Company, Natural Resources Defense Council, Northwest Power Planning Council, Northwest Public Power Association, Pacific Northwest Utilities Conference Committee, and others.

Achieved almost complete participation:
- 91% of homes received energy audits,
- 85% of homes had major measures installed, and
- participation even greater from renters and other hard-to-reach groups than from single-family homeowners.

Most (83%) of the recommended measures were installed, accounting for 93% of estimated electricity savings.

Electricity savings (2600 kWh/year, 15% of pre-Project levels) were less than expected, primarily because pre-HRCP electricity use was very low.

Post-HRCP electricity use among primary-electric single-family homes was very low, better than either typical new-home construction or postweatherization levels achieved in other programs.

Project cost $20 million (75% fieldwork and 25% data and analysis); weatherization costs averaged $4400 per house.

marily because pre-HRCP levels of electricity use were already quite low. On the other hand, the combination of HRCP savings and low prior levels of usage led to very low levels of electricity use after HRCP, lower than those in typical new homes constructed during the early 1980s and far below levels obtained in other weatherization programs throughout the U.S.

In addition, HRCP showed that groups that are normally adversaries can design and implement an important project and see it through to completion. The Regional Advisory Group, which included a diversity of interests within the region, met monthly from 1982 to the present. This group guided the project through its difficulties and was largely responsible for the Project's delivery of high-quality information on residential weatherization programs.

HRCP results have already proven useful, to both the Bonneville Power Administration (in their review of residential conservation programs) and the Regional Council (in development of their regional plan). The value of HRCP results stems from the high-quality data collected by the Project and the ongoing attention to process and results from the Regional Advisory Group.

List of Acronyms

Bonneville	Bonneville Power Administration
CCE	Cost of conserved energy
Council	Northwest Power Planning Council
EUM	End-use monitored homes
HDD	Heating degree days
HRCP	Hood River Conservation Project
HREC	Hood River Electric Cooperative
NOAA	National Oceanic and Atmospheric Administration
NRDC	Natural Resources Defense Council
NWPPA	Northwest Public Power Association
ORNL	Oak Ridge National Laboratory
OSU	Oregon State University
Pacific	Pacific Power & Light Company
PNUCC	Pacific Northwest Utilities Conference Committee
PNW	Pacific Northwest region
RWP	Residential Weatherization Program

Introduction

PROJECT OVERVIEW

The Hood River Conservation Project (HRCP) was a major residential retrofit demonstration, proposed by the Natural Resources Defense Council (NRDC), operated by Pacific Power & Light Company (Pacific), and funded by the Bonneville Power Administration (Bonneville). The project sought to install as many cost-effective retrofit measures in as many electrically heated homes as possible in the community of Hood River, Oregon. The retrofits were aimed at the building shell to reduce electricity use for space heating and at water-heating efficiency; no heating or water heating equipment was replaced. Major retrofit measures were installed in nearly 3000 homes, yielding a remarkably high 85% participation rate among the 3500 electrically heated homes in the area.

The Project had two principal components. One was the actual delivery of retrofits to Hood River homes. Energy audits were conducted and measures were installed between fall 1983 and the end of 1985. The second component was the research and supporting data collection, which began a year before field activity started and continued for more than a year after retrofits were installed. Substantial effort was devoted to data collection and analysis because the Project was an experiment, intended to address important energy policy issues for the Pacific Northwest.

The $20 million project involved higher levels of conventional measures than generally offered in weatherization programs in the Pacific Northwest [e.g., R-49 ceiling insulation rather than the R-38 generally recommended in the Bonneville Residential Weatherization Program (RWP)]. In addition, the Project paid for the installation of these measures up to a limit of $1.15/first-year estimated kWh saving, equivalent to an annualized cost of 5.3¢/kWh-saved, based on the cost of a new coal plant. That limit is almost four times the limit in the Bonneville RWP. Thus, HRCP offered the chance to examine levels of retrofit installation and subsequent electricity savings when cost to the household and prior retrofit activities are largely removed as barriers.

The town and county of Hood River (plus the town of Mosier in Wasco County) were selected as the location for this demonstration because the area is geographically delimited; includes a diversified economy, population, and housing stock; is served by both public and private utilities [Hood River Electric Cooperative (HREC) and Pacific]; and includes climate zones representative of the Pacific Northwest. Hood River lies along the northern edge of Oregon by the Columbia River, 60 miles east of Portland, in the transition zone between the western marine-influenced weather and the drier and colder climate east of the Cascade Mountains. Hood River County has a population of about 15,000. Roughly two-thirds of the 6,200 residences are served by Pacific, and the remainder by HREC.

The contract between Bonneville and Pacific to initiate this project was signed in May 1983 after almost two years of negotiation and planning. Energy audits were first offered in fall 1983 and installation of retrofit measures began in early 1984. Roughly 15% of the retrofit installations were completed in 1984, with the remainder done in 1985. All Hood River households were eligible for a free home energy audit. However, the Project paid for installation of measures only in homes with permanently installed (before March 1983) electric space heating equipment. Of the 3500 eligible households, 2989 (85%) received one or more HRCP-financed major retrofit measures. An additional 200 homes (6%) received an energy audit only.

HISTORICAL BACKGROUND

The roots of HRCP extend back to the 1970s, a period during which the Pacific Northwest expected serious electricity deficits during the 1980s. Because of these looming electricity shortfalls and their likely adverse effects on the region's economy, considerable urgency surrounded discussions over appropriate resources to develop. Bonneville and the region's electric utilities advocated construction of large central-station coal and nuclear power plants. Environmentalists, on the other hand, argued that aggressive utility conservation programs were viable and economically attractive alternatives to major power-plant construction programs. For example, NRDC successfully sued Bonneville in 1975 to force evaluation of alternatives to the large-scale power plants that dominated the region's utility planning; this litigation took five years to resolve.

The Project objectives were to determine the effects of weatherization on annual electricity use and on peak demands, the maximum penetration obtainable, the effectiveness of different marketing approaches, the social dynamics, and the costs.

During this period, several studies were prepared that identified large untapped conservation opportunities in all sectors of regional electricity use. Environmentalists saw in these results a justification for canceling or deferring several large power plants then under construction. The region's utilities disagreed, claiming that the conservation estimates overstated both participation rates and the cost-effective savings that such programs could deliver.

In 1980, the U.S. Congress (1980) passed the Pacific Northwest Electric Power Planning and Conservation Act to provide a mechanism for resolving regional energy disputes. The Act anticipated a regional power plan that would serve a growing economy's energy-service needs at the lowest possible cost. Conservation was to be assessed on equal terms with generation as a source of new power supply. The planning function was vested in a new, four-state agency called the Northwest Power Planning Council (Council), which was directed to develop long-term conservation and electric power plans for the region (Northwest Power Planning Council 1983 and 1986).

As the Council was developing its initial plan during 1981 and 1982, the same arguments were raised about treating conservation as a resource comparable to power plants. Once again, the utilities claimed that conservation was an uncertain, small, and expensive resource. Once again, environmentalists claimed that well-designed programs could capture much of the large potential for cost-effective efficiency improvements. Both groups agreed that conservation programs had not yet been adequately tested in the field; that is, insufficient empirical evidence was available on which to base long-term power planning decisions.

In October 1981, NRDC proposed a conservation demonstration project to Pacific executives[1] to help resolve disputes about the appropriate role of conservation in the region (Cavanagh 1986). The proposal was also seen as a way to address the longstanding controversy in a productive, nonadversarial fashion. Pacific and NRDC collaborated in the preparation of a funding proposal, which was submitted to Bonneville in February 1982. After several months of discussion and review among many organizations, which included the Council, the Pacific Northwest Utilities Conference Committee (PNUCC), the Northwest Public Power Association (NWPPA), and HREC, Bonneville agreed to fund the Project. Several months were required for detailed contract negotiations. In May 1983 two contracts were signed between Bonneville and Pacific, one for $13 million for the weatherization program (which included HREC also) and one for $7 million to fund the research and evaluation effort.

OBJECTIVES OF HRCP

The Project was intended to provide information (data and analysis) to reduce controversies about the appropriate role of the region's utilities in securing "conservation resources." Given the expectation of imminent electricity deficits, NRDC and Pacific envisioned a demonstration to test the limits of cost-effectiveness. They intended to construct a "conservation power plant" in a single community as quickly as possible. Thus, the Project had three fundamental goals: provide accurate and credible information to the region's energy planners on conservation resources, determine how quickly homes in a particular community could be retrofit, and determine how much conservation could be obtained. This type of field experiment was, and still is, unique!

[1]Pacific had been offering free energy audits to its customers since 1977. In 1978, the program was expanded to include zero-interest loans to finance installation of recommended retrofits in electrically heated homes. Thus, Pacific had substantial prior experience with conservation programs.

Table 1. Key objectives of the Hood River Conservation Project

1. Determine the effects of residential retrofit measures on: the transmission and distribution system individual customer load shapes (kW) overall electricity use and savings (kWh)
2. Determine the maximum reasonable penetration rates of: the program (household participation) individual retrofit measures installed
3. Determine the effectiveness of different approaches to conservation marketing
4. Assess community social interactions and impacts during the Project
5. Measure the costs associated with the Project

Source: Pacific Power & Light (1982).

In addition to these broad goals, the Project had five specific objectives (Table 1). These objectives dealt with the effects of the program on electricity use, participation in the project, the marketing activities that induced participation, the dynamics of social interactions within the community as the Project evolved, and the costs of running this aggressive Project. Staff from Pacific, NRDC, Bonneville, and other organizations developed a detailed evaluation plan in 1982 to address each of the five objectives. This plan was then reviewed by staff at the Oak Ridge National Laboratory (ORNL), who subsequently conducted much of the evaluation. Thus, a critical element in HRCP was the careful planning of the evaluation and associated data collection well before the Project itself began.

PROJECT ACTIVITIES

Planning for HRCP occurred throughout 1982 and 1983. In early 1983, almost a year before the Project began, Pacific contracted with a sociologist to conduct a community assessment. This assessment was used in deciding how best to market the Project.

A mail survey of households in Hood River and two comparison communities (Grants Pass and Pendleton, Oregon) was also conducted in early 1983. This survey measured demographic characteristics, attitudes, and energy conservation behaviors before the Project began. The post-HRCP counterpart, conducted in early 1986, provided similar information after the Project was completed.

The HRCP field office was staffed during late summer 1983, and the office officially opened its doors in October. Almost a thousand households (one-third of all those eligible) requested energy audits during the first three months. Audit requests were accepted through July 1985. All retrofit work was finished by the end of 1985 with about 85% having been completed that year.

Load-research meters were installed in the homes of a random sample of 320 Hood River homes in early 1984 to measure electricity uses for specific end uses at 15-minute intervals. These households had been recruited in mid-1983, but several factors delayed installation of the equipment. Detailed onsite interviews were conducted with these households in July 1984 to obtain demographic, structure, and appliance data on their [end-use-monitored (EUM)] homes.

Other surveys of Hood River households were conducted in late 1985 and in 1986 to collect information on reasons for nonparticipation in HRCP and patterns of wood use. Electricity-use data (both monthly bills and the load research data) were required through mid-1986 to provide a full winter after retrofit (1985/86); these data became available in the summer of 1986. Data analysis continued through early 1987, culminating in this comprehensive report.

CONTENTS OF THIS REPORT

This report summarizes more than a dozen major studies that addressed the five HRCP objectives. Chapter 2 discusses HRCP design and the data resources that were assembled to address its objectives. Chapter 3 describes the implementation process; unlike most program descriptions, which discuss only successes, HRCP included serious and independent efforts to identify and document problems encountered in running the Project (Brown 1986; Philips et al. 1986).

Chapter 4 summarizes the marketing efforts undertaken to achieve high participation levels (Social Impact Research 1983; Engels 1985; Engels, Kaplon, and Peach 1985). The chapter also documents the success of these efforts in gaining very high participation levels (Hirst and Goeltz 1986b) and in achieving high installation rates for most retrofit measures (Goeltz and Hirst 1986). Chapter 5 describes the patterns and trends of electricity use in Hood River and the two comparison communities, based on monthly billing data and the load research data (Hirst, Goeltz, and Trumble 1987; Stovall 1987). These data are then used with the cost information to assess the Project's economic benefits and costs in Chapter 6.

Chapter 7 briefly discusses several supplemental studies. These studies were not aimed directly at the five HRCP objectives. However, the existence of the Project's large, rich, high-quality, and well-documented data base permitted analysis of related issues. These studies examined the energy savings of the House Doctor approach; the accuracy of a simulation model used to estimate space-heating electricity use; the validity of a widely used weather-adjustment method; and changes in wood use, indoor temperatures, and electricity use for water heating after HRCP retrofits.

Project Design and Data Resources

PROJECT DESIGN

HRCP was intended to test the reasonable upper limits of a utility retrofit effort, reflecting then-current concerns about impending electricity deficits and the need for balanced long-range planning (Pacific Power & Light Company 1982 and 1983; Peach et al. 1983). Planners were interested in how much "conservation energy" could be obtained in a short time. Therefore, HRCP was based on the notion that the utility (Bonneville in this case) would purchase conservation resources from customers by funding installation of all cost-effective measures. To test that notion, financing was available only for homes with permanently installed (before March 1983) electric space heating equipment.

The allowable incentive level was based on an assumed average lifetime of 35 years for these measures, reductions in transmission and distribution losses, the 10% credit for conservation specified by the regional power act, and the avoided costs associated with a new coal-fired baseload power plant (Table 2). These assumptions led to an allowable expenditure on retrofit measures of $1.15 per estimated first-year kWh saving.[2] In other words, HRCP would pay all the costs associated with installation of measures that were expected to save enough electricity to meet the $1.15/kWh limit; households could pay the difference for those measures that cost more than the limit.

The HRCP limit, roughly four times higher than that used in the Bonneville Residential Weatherization Program, permitted installation of an extensive set of measures (Table 3). For example, triple-glazing was the target level for windows, rather than double-glazing.

Hood River was selected as the location for this experiment for several reasons. The primary selection criterion "was the ability of the study area to represent other communities of the Pacific Northwest" (Pacific Power & Light Company 1982). Hood River is geographically delimited, which made it possible to test different marketing strategies and to compare changes in Hood River with those in comparison communities. Hood River includes a range of construction vintages and house types, which allowed examination of retrofit effectiveness by house type and age. The area includes a mix of household characteristics (ages, sexes, and occupations) and locations (urban, suburban, and rural). The Hood River economy is diversified and was expected to follow roughly the same economic trends as the region. The area is served by both public and private utilities, which permitted comparison of results in service territories with different electricity prices and price increases. Finally, Hood River is close enough to Pacific headquarters to permit administrative access and support, but far enough from Portland (60 miles) to be unaffected by Portland's media attention to energy issues and the Project itself.[3]

EVALUATION PLAN

The emphasis on development of accurate and credible information about conservation resources led to substantial efforts, before field work began, to plan the data collection and analyses needed to address the five HRCP objectives (Table 4). Data collection began almost a year before field work started, with the community assessment and pretest mail survey. Data collection continued through summer 1986 (wood-use survey, monthly electricity bills, and load-research data), and analysis of energy and load effects continued through early 1987. As discussed in Chapter 7, collection of data will continue until 1989.

[2]The HRCP cost-effectiveness limit was very close to that specified by the Northwest Power Planning Council (1983) in their initial plan.

[3]This was an important issue because Bonneville, the Council, and Pacific (as well as Portland General Electric and the Pacific Northwest Utilities Conference Committee) are all headquartered in Portland.

Table 2. Basis for incentive level for HRCP retrofit measures

Component	Existing programs	HRCP
Discount rate (%/year)	13.7 nominal[a]	3.8 real
Lifetime of measures (years)	20	35
Preference for conservation (%)	0	10[b]
Adjustment for transmission and distribution losses (%)	10 total	10 energy 16 capacity
Power plant load factor (%)	70	70
Cost of generating resources (¢/kWh)	1.5–3.0	Bonneville LRIC[c]
Resultant cost-effectiveness limit (1983-$/first-year kWh saved)	0.32	1.15

Source: Pacific Power & Light (1982).

[a]Assuming a 5% inflation rate, 13.7% is equivalent to an 8.3% real discount rate.

[b]The Pacific Northwest Electric Power Planning and Conservation Act assigned a 10% preference to conservation resources to account for social and environmental costs of generation resources.

[c]This is Bonneville's study of their long-run incremental costs, based on a new baseload coal plant (Bonneville Power Administration 1982).

A critical element of HRCP's success in meeting its objectives was the Regional Advisory Group. The Group, comprised of technical staff from organizations interested in HRCP, met monthly to manage the Project (Table 5). Although Bonneville was the Project's primary funder and Pacific had primary management responsibility, neither organization made unilateral decisions concerning either the fieldwork or the research. In general, consensus views developed during Regional Advisory Group meetings determined the course of action. The Group was particularly helpful in maintaining the technical integrity and credibility of the research effort.

Two communities (Fig. 1) served as comparisons (i.e., as statistical controls) to help measure the HRCP-induced changes in Hood River. To ensure comparable changes in electricity rates, the search for comparison communities was limited to areas served by Pacific in Oregon (Pacific Power & Light Company 1982). The communities also had to be far enough away from Hood River and Portland to be largely unaffected by HRCP publicity. Grants Pass (and the surrounding Pacific service area in Josephine County) and Pendleton (and the surrounding Pacific area in Umatilla County) were selected because they met the above criteria and were similar to Hood River in terms of per-household electricity use, saturation of electric space heating, climate, and unemployment levels.

DATA RESOURCES

Data were collected from several sources to use in analysis of program process and effects (i.e., to address the issues listed in Table 4). Results obtained with the data related to the Project's operations are discussed in Chapters 3 and 4. Results obtained with the data related to the Project's effects are discussed in Chapters 4, 5, and 6. Both sets of data contributed to the supplemental studies discussed in Chapter 7.

HRCP Effects

The data available for analysis of HRCP performance (Table 6 and Fig. 2) include detailed information on participant households, available largely from

Table 3. HRCP conservation measures

Measure	Target level
Home energy audit	All electrically heated homes[a]
Ceiling insulation and appropriate ventilation	R-49
Floor insulation[b]	R-38
Wall insulation	R-11 to R-19
Cold and hot water pipe insulation to water heater[c]	R-3
Dehumidifiers and air-to-air heat exchangers[d]	As required
Clock thermostats	Where applicable
Duct insulation	Crawl space R-11, attic R-30, where applicable
Storm windows and thermal replacement sash and glazing	Triple-glazing
Thermal doors and double-glazed sliding doors	Where applicable
Caulking and weatherstripping	Where applicable
Outlet and switchplate gaskets[c]	Where applicable
Heat pump conversion of existing furnace system[d]	Where appropriate conventional measures cannot be installed
Electric water heater wraps[c]	R-11
Low-flow showerheads and other hot water flow regulators[c]	As required

Source: Peach et al. (1984).

[a]Audits were provided to homes heated with nonelectric fuels, primarily to maintain good relations with the community.

[b]Includes insulation of hot and cold water pipes, if under the floor.

[c]These four low-cost measures were installed by the auditor at the time of the energy audit or soon thereafter.

[d]These measures were installed only in special circumstances.

Table 4. Key objectives of HRCP and research plans to address them

Objective	Actions taken to achieve objective
1. Determine the effects of residential retrofit measures on:	
a. The transmission and distribution system	Monitor distribution feeders in Hood River
b. Individual customer load shapes (kW)	Install four-channel end-use meters on 320 homes; conduct detailed interview with their occupants
c. Overall electricity use and savings (kWh)	Collect monthly electricity bills for HREC and Pacific households in Hood River and for households in comparison communities; collect NOAA weather data for three communities; collect survey data from samples of households in three communities
2. Determine the maximum reasonable penetration rates of:	
a. The program (household participation)	Maintain detailed Project records on requests for participation and on participants
b. Individual retrofit measures installed	Maintain detailed Project records on measures recommended during energy audits and installed by HRCP
3. Determine the effectiveness of different approaches to conservation marketing	Conduct pretest and posttest surveys among households in three communities; track requests for participation over time with Project data base
4. Assess community social interactions and impacts during the Project	Conduct sociological community assessment before HRCP begins; interview residents, HRCP staff, and contractors during Project
5. Measure the costs associated with the Project	Track costs by type with Project data base

Source: Pacific Power & Light (1982).

Table 5. Membership in the HRCP Regional Advisory Group

Bonneville Power Administration
Hood River Electric Cooperative
Natural Resources Defense Council
Northwest Power Planning Council
Northwest Public Power Association
Pacific Northwest Utilities Conference Committee
Pacific Power & Light Company

the Project data base. Data collected as part of the participation process include information on participant homes and the appliances therein, demographic characteristics of the household, the measures recommended and installed, cost of the installed measures, and the dates of participation (audit, beginning of installation, and completion of retrofits). The Appendix in Philips et al. (1986) includes the 19 HRCP data collection forms.

The primary data sets used to analyze changes in electricity use were the participants' monthly electricity bills from Pacific and HREC and daily temperature data from the NOAA weather station in Hood River, all available from 1980 through June 1986. We used 1982/83 as the preparticipation period and 1985/86 as the postparticipation period.

Detailed electricity end-use data (to determine how much electricity was used for specific purposes as a function of time) were obtained from a 10% random sample, consisting of 320 participant homes. Information on total, space heating, and water heating electricity uses as well as indoor temperatures were collected at 15-minute intervals in these homes, from mid-1984 through mid-1986. Wood-heat sensors were used in place of the water-heating electricity use monitors in 100 of these homes. Detailed weather data (also recorded at 15-minute intervals) were obtained from three weather stations in Hood River County. Because these EUM homes were all retrofit in mid-1985, a full year of preretrofit and a full year of postretrofit load data were available for analysis. Finally, these EUM households were interviewed in July 1984 to collect information on their demographic, structure, and appliance characteristics. Because the data available on these homes is unusually rich (monthly electricity bills, detailed Project data on retrofit measures recommended and installed, four-channel end-use load data, and the onsite home interview), collection of load data was extended for another three years (to 1989).

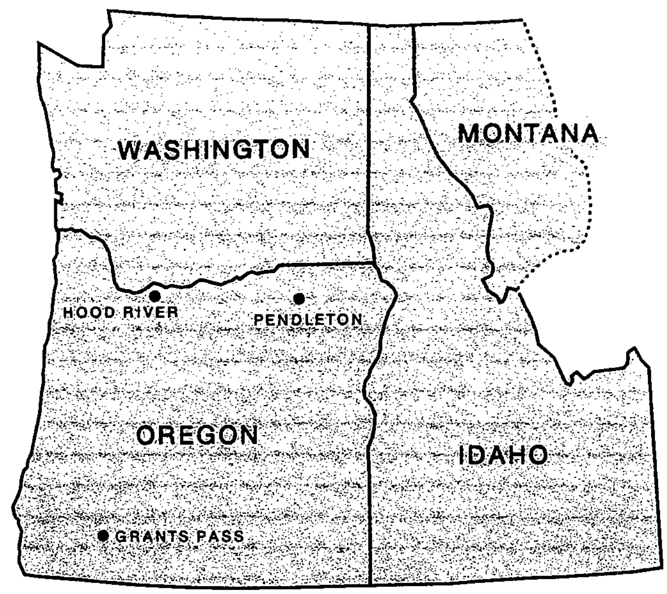

Fig. 1. Map of the Pacific Northwest showing the location of Hood River and the two comparison communities (Pendleton and Grants Pass).

In addition, substantial information on random samples of households in Hood River and the two comparison communities was collected. These data include monthly electricity bills for all households in the three communities.

National Oceanic and Atmospheric Administration (NOAA 1982 and 1984) weather stations provide daily temperature data for locations in each of the three communities: Hood River Experiment Station in Hood River, Cave Junction in Grants Pass, and Pendleton Station in Pendleton.

Additional data on household characteristics, household attitudes, dwelling unit characteristics, retrofit measures installed, residential electricity prices, and other factors were obtained from the 1983 pretest survey and the 1986 posttest survey (Berg and Bodenroeder 1983 and 1986). These data were used in the energy analysis to help determine the net electricity-saving effects of HRCP and to understand changes in energy-related behaviors and attitudes among the three communities over this three-year period.

Two surveys were conducted towards the end of the Project. The nonparticipant survey helped identify the few Hood River households eligible for participation that did not participate and their reasons for so doing. Results of this survey were used in analysis of program participation. The wood-use survey examined

Table 6. Data used in evaluation of HRCP effects

Data	Collector	Content
Pretest (1983) mail survey	Oregon State University	Random samples of households in Hood River, Grants Pass, Pendleton, and PNW region
Household monthly electricity bills and rate schedules	Pacific and HREC	Households in Hood River, Grants Pass, and Pendleton
Detailed and daily weather data	National Oceanic and Atmospheric Administration; University of Oregon	NOAA weather stations in three communities; three detailed weather stations in Hood River
End-use load data	Pacific	320 homes in Hood River; 15-minute data on total, space, and water heat electricity use, and indoor temperatures; wood-heat sensors replace water heater load in 100 homes
Onsite home interview	Bardsley & Haslacher	320 load-metered homes, conducted in July 1984
Load monitors on one feeder line	Pacific	
Project data	Pacific	Participating households: Marketing questionnaire Demographics and appliance data Energy audit results Barriers to retrofit measures Water heating measures installed Cost-effectiveness results Postinstallation inspection
Nonparticipant survey	Bardsley & Haslacher	Telephone interviews in late 1985 with eligible households that did not participate in HRCP
Wood heat survey	Columbia Research and Pacific	Mail survey in mid-1986 to determine ownership of wood burning equipment and wood use for space heating
Posttest (1986) mail survey	Oregon State University and Pacific	Random samples of households in Hood River, Grants Pass, Pendleton, and PNW region

Source: Hirst, Goeltz, and Trumble (1987).

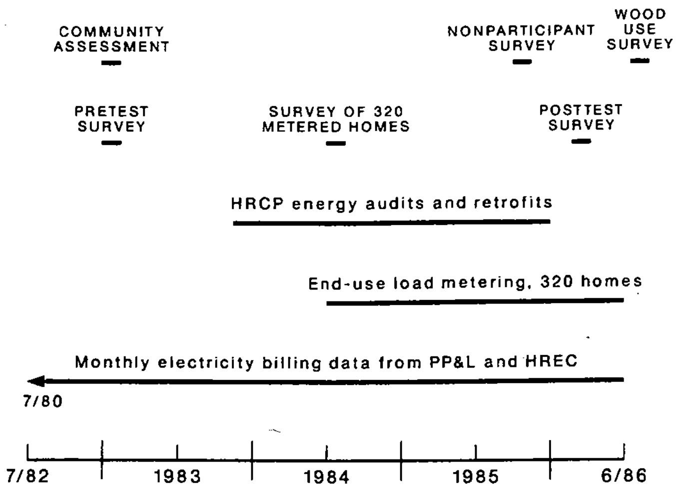

Fig. 2. Timeline of HRCP showing the key elements of project implementation and data collection.

levels of wood use in 1984/85 and 1985/86 for a sample of participants. This information was used to help understand trends in electricity use.

HRCP Operations

The data on HRCP performance were also used to assess the HRCP process and activities (Table 7). In addition, several activities were undertaken to assist in program implementation and to understand better the perspectives of the people involved with program implementation (Hood River residents, Pacific staff in the Project office and in headquarters, and contractors).

The community assessment was based on a series of interviews with Hood River residents, conducted in early 1983. Its recognition of diverse groups within Hood River and their attitudes towards large government and utility organizations helped shape HRCP marketing efforts.

The process evaluation included 24 rounds of informal interviews with Hood River residents, conducted between September 1983 and February 1986. These open-ended interviews helped Project staff understand community perceptions of, information sources about, and attitudes towards HRCP. Similar interviews were conducted with those responsible for supplying HRCP services: the Pacific staff and the retrofit contractors.

In summary, HRCP involved collection, organization, and management of data on a scale unheard of in any other energy conservation program. The amount, variety, and high quality of this data were crucial to the Project's success in addressing its objectives.

Table 7. Data collected on HRCP process and activities

Data	Collector	Content
Community assessment	Social Impact Research, Inc.	Interviews with 60 Hood River residents in early 1983
Pretest (1983) mail survey	Oregon State University	Random samples of households in Hood River, Grants Pass, and Pendleton
Process evaluation	Social Impact Research, Inc.	Interviews with 329 Hood River residents, 32 Pacific/HRCP staff, and 14 contractors
Monthly reports to Bonneville	Pacific Power & Light	Summary of monthly activities
HRCP Project data base	Pacific Power & Light	Information on all HRCP participants, contractors, dates of project actions, and costs
Posttest (1986) mail survey	Oregon State University and Pacific	Random samples of households in Hood River, Grants Pass, and Pendleton

HRCP Process and Operations

A unique feature of HRCP was its careful documentation of program delivery. This documentation was accomplished by internal staff (Philips et al. 1986) and by a consulting sociologist who conducted an independent process evaluation (Brown 1986). Thus, part of HRCP's legacy is a detailed understanding of problems that arose in operating this major project and of the solutions developed to overcome problems and to retrofit Hood River homes.

PRE-PROGRAM ACTIVITIES

Field work began in January 1983 with the community assessment (Social Impact Research, Inc. 1983). This set of 60 informal and nonrandom interviews with Hood River residents helped identify the community's structure, media channels, local issues, and possible impediments that HRCP might face.

The assessment identified eight major demographic groups in the area (Table 8) and hypothesized the likely reactions to the Project from each group. For example, blue collar workers relied on wood as a heating fuel more than the other groups and therefore might benefit less from the Project. Also, this group was more distrustful of government and utility organizations and would not want "outsiders" dictating to them. These insights were later used in deciding how to promote and position HRCP within the community.

Five concerns were identified by the assessment that could limit the Project's success: general aversion to handouts, dislike of dictates from outsiders, suspicion by blue collar workers, the effect of conservation on rate increases, and equity issues (both between electrically heated homes and oil-heated homes and between homes that had and had not installed retrofit measures earlier).

The assessment suggested several actions that Pacific could take to avoid these pitfalls. A major first step was establishment of a Community Advisory Committee, which was formed in summer 1983 (Table 9). The Committee provided an important communication link between Pacific and the local community. It also helped educate community residents about HRCP and provided valuable feedback to HRCP staff about community concerns with the Project.

Pacific developed a promotional plan during summer 1983. The plan called for increasingly vigorous marketing efforts to "achieve the maximum possible penetration of a very aggressive weatherization program. ... If we need to, we'll be going door-to-door knocking to get the pitch across to every single house-

Table 8. Groups identified during the HRCP community assessment

Business/professional
Counter-culture
Orchardists
Japanese-Americans
Seasonal migrants (Mexicans)
Settled-out migrants (Mexican-Americans)
Blue collar workers
Mosier residents

Source: Social Impact Research, Inc. (1983).

Table 9. Membership in the HRCP Community Advisory Committee

Civic leaders
County and city government leaders
Educational leaders
Conservation leaders
Business leaders
Agricultural leaders
Other community leaders

hold in the county and try to talk them into participating" (*Northwest Energy News*, March/April 1983).

Households were recruited for participation in several special studies during summer 1983. Specifically, random samples of households were contacted, told about HRCP, and recruited for the end-use metering, House Doctor, and blower-door studies. These one-on-one personal contacts with 15% of the area's households fortuitously proved to be a very powerful marketing force. The discussions between HRCP staff and these households yielded a well-informed and enthusiastic group of people who then told their friends and neighbors about this forthcoming project.

PHASE I (October 1983–May 1984)

The Project officially began in October 1983. Media coverage began with articles in the weekly newspaper, the *Hood River News*. The Project logo was placed on two large billboards in Hood River, both of which proclaimed the town "the conservation capital of the world." Ads and news articles invited residents to the Project office Open House in early November. The net effect of these activities was overwhelming—nearly 1000 (almost one-third of the eligible homes) signed up for participation during the first three months of the Project (October through December 1983).

Participation was straightforward. Soon after a household contacted the HRCP office, an auditor inspected the house. Energy audits were conducted by a vendor hired by Pacific; the vendor used a staff of four to six people. The audit identified cost-effective retrofit measures that could be installed. The auditor examined existing levels of insulation in the ceiling, walls, floor, and (where applicable) heating ducts. The auditor examined windows, exterior doors, and sliding glass doors in terms of the need for additional glazing and infiltration reduction. Needs for a clock thermostat (suitable only for homes with central heating) and/or an air-to-air heat exchanger to ameliorate indoor air quality problems were also assessed. Finally, the auditor installed several low cost measures during the audit: outlet gaskets, water heater insulation, hot water pipe insulation in the immediate vicinity of the water heater, and low-flow showerheads.

The auditor's measurements were input to a computer program that calculated the expected electricity savings and costs for each measure. Bonneville's Standard Heat Loss Methodology was used to do these calculations. These results were used to determine whether the package of measures was cost-effective. Contractors were then invited to bid on the retrofit work at the house. The final determination on expected cost-effectiveness (and therefore on which measures HRCP could finance) was made after contractor bids were reviewed by HRCP staff. If the package was too expensive (i.e., if its cost exceeded the \$1.15 limit), the household could choose to pay the additional amount or drop the measures whose costs exceeded the limit. Because the cost limit was applied to the entire package of measures, some measures whose cost exceeded the limit could often be installed if they were offset by other measures whose cost fell below the limit. The \$1.15 limit was not applied to the four auditor-installed measures because of their very low cost (\$20/house); nor was the limit applied to the air-to-air heat exchangers.

If the household approved of the measures, contractors were then assigned to the work. Some time later, depending on the backlog of retrofit jobs, the contractors installed the measures (Fig. 3). Generally, three contractors worked on each house, one to install insulation measures, one to install glass measures, and one to install clock thermostats.

Fig. 3. Contractors installing storm windows on a Hood River house. Project specifications called for triple-glazing wherever cost-justified.

Fig. 4. Inspector examining attic insulation installed in a Hood River home. Every HRCP retrofit was inspected by Pacific staff for compliance with materials and installation specifications.

After installation of the measures, HRCP staff inspected the house to make sure that the correct measures had been installed properly (Fig. 4). Inspections were conducted in 100% of the homes. If the work passed inspection, the contractors were paid. If not, the contractor returned to the house to rectify the problems, and the inspection was repeated.

This initial phase of Project implementation was characterized by the overwhelming success of the promotional plan (reflected in many requests for participation) and serious shortfalls in completion of retrofits. The shortfall was a consequence of the unanticipated immediate response to the Project, the initial restriction that only local contractors could participate (five were involved during this phase), the complexity of the competitive-bid process (caused in part by the high levels of retrofit measures), Bonneville's detailed specifications for materials and installation, difficulties in locating adequate supplies of some measures (e.g., double-pane storm windows), and delays in completion of the Project's computerized tracking system. By May 1984, roughly half the energy audits had been completed, but fewer than 3% of the homes had been fully retrofit.

PHASE II (June–December 1984)

Phase II was characterized by organizational changes within the Project office, expansion of the field-office staff from 6 to 14, use of the computer record-keeping and tracking system as an effective production tool, implementation of unit prices in purchasing retrofit measures and their installation, and changes in the number of contractors installing retrofit measures.

Because of the delays in completing retrofits and increasing concern about meeting the Project's ambitious goals, Pacific gave the field office much greater autonomy than it had before. Four more inspectors were hired (bringing the total to six), which reduced delays between inspection of completed work and payment of invoices.

By the summer of 1984, the vendor finally completed installation and debugging of the project-tracking system. For the first time, it was possible to use the detailed data collected on each participant to better manage the flow of work; more than 20 forms were used to collect data needed for project management and for the evaluation. The computer system was a vital link both for weatherization and research.

The number of requests for energy audits remained roughly constant throughout much of 1984, about 75 per month. At the request of the Project, the audit vendor increased the number of completed audits during summer 1984, which reduced the audit backlog and increased the number of jobs available for retrofit.

As noted above, the number of completed homes was far below the Project's target. Therefore, in May 1984, the Project requested and received a six month extension (through December 1985) from Bonneville. Six additional contractors (not local firms) were permitted to participate in the Project beginning in the summer of 1984. At about the same time, two of the original contractors were eliminated from the Project because of continuing quality-control problems. During Phase I, nearly half of the completed jobs failed the first inspection and required additional work on the part of the contractor. Towards the end of Phase II, the failure rate declined to less than 20%, which further increased the efficiency and throughput of the Project.

During the Project's final year (1985), 84% of the homes were retrofit.

During this phase, a unit-pricing system was implemented. Initial plans had envisioned use of unit prices (rather than competitive bidding), but this proved unfeasible, primarily because established prices did not exist in mid-1983 for the HRCP "super" measures. After several months of competitive bidding, Bonneville and Pacific felt they had sufficient data and experience to develop reasonable unit prices. These prices were used beginning in September 1984.

The initial competitive bid process generated considerable paperwork, duplication of effort, and delays in installation of measures. These problems led to adoption of the unit price system. Unit prices included fixed rates for each measure (e.g., Y¢/ft for hot-water pipe insulation). With the new system, Project staff randomly assigned each job to a contractor, and work could be started more quickly. In sum, the unit-price system greatly increased operational efficiency, cut delays, and reduced retrofit costs (Philips et al. 1986 and 1987).

Production increased during this second phase. However, by the end of 1984, only 16% of the eligible homes had been completed. Thus, 1985 began with substantial concern over the Project's ability to meet its ambitious targets.

PHASE III (January–December 1985)

During this final phase of fieldwork, 84% (2500) of the homes were retrofit. The problems that arose during the first two phases within the Project office, between the Project and Pacific headquarters, between the Project and its contractors, and between Pacific and Bonneville were resolved to yield an efficient, mature, smoothly functioning operation.

Project staff made a final push in early 1985 to sign up as many of the remaining eligible households as possible. A special one-on-one effort contacted, by telephone or in person, all eligible nonparticipants. These contacts were made by present and former employees of Pacific and HREC. The success of this effort is shown by the dramatic increase in participation rate during early 1985 (Fig. 5); almost 500 homes signed up during the first quarter of 1985.

Appropriate retrofit measures and procedures for mobile homes became a problem during Phase II. Lack of experience in retrofitting mobile homes and the absence of material and installation specifications delayed their participation until the final year. A block of 55 mobile homes was set aside for experimental retrofits before work began on the remaining 500 units registered for the Project. Retrofits of the 55 test units were completed in March 1985, and retrofits of the other mobile homes were well underway by midsummer.

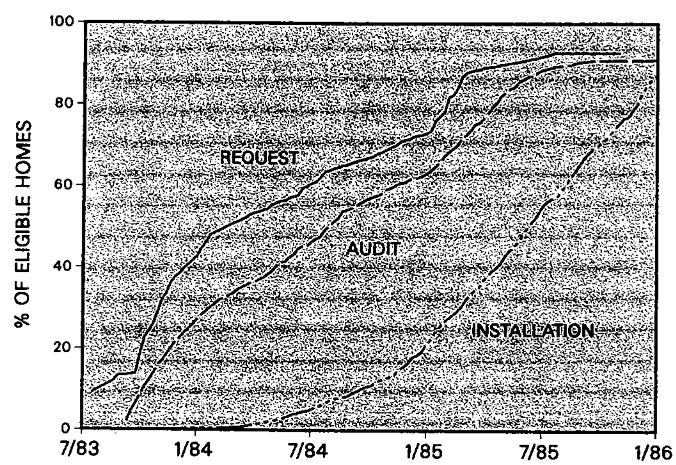

Fig. 5. Cumulative record of HRCP participation: audit request, energy audit, and installation of retrofit measures from summer 1983 through 1985.

Indoor air quality became an important regionwide issue while HRCP was underway, prompting modifications to the Project. The Bonneville Power Administration (1984) issued a final Environmental Impact Statement on changes in indoor air quality after retrofit. Based on Bonneville's findings, HRCP decided to install air-to-air heat exchangers only in homes whose occupants complained of stuffy air and health problems, and in homes with measured radon levels exceeding allowable limits. Radon monitors were installed in about two-thirds of the participant homes; fewer than 3% showed excessive radon levels.

In total, HRCP installed about 14,000 major retrofit measures in 2989 homes during a 27-month period. The dynamics of activities changed dramatically over time (Hirst and Goeltz 1986b) in response to both Project maturation and demand for Project services (Fig. 5).

The mean time between household request for participation and the energy audit was three months. Half the homes received their audit within two months, but 10% of the homes waited six or more months. In October 1983, when HRCP began, delays were short (Fig. 6). However, delays quickly grew to about four months. So many people signed up for the Project soon after it was announced that the limited audit staff could not keep up. Beginning in early 1984, however, the auditors began to reduce this backlog. Delays between request and audit declined throughout 1984 and 1985 because of the decline in household requests and increases in auditor efficiency.

The mean time between the energy audit and completion of retrofits was almost nine months. When HRCP began, the time between audit and completion varied enormously; on the average, homes audited during the last quarter of 1983 experienced a 13-month lag (Fig. 7). This delay decreased to 12 months during the following quarter as the contractors began to catch up with the auditors. The average time between audit and completion continued to decline, averaging eight months during the second half of 1984 and six months during the first half of 1985. Reductions in time required to install and inspect measures declined, in part, because contractors and HRCP staff became more efficient as they gained experience. Also, the Bonneville/Pacific commitment to complete all retrofits by the end of 1985 helped motivate staff and contractors to get work done quickly as the deadline approached.

PROJECT COSTS

Because HRCP was an experimental project, costs were carefully tracked (Philips et al. 1987). These data are quite useful both in assessing the economics of the Project and in planning future retrofit programs. Pacific and Bonneville signed two contracts, one for weatherization operations and the second for research and evaluation. Weatherization accounted for three-fourths of the total budget (Table 10).

Interpretation of these costs must be done cautiously because the Project's design and objectives

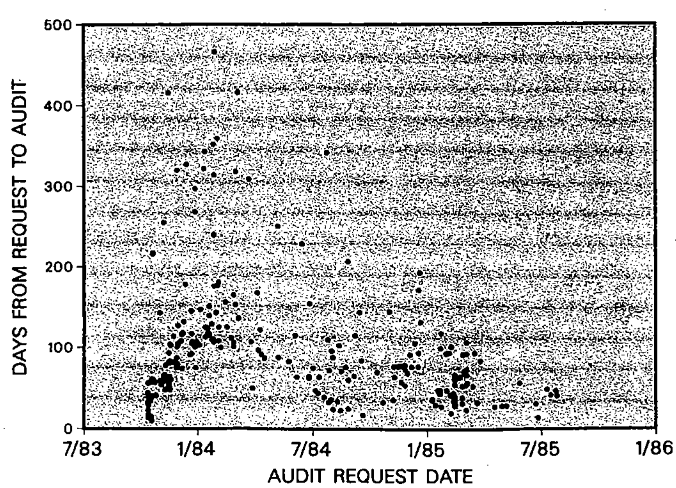

Fig. 6. Elapsed time between request for, and receipt of, energy audit as a function of audit request date. To improve clarity, the figure includes only a one-tenth random sample of HRCP homes.

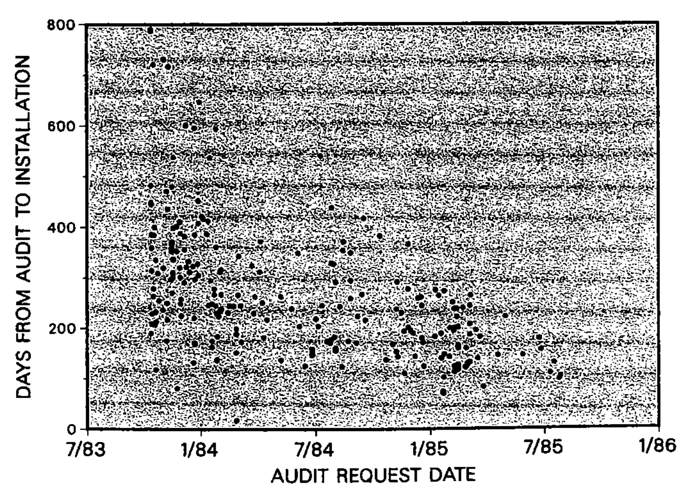

Fig. 7. Elapsed time between energy audit and installation of HRCP retrofit measures as a function of audit request date. To improve clarity, the figure includes only a one-tenth random sample of HRCP homes.

Table 10. HRCP costs for retrofit and research

Budget category	Cost (thousand $)	Percentage of	
		Subtotal	Total
Retrofit (fieldwork)			
Administration	1,288	9	7
Marketing	113	1	1
Computer system	395	3	2
Energy audits[a]	171	1	1
Retrofit measures			
Four low-cost measures[b]	85	1	0
Eleven major measures	11,056	77	57
Air-quality measures	1,294	9	7
Subtotal	14,402	100	(75)
Research and Evaluation[c]			
Pacific costs	1,600	33	8
Consultants	1,285	27	7
Materials	1,945	40	10
Subtotal	4,830	100	(25)
Total	19,232		100

Source: Philips et al. (1987).

[a]An additional $5,000 was spent on energy audits for homes not heated with electricity.

[b]An additional $10,000 was spent on installing low-cost measures in homes not heated with electricity.

[c]The research and evaluation costs are estimates as of early 1987. Because these activities will continue until 1989, it is difficult to estimate the costs associated solely with the original HRCP research and evaluation tasks. The total cost through March 1989 is expected to be $5.6 million.

sometimes conflicted with cost minimization. HRCP was intended to trace out the full cost curve for installation of residential retrofit measures; that is, it was designed to evaluate measures that might go beyond the point of minimum lifecyle cost. Cost estimates were weak for some measures because they had previously been installed in only a few homes, rather than as part of a utility's systemwide program. By pushing the limits, the Project sought to better define the costs of installing a variety of measures.

The need to complete all retrofit work within two years and the decision to rely primarily on local contractors raised costs beyond what might occur in a slower-paced program. Both the initial competitively bid prices and the later (lower) unit prices were higher than regionwide costs compiled by the Council. Efforts to further reduce costs would not have been compatible with the tight Project schedule.

Also, some measures were included that turned out to be more expensive than anticipated. For example, the Project's target for floor insulation was R-38 (far beyond the R-19 installed in most other retrofit programs). The Project ultimately achieved high-quality installations of this measure. But the extra time and expense associated with limited space in which to work and the need to construct supports to hold the insulation in place do not support inclusion of this measure in future retrofit programs.

For glazing, Project planners believed that the optimal retrofit was triple-glazing and proposed that double-paned storms be added to existing single-pane windows as the standard retrofit. There was also agreement that adding single-pane storm windows to existing double-pane windows was not cost-effective. This measure was, however, included in the HRCP package to provide all homes with the same final levels of conservation measures. The total cost of the single-pane additions turned out to be much greater than initially anticipated. Almost $800,000 was spent on installation of single-pane storm windows over double-pane windows in 622 homes, an average of almost $1300/home.

The cost to install 14,000 major measures was just over $11 million, almost 80% of the operations budget. If unit prices had been used throughout the Project, rather than the combination of competitively-bid and unit prices, retrofit costs would have been reduced by almost 10%. Unit prices were 7% to 22% lower than competitive prices for all housing types except multiplex units, for which unit prices were 10% higher.

The Project cost $20 million, $15 million for fieldwork and $5 million for data and analysis. The average cost of HRCP-installed measures was $4400/house, of which the Project paid 99%.

The four low-cost measures installed by energy auditors cost only $85,000. Energy audits cost an average of $53/house, a total of $171,000. The cost of radon monitoring to check for indoor air quality problems and installation of 1160 air-to-air heat exchangers in 1044 homes was $1.3 million.

Administration, which accounted for almost 10% of the operations budget, paid primarily for Pacific staff, which ranged from 6 to 17 full-time plus 6 part-time employees. Marketing accounted for a negligible share of total costs because of the Project's initial success in gaining participation. Almost 75% of the planned marketing budget was not spent. The computer system accounted for 3% of the operations budget, primarily for the consultant that developed the system. Overall, administration totaled 14% of implementation costs.

The research and evaluation budget was about $4.8 million. The biggest share of this total (almost $2 million) was for end-use monitoring equipment. These costs averaged $6000/house for the sample of 320 metered homes. Including the costs associated with the onsite home interviews; the three weather stations; and load-research data translation, processing, and analysis more than doubles the cost of the EUM component. Pacific's costs for research and evaluation activities amounted to about $1.6 million for salaries, overhead, administration, and travel. Finally, consultants accounted for almost $1.3 million. These consultants were responsible for most of the surveys and for many of the evaluations.

The total cost of the Project includes, in addition to the items discussed above, Pacific's inhouse costs of initial planning plus the costs to conduct energy audits and install low-cost measures in nonelectric Hood River homes. Altogether, HRCP cost almost $20 million.

The detailed cost data collected by the Project permit energy planners to assess the cost of saved energy for a range of alternative program designs. For example, the effects on program costs and predicted electricity savings of a cost limit lower than the $1.15/estimated annual kWh saved used in Hood River could be computed. Stricter rules could be imposed to limit the extent to which cost-effective measures "carry" measures that are not cost effective. And the eligibility of wood-heated homes in retrofit programs could be restricted, thereby increasing the short-term electricity savings achieved by such programs. Various combinations of these program-design features can be assessed with HRCP data.

The total cost of HRCP retrofit measures, including audits and administrative expenses but not including the air-quality measures, averaged $4400/house. The average direct cost of installed measures, exclusive of both air-quality measures and administrative costs, was $3760 per retrofit house (Fig. 8). The insulation measures accounted for almost half (48%) of the total retrofit cost, as did windows and doors (47%). The infiltration reduction, water heating, and clock thermostat measures accounted for only 5% of the cost.

Only 10% of the participants paid anything for the measures installed in their homes. These households paid for measures that exceeded HRCP levels (e.g., attic insulation beyond R-49), exceeded the HRCP cost-effectiveness limit (i.e., cost more than $1.15/kWh saved), or exceeded HRCP standards (e.g., storm win-

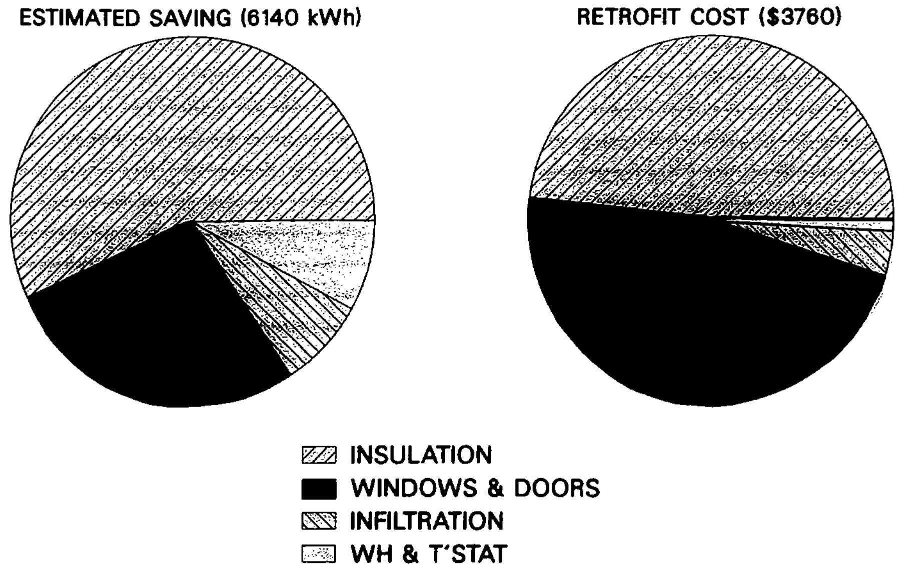

Fig. 8. Estimated electricity savings and retrofit costs for HRCP-installed measures. (WH & T'STAT refers to water heating measures and clock thermostats.)

dows that cost more than those called for by specifications). These households paid an average of $430. Averaged over all homes, households paid only 1% of the total retrofit cost.

RECOMMENDATIONS

The HRCP experience led to several suggestions on ways to operate large retrofit programs (Schoch 1987). Project managers should expect changes as administration and operations evolve. Relationships with the administrative departments within the utility, government agencies, community groups, and others should be characterized by strong communication and flexibility.

The project manager should have enough autonomy and flexibility in expenditures and personnel to run the project as a small business that is evaluated on bottom-line results. The project manager should be exempt from centralized personnel directives, position control, rigid pay or grade systems, and should have the freedom to hire and fire staff and to use overtime.

Access to the service departments within the utility provides high quality structural support that could not be developed independently within a short time. A large-scale project needs expertise in corporate management techniques, accounting, records management, marketing, computer systems, and forms production.

Contractors should be selected from an unrestricted pool with preference granted to local contractors. Although initially more administration is involved in dealing with a large pool of contractors, it provides more leeway in regards to disciplinary action, quality control, prices, and production. There are benefits to using local contractors because they tend to be concerned about the quality of their work, customer satisfaction, and their reputation in general. However, it is not necessary to restrict participation to local contractors.

Contractors should be closely supervised from the beginning, with 100% inspection of the first jobs completed. There should be set penalties for violations or poor work, commensurate with the cost to the project for correcting the problem. Clear criteria with which to evaluate contractors should be in place and used to maintain high-quality work. Instituting a system of fines in Hood River corrected many of the early problems that required multiple inspections.

Maintenance of high standards is important in the selection, training, and performance of energy auditors because they, along with the contractors, have substantial contact with participating households.

The community advisory committee should represent a cross-section of the community in terms of geography, occupation, and values. It should have a clear mission, including an active role in reviewing program progress. As long as the group functions, attendance should be expected, and the absentees replaced by persons with similar backgrounds.

A community assessment is valuable for positioning the project to gain wide acceptance. Standard media sources (newspaper, radio, and TV) can provide ongoing background information, answer typical questions, address common complaints, and correct misconceptions. One-on-one meetings with a substantial and representative minority of the community to explain the project, as was done with the EUM residents, is a very effective way to market a conservation project. Weatherization contractors can also help spread the word.

Care should be taken in what is promised homeowners. Unforeseen problems (monitoring equipment delays or mobile home technology limitations) or policy changes (door replacement, air-to-air heat exchangers, or cost-sharing) can cause bad feelings on the part of the community. The residents should be given realistic timelines for when various steps will occur at the time they register for the project, and should be notified if schedules change.

Word-of-mouth was the primary information source about the Project. More than half the participants first learned about the Project from a friend, neighbor, relative, or community leader.

The communication required among auditors, inspectors, and field specialists is extensive enough so that they should operate from a central office. It may even be useful to cross-train staff to perform all three functions. The auditors, the field specialists, and the inspectors must evaluate the homes in a consistent fashion. All persons representing the project should act in a professional manner and be appropriately dressed for the task at hand; appropriateness will vary by community and function.

If the Project has a strong research component, early formation of a coalition of those who will evaluate the findings and support the research effort during program implementation is vital to success (Peach et al. 1986). For HRCP, the Regional Advisory Group was able to limit the scope of the research and thereby increase the probability that all key research tasks would be completed successfully. It also functioned as an advocacy group to protect the Project from being weakened as problems arose.

There are advantages to designing the project with measures and equipment that are readily available from multiple suppliers, especially if the project is on a tight schedule. HRCP had trouble because there was only one supplier of the monitoring equipment and, at times, only one supplier of double-pane storm windows. Using such a project to create a market for state-of-the-art products has advantages, also, even if only one manufacturer can supply them.

The project needs to educate homeowners about what will happen to their homes during retrofit. Many homeowners are ignorant of weatherization procedures, and the responsibility for informing them should not fall on the contractors. Homeowners were required to sign an authorization for the work to be done by the Project. However, they did not choose, supervise, or pay contractors; these functions were performed by Project staff. Thus, HRCP assumed much of the authority and responsibility normally held by homeowners. On the other hand, this design made it easy for people to participate, by offering a one-stop shopping service.

A project of this kind should carefully consider the use of unit prices. For HRCP, unit prices led to savings in both the cost of weatherization and the administrative time for staff and contractors. However, unit prices were developed only after the Project had been operating for several months and were based on the experience gained through competitive bidding; these unit prices were therefore substantially lower than the initial unit price schedule. This suggests that both methods may be useful.

A clear set of specifications for materials and installation of measures should be developed before fieldwork begins. Such specifications should be prepared in consultation with experienced contractors. For innovative applications, pilot projects should be run with a variety of housing stock to test the flexibility and feasibility of the specifications. Once the project begins, interpretations of the specifications should be decentralized to avoid delays in installation of measures.

HRCP Marketing and Its Success

The overall success of a conservation program depends on four factors: the fraction of eligible customers that participate in the program, the fraction of recommended conservation actions adopted by participants, the actual electricity savings achieved by these actions, and the reliable reduction in electricity use made possible by these measures. This chapter deals with HRCP's marketing efforts and their success in addressing the first two factors; the following chapter deals with the third and fourth factors.

Two of the five HRCP objectives (Table 1) dealt with alternative marketing approaches to maximize participation in the Project. Activities aimed at achieving high penetration of both households and measures began with the January 1983 community assessment (Social Impact Research 1983) and pretest mail survey (Berg and Bodenroeder 1983) and continued with development of marketing and promotional plans (Engels 1985; Engels, Kaplon, and Peach 1985; Kaplon 1987). The first section of this chapter discusses these planning efforts, while the second and third sections discuss the Project's success in attracting households and in getting measures installed (Hirst and Goeltz 1985 and 1986a; Goeltz and Hirst 1986).

PLANNING

As discussed in Chapter 3, the community assessment helped identify market segments in Hood River (Table 8) and their likely attitudes towards the Project, information that was valuable in developing marketing strategies. For example, members of the Business/professional segment were very cost-conscious and would therefore be receptive to the Project. Resistance would arise primarily from those who had installed retrofit measures before the Project began or from those who used fuels other than electricity for heating; these households would receive few benefits from HRCP. In addition, the pretest survey identified energy-related attitudes among a random sample of Hood River residents.

The Project's promotional plan (Table 11) was intended to increase awareness, acceptance, and support of the Project and thereby stimulate requests for participation. The plan, which included only conventional elements that other electric utilities could undertake in marketing conservation programs, consisted of four components: advertising, promotion, community activities, and personal contacts. General advertising was planned on a regular basis and used local newspaper ads and articles, radio, and billboards.

The plan included a logical progression beginning with announcement of the Project's start, placement of two billboards to increase awareness of HRCP (Fig. 9), and general information. According to the plan, informal progress reports would keep people informed of the Project's activities and weekly ads in the newspaper would invite people to participate. Subsequently, testimonials from prior participants would be used to encourage additional participation. Finally, ads would emphasize the benefits of participation and actively encourage the remaining households to sign up.

The second promotional component focused on recruiting: getting people to participate. Here, too, the initial phases were general (bill stuffers), followed by more focused and assertive actions. The third element dealt with the community in general. Here the emphasis was on establishment of the HRCP office in an easily accessible location in downtown Hood River and establishment of the Community Advisory Committee (Table 9). The fourth element featured one-on-one contacts between Project staff and potential participants.

The plan envisioned three primary mechanisms to keep staff informed about the effectiveness of these activities: the process evaluation (Brown 1986), responses to the marketing questionnaire (completed

Table 11. Chronological listing of HRCP promotional activities planned

Advertising	Promotion	Community activities	Personal contacts
Announcement of contract		Presentations to key groups	Telephone
			Door-to-door
Billboards		Establishment of local office	
General information		Community Advisory Committee	
Reporting of activities			
Invitation to participate	Utility-bill enclosure		
Testimonials	Door hanger		
Recruitment activities	Letter from HRCP manager		

Source: Engels, Kaplon, and Peach (1985).

when people called the office to sign up), and the Community Advisory Committee. Of course, the rate of requests for participation provided the best information on marketing effectiveness. As it turned out, participation was overwhelming, so many of these planned activities were not adopted (Fig. 10).

PROJECT PARTICIPATION

No matter how sophisticated the energy audit is, how attractive the financial incentives are, or how much energy is saved by the program-sponsored measures, the program's ultimate success depends on attracting eligible customers. Of the many issues associated with design and operation of effective programs, those related to the determinants and dynamics of program participation are probably least understood.

The terms "participant" and "nonparticipant" can be defined in different ways. A strict definition of participation would include only those homes that received HRCP-financed major retrofits (i.e., more than the low-cost auditor-installed measures). A less stringent definition might include those homes that received an energy audit only or even those homes that had some contact with the Project but received no services.

These distinctions are unimportant in HRCP, because such a large fraction of the eligible households received retrofits (Table 12). HRCP succeeded in providing energy conservation services to 91% of the eligible households during a two-year period. About 85% of the eligible homes had one or more major measures installed. Almost two-thirds of the homes that received only an audit did not participate further because additional measures would have been cost-ineffective (as discussed later in this chapter).

Audit Requests

About 91% of the 3500 eligible households participated between July 1983 and July 1985. Project staff solicited participation from about 13% (469) of the eligible households during the summer of 1983. Subsequently, almost 1000 households contacted the field office during the first three months after the Project officially began in October 1983 (Fig. 11).

This dramatic response is in sharp contrast to that experienced in most retrofit programs (Coltrane, Archer and Aronson 1986). For example, state reports on the federal Residential Conservation Service show

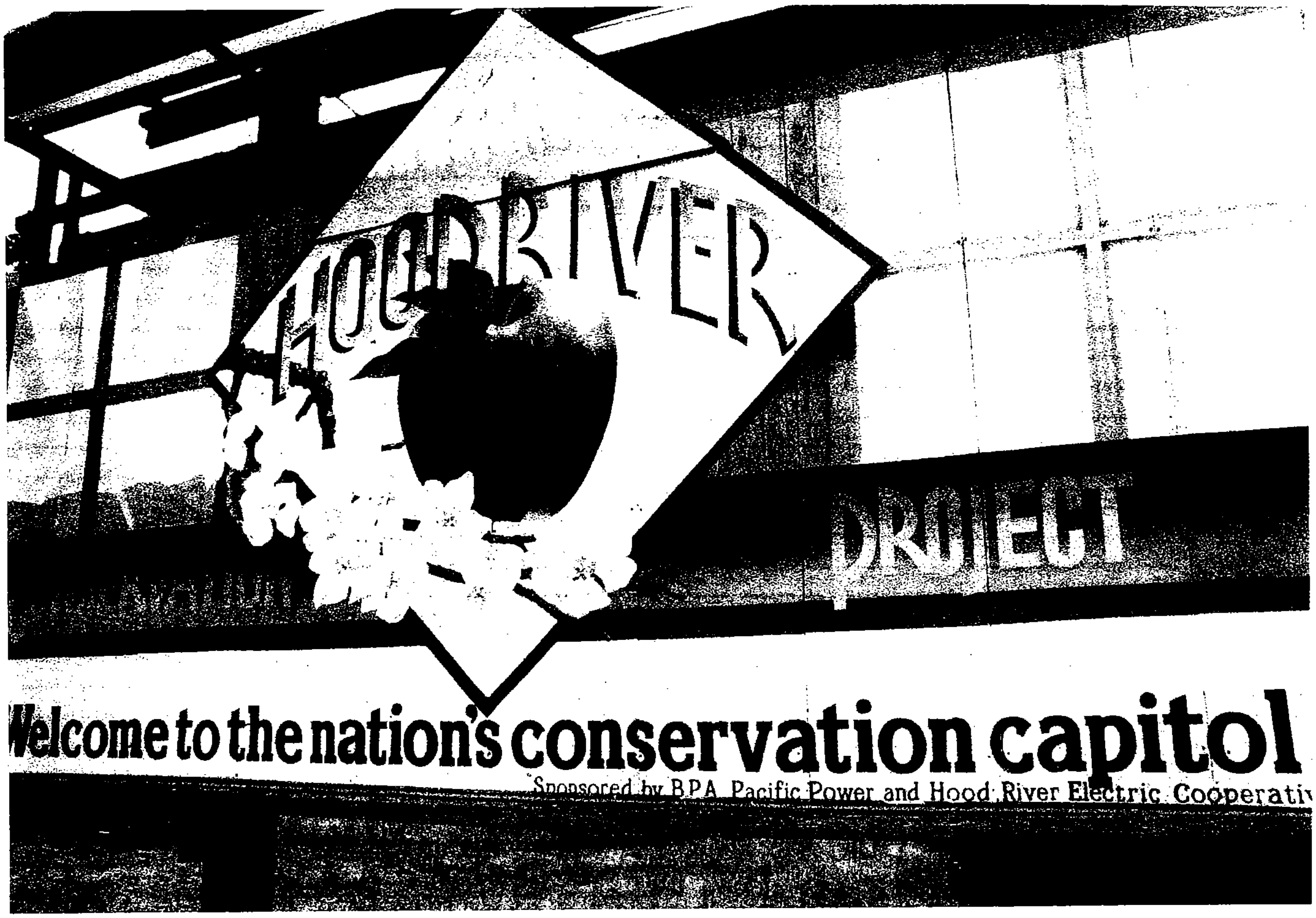

Fig. 9. One of the two billboards used to promote HRCP in Hood River. The logo was widely used to increase awareness of the Project.

that only about 2% of the eligible households request energy audits each year (Centaur Associates 1985). Even when programs include financial incentives, response rates are typically much lower than that experienced in Hood River. During the first two years that Bonneville operated its regionwide Residential Weatherization Program (RWP), 211,000 homes were audited (Eissler 1984), equivalent to an annual participation rate of 9%. Only half the audited homes were retrofit by the Bonneville program. HRCP, on the other hand, achieved a 27% response in three months and an annualized response rate of about 45%.

The Regional Advisory Group believes that the high HRCP participation rates can be achieved by other utilities. Thoughtful use of a variety of marketing approaches and close links to the community are key determinants of success. Indeed, some conservation programs that use community groups to solicit participation achieve high participation rates. For example, the Santa Monica Energy Fitness Program, operated by the municipal government, conducted energy audits among one-third of the eligible homes between May 1984 and May 1985 (Egel 1986). Similar experiences with community programs were reported in Minnesota (Brummitt 1984) and Maine (Morgan 1986). But none of these programs comes close to the participation achieved by HRCP. [The Residential Energy Conservation Action Program, operated by General Public Utilities, attracted 84% of the eligible households in a New Jersey retirement community (Brown and Reeves 1985). Success was due to the near homogeneity of households and the utility's close coordination with the condominium association.]

After the first two months of Project operation, the rate of audit requests declined. For example, 400 requests per month were received during October and November 1983, 200 per month in December 1983 and January 1984, and less than 100 per month during the next several months.

Table 12. Participation in the Hood River Conservation Project

HRCP status	Number of eligible homes	Percentage of eligible homes
Participants		
Retrofit	2989	85
Audit only	200	6
Nonparticipants		
Contact with HRCP, but no services	60	2
No contact with HRCP	251	7
Total	3500	100

Source: Hirst and Goeltz (1986b).

According to Project personnel, three main factors were important in achieving high participation (Table 13). First, word of mouth from households participating in the special studies generated many requests during fall 1983. Second, frequent stories in the newspaper kept people informed about the Project's purposes and progress. Finally, in early 1985 a special one-on-one effort contacted (by telephone or in person) virtually all eligible households that had not yet signed up; the success of this effort is shown in the dramatic increase in participation rate during early 1985 (Figs. 10 and 11), especially for housing/tenure types other than single-family homeowners.

More than half (57%) of the respondents to the marketing questionnaire cited rising electricity prices and the need to control electricity costs as the primary reason for participation. Roughly 15% cited a belief in energy conservation and environmental protection.

Almost 55% of the participants first learned of HRCP from another person not employed by the Project (friend, relative, neighbor, community leader). Another 28% learned of the Project from the *Hood River News*. The percentage of people learning about the Project from other people increased over time, from 52% during the first quarter to 80% during the last half year. Thus, as more and more people participated in the Project, word-of-mouth became an increasingly powerful way to inform other people. About 10% of the participants first learned of HRCP from a Project employee; during the first quarter of 1985 this figure jumped to 28%.

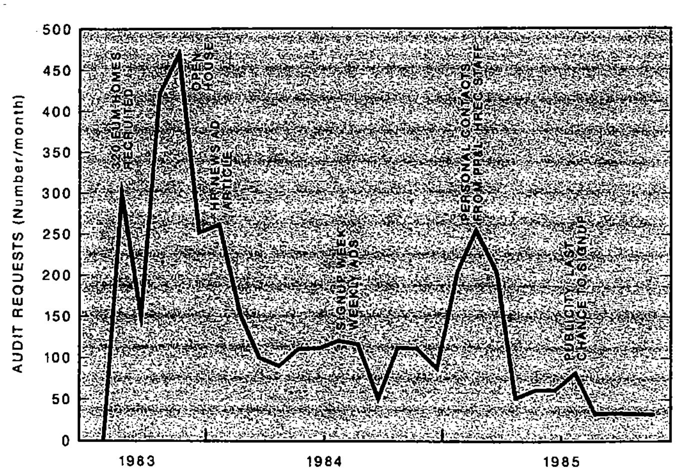

Fig. 10. **Relationship between audit requests and marketing activities.**

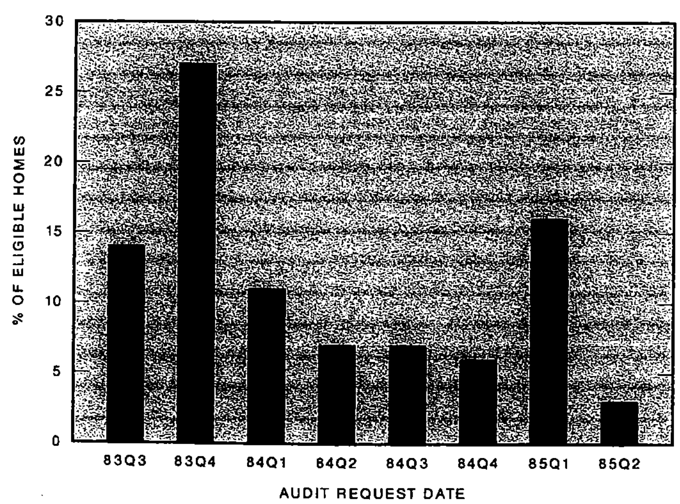

Fig. 11. Household signups for HRCP, by quarter and year, from summer 1983 through spring 1985. The signups for the first quarter reflect households recruited for the special studies.

Table 13. Major marketing activities employed by HRCP

Date	Activity
July 1983	Community Advisory Committee formed First contacts with end-use metered, House Doctor, and blower door households
October 1983	Article and pictures in *Hood River News* HRCP administrator on KIHR radio program
November 1983	Several ads in *Hood River News* Several articles in *Hood River News* Open House at HRCP office with TV coverage
December 1983	Ads in *Hood River News*
January 1984	Article in *Hood River News*
February 1984	Article in *Hood River News*
May 1984	Article in *Hood River News*
June 1984	HRCP administrator on KIHR radio program
July 1984	Article in *Hood River News*
November 1984	Testimonial ads in *Hood River News* for six weeks
January 1985–March 1985	Personal contacts (telephone calls and onsite visits) with eligible households not yet signed up
June 1985	HRCP administrator on KIHR radio program Last ad in *Hood River News,* announcing July 31 deadline to request energy audit

Source: Quinn (1986).

Nonparticipant Characteristics

Only 9% of the eligible households did not participate. The major differences between participants and nonparticipants are house type and tenure (Table 14): larger fractions of nonparticipants are homeowners (88 vs 68%) and live in single-family homes (73 vs 58%). Limiting the comparison to single-family homeowners shows that nonparticipants had higher incomes, newer homes, and had lived in their homes for fewer years than had participants.

Nonparticipants were asked an open-ended question during the December 1985 telephone survey (Kaplon and Engels 1986) about why their home was "not weatherized by the Hood River Conservation Project." Almost 40% of the respondents said that they did not need the weatherization (i.e., their homes were already energy-efficient), almost 15% said they thought their home did not qualify, another 15% said they were never contacted by the Project, and 10% said they missed the deadline. (We have no way of knowing whether the homes of those who claimed they did not need HRCP services were really energy-efficient. Also, some survey respondents said their homes did not qualify for participation, but all of these reported electricity as a heating fuel; therefore, their homes were eligible.)

The differences between participants and nonparticipants point out an important success of HRCP. Most residential conservation programs have appealed primarily to single-family homeowners and have been able to attract only small fractions of eligible renters, low-income households, and occupants of multifamily buildings (Hirst 1984; Berry, Hubbard, and White 1986; Coltrane, Archer, and Aronson 1986). HRCP, on the other hand, attracted larger fractions of these

Table 14. Comparison of HRCP participants and eligible nonparticipants

	Percentage of households	
	Participants	Nonparticipants
Household income		
Less than $10,000	21	14
$10,000 to $16,000	18	9
Greater than $16,000	61	77
Housing tenure		
Renters	34	12
Owners	66	88
Housing type		
Multifamily buildings with five or more units	14	1
Other housing types	86	99
Number of households	3189	311

Source: Hirst and Goeltz (1986b).

traditionally hard-to-reach groups (Table 14). For example, 39% of the HRCP participants had incomes of $16,000 or less, while only 23% of the nonparticipants fell into this "low-income" group. Much larger fractions of participants than nonparticipants were renters (34 vs 12%) and occupants of multifamily buildings (14 vs 1%).

RETROFIT MEASURES INSTALLED

Many definitions of retrofit "potential" are possible. The most inclusive refers to installation of the maximum amount of every measure in every house. This unrealistic definition assumes that existing homes presently have no energy-conserving devices in them.

An alternative definition includes only those measures that can be installed, where "can" means physically possible. This definition excludes cases where the measure is already fully installed and cases where installation is not feasible (e.g., attic insulation in a cathedral ceiling or heating duct insulation in a house without a central heating system).

The potential could also be defined in terms of measures whose installation is both technically feasible and economical. This definition would reduce the potential further by excluding measures whose high installation cost and/or low expected energy savings make them not cost-effective.

In addition to physical and economic barriers, other reasons cause measures not to be installed. A major class of barriers relates to the household and includes aesthetics, inconvenience, perceived ineffectiveness of measures, and other customer concerns.

These comments suggest that the definition of "potential" is not simple. The HRCP data permit analysis from various viewpoints.

Participant Homes with No Major Measures Installed

About 92% of the households that contacted HRCP had at least one major measure installed in their homes by the Project. Only 260 of 3249 homes had no major retrofit measures installed. A few of the four low-cost measures installed by the auditors (outlet gaskets, water heater wrap, hot water pipe wrap, and low-flow showerhead) were installed in these homes.

The homes with no major measures installed differed substantially from the other homes. The households with no major measures had higher incomes, more education, and shorter tenures in their homes. In addition, these households were more likely to own their homes, to live in single-family homes that were newer and larger, and to have more electricity-using equipment than the other households.

Many of the households in homes with no major measures installed had installed retrofit measures earlier, either on their own or with assistance from prior Pacific or HREC conservation programs. For example, 25% of these 260 households had participated in a prior conservation program, compared with 8% of the other households.

Barriers to installation of all major measures arose for various reasons. Lack of cost-effectiveness (failure to meet the $1.15/kWh criterion), the most frequent barrier, accounted for 56% of these 260 homes. In 23% of these cases, the audit could not be conducted because the residents refused to allow the auditor to enter the house, the house was vacant, or the occupants were unavailable. Finally, 21% of these households declined to participate in HRCP after the energy audit was conducted. Thus, residents changed their minds about participation some time after their initial contact with the Project in 44% of these cases.

Aggregate Potential

The hypothetical potential existed to install 48,735 measures (15 measures[4] in 3249 homes; Table 3). Slightly less than half were actually installed by the program (Fig. 12), and measures were neither recommended nor installed in nearly half the cases. Thus most noninstallations occurred because the measure was not recommended.

If all measures could be installed in all homes (a maximum definition of potential), the potential savings (from the audit's engineering analysis) would be 12,500 kWh/house. The estimated savings for the auditor-installed measures in the homes with no major measures installed average 610 kWh/house. The estimated savings, averaged over all 15 measures, for measures installed in the remaining homes is 6,140 kWh/year. Thus, the average estimated savings per eligible house for measures installed is 5700 kWh/year, almost half the theoretical potential (top part of Table 15).

The preceding discussion artificially assumes installation of every measure in every home. If one assumes that program planners have accurate information on the current condition of homes in their service area, then the potential can be defined to include only those measures applicable to that housing stock. This definition is more realistically based on the measures recommended during the energy audit. Of the measures recommended during energy audits of the 2989 homes that had major measures installed, 83% were actually installed. However, these installed measures accounted for 93% of the potential electricity savings for the measures recommended during the audits (bottom part of Table 15).

[4]Heat pumps, dehumidifiers, and air-to-air heat exchangers are excluded from this analysis. The first two measures were almost never installed by HRCP. The third measure was not intended to save energy; units were installed only if indoor air quality was a problem (Bonneville Power Administration 1984).

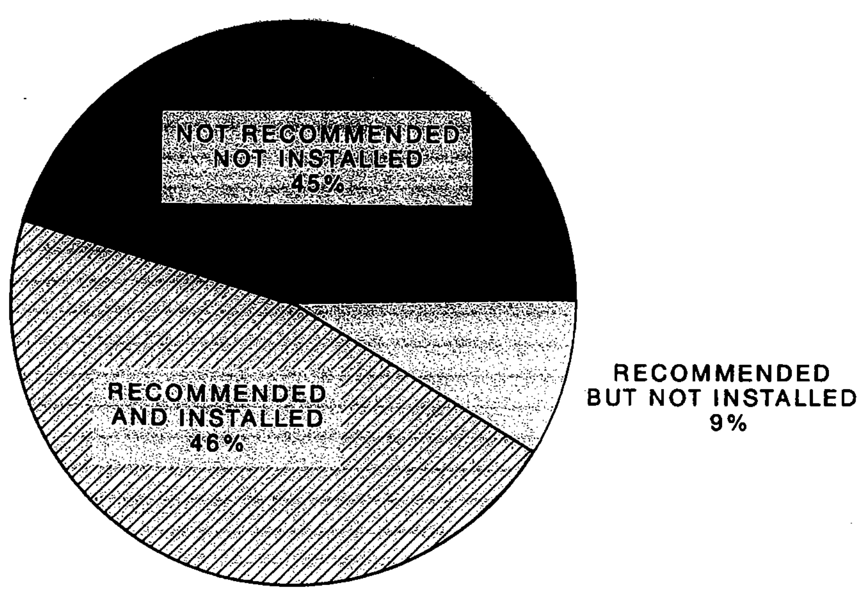

Fig. 12. Distribution of HRCP measures by recommendation and installation.

Installation of and Barriers to Retrofit Measures

Several measures were recommended in the vast majority of homes (Table 16): ceiling insulation, floor insulation, storm windows, caulking, and door weatherstripping. Heating duct insulation, insulated doors, and window weatherstripping were installed in very few homes. Homes with baseboard heating have no heating ducts, insulated doors are rarely cost effective, and the need for window weatherstripping was usually obviated by the installation of storm windows.

In almost half the cases where measures were not installed, all or some of the measure was already in place.

The measures also differ substantially in retrofit cost and in estimated energy savings. Storm windows and floor insulation are the most expensive measures; the four measures installed at the time of the audit are the least expensive. Estimated energy savings are largest for wall insulation; ceiling and floor insulation and storm windows are also large energy savers.

To examine the barriers that prevented installation of retrofit measures, we aggregated the individual barriers (recorded by auditors and contractors on an HRCP data collection form) into five groups:

- Not compatible—refers to measures that are not applicable to the particular house, such as duct insulation in a house that has no ducts or floor insulation for a house on a concrete slab.
- Physical—refers to conditions in the house that prevent installation of a measure, such as spaces too small to install additional insulation or water heaters without pressure relief valves.
- Existing installation—refers to situations in which some or all of the recommended measure is already in place; installation of more of the measure would not be cost-justified.
- Customer—refers to cases in which the resident decides that the measure will not be installed.
- Other/none—refers to other barriers that are infrequently cited or to measures not installed for which no barrier was recorded.

Table 15. Comparison of maximum savings with estimates of savings produced by HRCP-installed measures

	Audit estimate of savings per house (kWh/year)
All homes	
Homes with no major measures installed 0.08 × 610 kWh/house	50
Remaining homes 0.92 × 6140 kWh/house	5,650
Total	5,700
Total potential savings if all measures installed in all homes	12,500
Homes with major measures installed	
Measures installed	6,140
Total potential savings if all audit recommendations installed	6,590

Source: Goeltz and Hirst (1986).

Table 16. Retrofit measures recommended and installed by HRCP

Measure	Percentage of homes in which measure: Recom-mended	Installed	Installed as % of recommended	Installed: Cost ($)	Savings (kWh/yr)[a]
Insulation					
Ceiling	88	67	76	960	1690
Floor	87	63	72	1350	2080
Wall	49	39	80	720	2460
Duct	19	12	63	270	720
Windows and doors					
Storm windows	99	89	90	1730	1670
Sliding glass doors	40	29	73	720	500
Insulated doors	12	3	25	430	210
Infiltration					
Caulking	89	78	88	110	140
Window weatherstrip	17	0	0		
Door weatherstrip	90	69	77	80	50
Outlet gaskets	85	85	100	10	400
Clock thermostat	32	26	81	150	250
Water heater					
Insulation	51	51	100	20	360
Pipe insulation	63	63	100	10	30
Low-flow showerheads	62	62	100	10	450

Source: Goeltz and Hirst (1986).

[a]These are audit predictions of savings for the measures.

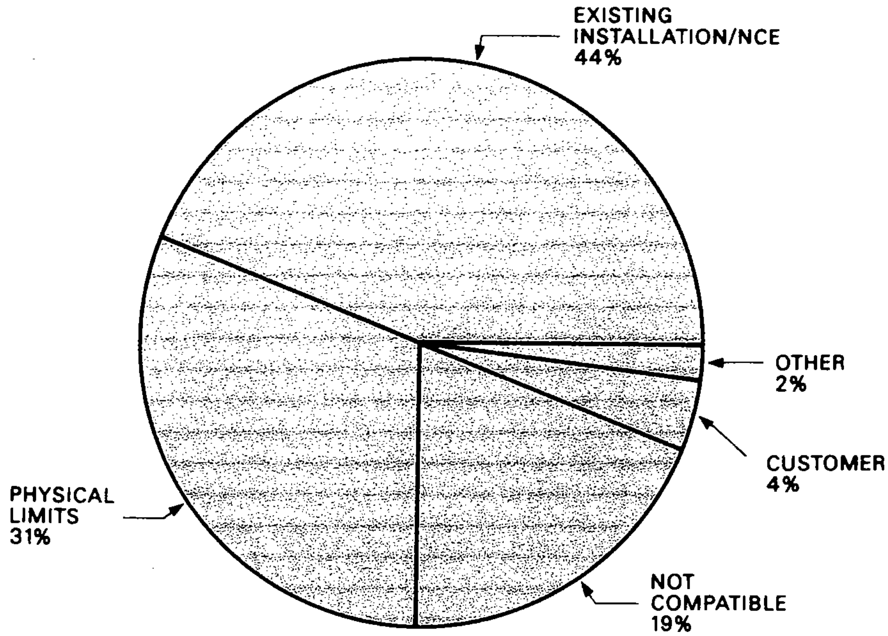

Fig. 13. Distribution of barriers for measures not installed. (NCE is not cost-effective.)

Noncompatible conditions were cited for 19% of the noninstalled measures (Fig. 13). An additional 31% of the measures were not installed because of physical conditions that prevented installation. Thus, half of the measures could not be installed, regardless of potential energy savings, measure costs, or participant willingness.

The presence of partial measures or lack of cost-effectiveness prevented installation in another 45% of the cases. Here, the homes already had enough of a measure (e.g., R-38 attic insulation) so additions to bring the measure up to the Project level (e.g., R-49) could not be justified.

HRCP was remarkably popular. About 91% of the eligible households received at least an energy audit; 85% of the homes had major measures installed by the Project.

Customer concerns prevented installation of only 4% of the measures. The fact that almost all measures were installed at no cost to the household contributed significantly to the lack of customer barriers.

Finally, other barriers were cited for less than 2% of the measures.

HRCP Energy Effects

The success of a conservation program depends on the energy savings and load reductions achieved by program-induced actions. In addition, program success can be measured in terms of reduced postprogram electricity use because the levels of electricity use (rather than savings) determine the need for additional power plants. This chapter analyzes electricity consumption and savings based on monthly electricity bills and the load research data collected from the end-use-monitored (EUM) homes (Hirst, Goeltz, and Trumble 1987; Stovall 1987).

ANNUAL ELECTRICITY USE AND SAVINGS

Pre-HRCP Electricity Use

Total weather-adjusted electricity use among participants before the Project began (1982/83) averaged less than 19,000 kWh/year (Tables 17 and 18), far below typical levels observed throughout the Pacific Northwest at that time. For example, single-family homes used about 20,000 kWh/year in Hood River, compared with almost 25,000 kWh throughout the region (Hirst and Keating 1987). Regionwide, households that participated in Bonneville's Residential Weatherization Program (RWP) in 1985 used 24,000 kWh the year before participation (Bronfman and Lerman 1987). Similarly, pre-HRCP space heating electricity use averaged less than 8,000 kWh/year, much less than the 13,000 kWh observed throughout the region (Watson 1986). Levels of electricity use in Hood River were lower than those typical of the region because Hood River homes were newer and because their occupants were more likely to use wood for heating.

Thus, one important finding is that electricity use in Hood River homes nominally heated with electricity was much lower in 1982/83 (and substantially lower still in 1985/86) than energy planners in the Northwest had anticipated. These low levels of consumption before HRCP began were caused by several factors. The dramatic increase in electricity prices during the late 1970s and early 1980s had a substantial effect on electricity use. During the two years before HRCP began, real (adjusted for inflation) prices increased by 40%.

Table 17. Electricity use and savings (kWh/year) for homes retrofit by HRCP, by utility

	All homes		Single-family		Other types	
	HREC	Pacific	HREC	Pacific	HREC	Pacific
Total use						
1982/83 (pre-HRCP)	22,500	16,200	23,000	18,000	21,000	13,500
1985/86 (post-HRCP)	18,600	14,400	19,000	16,000	17,400	12,000
Total savings						
1982/83–1985/86	3,900	1,800	4,000	2,000	3,600	1,500
Number of households	872	1,490	653	892	219	598

Source: Hirst, Goeltz, and Trumble (1987).

Table 18. Electricity use and savings for homes retrofit by HRCP, by housing type

	Total	Housing type		
		Single-family	Multi-family	Mobile home
Electricity use (kWh/yr)				
Total use				
1982/83	18,600	20,400	10,700	19,200
1985/86	16,000	17,500	9,200	16,700
Space heating[a]				
1982/83	7,500	7,600	5,700	8,500
1985/86	4,800	4,600	3,700	6,300
Total savings				
1982/83–85/86	2,600	2,900	1,600	2,500
Floor area (ft^2)	1,350	1,560	800	1,090
Pre-HRCP use/ft^2	15.3	14.7	13.6	19.2
Total savings/ft^2	2.2	2.1	2.1	2.5
Retrofit cost ($)	4,320	5,420	2,150	2,350
Number of households	2,362	1,545	396	421

Source: Hirst, Goeltz, and Trumble (1987).

[a]These estimates are based on adjustment to a weather-normalization method that may not apply well to post-HRCP electricity use levels. Thus, the estimated space-heating savings may be incorrect; indeed, they are generally larger than the total savings (which implies, incorrectly, that the savings produced by the water-heating measures are negative).

The importance of electricity prices is clearly shown by the much higher pre-HRCP electricity use for households served by HREC vs those served by Pacific (22,500 vs 16,200 kWh/year; Table 17). The 6300 kWh difference is related to differences in housing types (75% of the HREC participants lived in single-family homes, compared with 60% for the Pacific participants; Table 18) as well as the much lower electricity price paid by HREC customers (2.5 vs 4.7¢/kWh in 1982/83).

Other forces affecting electricity use were at work during this period. Considerable public awareness of energy issues, knowledge of the potential for saving money through adoption of energy-conservation practices and measures, changes in household income and in the local economy, and the existence of prior utility and government conservation programs all affected household electricity use. For example, almost 10% of the homes retrofit by HRCP had participated in earlier conservation programs operated by Pacific or HREC. As a result, pre-HRCP electricity use was 1500 kWh higher for single-family homes that had not participated in prior programs than for those that had participated in earlier programs. Finally, almost two-thirds of the participants used wood as a heating fuel, probably because of increases in electricity prices and unemployment; use of wood reduced annual electricity use by as much as 6000 kWh per wood-burning home.

Electricity Savings

The overall three-year reduction (1982/83 minus 1985/86) in electricity use for retrofit homes averaged 2600 kWh/year, almost entirely because of reductions in space heating (Table 18).

The savings for HREC homes were double those for Pacific homes (3900 vs 1800 kWh/year; Table 17), roughly consistent across housing types. This difference is primarily attributable to the much lower electricity prices faced by HREC customers and the higher fraction of single-family homes in the HREC service area.

The savings averaged 3050 kWh for single-family homes that had not participated in prior retrofit programs, lower than those observed in prior programs in the region. For example, the one-year saving averaged 5400 kWh for participants in Bonneville's pilot program and 4900 kWh for participants (one to two years later) in the regionwide program (Hirst et al. 1985a; Hirst and Keating 1987). Overall, the HRCP savings of 15% of total preretrofit electricity use were comparable to those observed in the Bonneville program.

Recent (1985) participants in Bonneville's program provide the most meaningful comparison with HRCP. Presumably, these later Bonneville participants were faced with similar changes in their external environment. These Bonneville participants saved 2000 kWh/year (Bronfman and Lerman 1987), substantially less than the 3050 kWh saving achieved by single-family homes retrofit by HRCP. However, HRCP spent $5400 on retrofit materials, installation, and administration, compared with $2300 for the Bonneville program.

Postweatherization electricity use was remarkably low, 16,000 kWh/year. Space heating accounted for less than 5000 kWh. These very low usage levels were caused by low levels of pre-HRCP electricity use and the weatherization measures.

Just as there are several factors that explain the low levels of pre-HRCP electricity use, so there are many reasons for the modest electricity savings: wood use, room closures, indoor temperature settings, electricity price increases, etc. Perhaps the most important reason is the low level of preparticipation electricity use. Analyses of electricity savings after retrofit by Bonneville's RWP showed that preparticipation consumption is the most important determinant of savings; on average a 1 kWh/year increase in preretrofit use increases savings by about 0.25 kWh (Hirst et al. 1985b). This correlation suggests that savings would have been about 1500 kWh higher had pre-HRCP consumption been the same as that for participants in Bonneville's program. Many of the factors that contributed to low levels of pre-HRCP consumption are reversible (e.g., room closures and temperature settings). Savings that now look modest could increase if energy-use behaviors revert to earlier patterns.

Other factors that affected the HRCP savings include the mix of housing types, the income of participants, changes in the community's economy (especially unemployment), wood use for heating, and participation in prior programs (which reduced the potential for savings by HRCP). Single-family homes saved 3050 kWh if they had not participated in a prior program, and only 1960 kWh if they had.

HRCP was unlike most retrofit programs in that it sought and obtained participation from all housing types. On the average, the savings in single-family homes (2900 kWh) were almost double those in multifamily units and 15% higher than those in mobile homes (Tables 17 and 18). However, the percentage reduction in electricity use relative to 1982/83 levels (15%) and the annual savings per unit floor area (2.2 kWh/ft2) were roughly constant across housing types.

Savings also depend on changes in household behavior, pre- vs post-HRCP. Indoor temperatures were measured in the EUM homes for a full year before and a full year after retrofit. Dinan's (1987) analysis of indoor temperatures suggests that households increased indoor temperatures by about 0.6°F after retrofit. The effect of this "takeback" was to cut annual electricity savings by 200 to 400 kWh per home.

Wood Use

Wood use is a crucial factor in explaining differences between HRCP and other programs. Homes that use wood for some or all of their heating will, all else being equal, use less electricity and will experience smaller electricity savings after retrofit. Also, households may use disproportionately less wood after retrofit than before further reducing the electricity savings. In other words, some people will take the efficiency improvements associated with retrofits partly in reduced electricity bills and partly in greater convenience and comfort.

Comparison of the homes that probably used electricity as their primary heating fuel with the other homes shows the effects of wood use on electricity use. The primary-electric households used 12% more electricity pre-HRCP than did participants overall (21,000 vs 18,600 kWh; compare Tables 18 and 19). These households also saved almost 25% more than did participants overall, 3200 vs 2600 kWh. For single-family primary-electric homes, pre-HRCP consumption averaged 24,400 kWh (close to the value for the 1985 participants in Bonneville's program), and their four-year savings were 4000 kWh (double the Bonneville savings). Single-family homes that had not participated in a prior program saved 4500 kWh, compared with only 2200 kWh for prior participants.

Almost two-thirds of the participants used wood as their primary or supplemental heating fuel.

Almost two-thirds (66%) of the respondents to the 1986 wood-use survey reported electricity as their primary heating fuel, while 31% reported wood as the primary fuel. An additional 28% used wood as a supplemental fuel. Thus, almost 60% of the HRCP participants used some wood for heating during 1985/86.

The survey asked "what percentage of your space heating is provided by wood?" Responses showed that electricity use declined as the percentage reported for wood increased: homes in which wood provided more than three-fourths of the space heating used 6000 kWh less in 1985/86 than did homes in which wood provided less than one-fourth of the total. The difference in 1982/83 was higher, 6800 kWh/year.

Responses to the wood-use survey showed that overall wood use decreased between 1984/85 and 1985/86 by an average of 0.4 cords. A reported decrease in wood use of 1 cord/year increased electricity use by about 800 kWh/year (Fig. 14). This suggests that the 0.4 cord/year average reduction in wood use among HRCP participants (in general, not just those that used wood) between 1984/85 and 1985/86 led to an increase in electricity use of approximately 300 kWh/participant. The total reduction in wood use between 1982/83 and 1985/86 was surely greater than that reported between only the last two years.

The EUM homes provide another, and probably more reliable, view of changes in electricity and wood

Table 19. Electricity use and savings for homes retrofit by HRCP that probably used electricity as their primary heating fuel

	Total	Housing type		
		Single-family	Multi-family	Mobile home
Electricity use (kWh/yr)				
Total use				
1982/83	21,000	24,400	10,600	20,800
1985/86	17,800	20,400	8,700	18,800
Space heating				
1982/83	9,200	10,300	5,000	9,700
1985/86	6,600	7,000	3,200	8,100
Total savings				
1982/83–85/86	3,200	4,000	1,900	2,000
Floor area (ft^2)	1,360	1,670	810	1,010
Pre-HRCP use/ft^2	16.8	16.0	13.1	21.8
Savings/ft^2	2.5	2.8	2.4	2.0
Retrofit cost ($)	4,080	5,480	2,080	2,070
Number of households	615	362	115	138

Source: Hirst, Goeltz, and Trumble (1987).

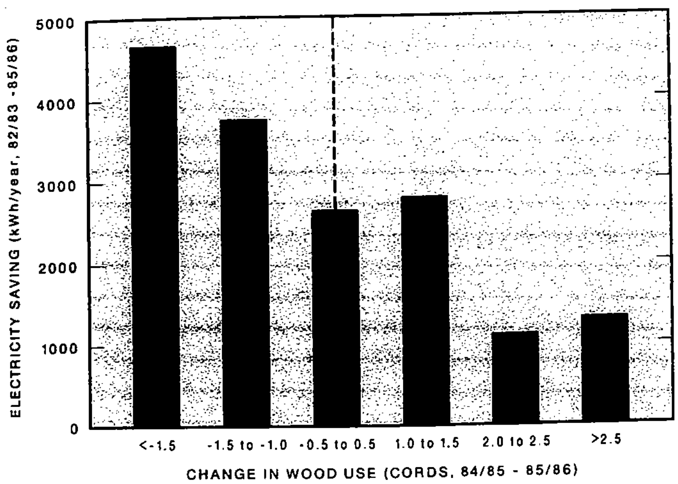

Fig. 14. Four-year electricity savings as a function of one-year changes in wood use (1984/85 vs 1985/86).

uses. Of these homes, 32 were monitored for wood use and had two full years of reliable data. Outputs from the wood-stove monitors were calibrated to reflect the energy output of each stove in terms of kWh (Oliver et al. 1984).

Use of wood reduced annual space-heating electricity use by as much as 6000 kWh per wood-burning home. In addition, participation in prior conservation programs and general energy-conservation savvy contributed to lower electricity use.

Wood use in these 32 homes declined by the equivalent of 1800 kWh/year between 1984/85 and 1985/86. Nonspace-heating and space-heating electricity uses dropped by 700 and 1000 kWh/year, respectively. Thus, total space-heating energy use (electricity plus wood) dropped by 2800 kWh, 22% of the pre-HRCP level. However, the 1800 kWh decline in wood use was 26% of pre-HRCP wood use. Thus, 300 kWh of the reduction in wood use (and consequent "loss" of electricity saving) occurred because of changes in household wood-use behavior, consistent with the estimate based on the wood-use survey discussed above.

In summary, some of the efficiency gains produced by the HRCP retrofits were taken in reduced wood use associated with proportional reductions in electricity and wood uses amounting to about 1500 kWh/year. In addition, changes in household behavior associated with disproportionate declines in wood use cut electricity use by an additional 300 kWh/year. These results are consistent with other analyses of wood use in the Pacific Northwest (Tonn and White 1986). In general, homes retrofit by Bonneville's RWP that used electricity as a supplemental fuel saved less electricity than those that used electricity as the primary heating fuel.

Post-HRCP Electricity Use

Average levels of electricity use after installation of measures (1985/86) were very low, because of the low levels of pre-HRCP electricity use and the savings produced by the HRCP measures (Tables 17 to 19). Single-family homes used less than 18,000 kWh/year after HRCP retrofit, compared with 22,000 kWh for homes retrofit by the Bonneville program in 1985.

Space-heating electricity use in HRCP single-family homes heated primarily with electricity averaged 7000 kWh/year, equivalent to 4.2 kWh/ft^2. This is 25% *less* than that for new homes constructed during the early 1980s (Meier et al. 1986) and only 25% *more* than the 3.3. kWh/ft^2 achieved by new homes that meet the Council's Model Conservation Standards.

Watson (1987) reviewed post-retrofit levels of electricity use for homes retrofit by other programs throughout the U.S. His search suggests that post-HRCP levels of space-heating electricity use are less than half those achieved in other programs.

Interpretation

HRCP demonstrated electricity savings that averaged 2600 kWh per retrofit home in a climate with 5600 heating degree days (65°F base). Savings varied considerably as functions of house type and age, use of fuelwood, participation in prior retrofit programs, and electricity-price histories. Single-family homes experienced higher savings, averaging 2900 kWh; and single-family homes that relied primarily on electricity as their heating fuel saved 4000 kWh. On the other hand, multifamily and mobile homes and homes that relied heavily on wood saved less electricity.

The savings averaged only 43% of that predicted during energy audits of these homes (6100 kWh, on average; Fig. 15). Differences between actual and predicted savings were caused by typical discrepancies between actual and predicted savings, by pre-HRCP reductions in electricity use, and by post-HRCP changes in energy-related behaviors (e.g., higher indoor temperatures and less use of wood).

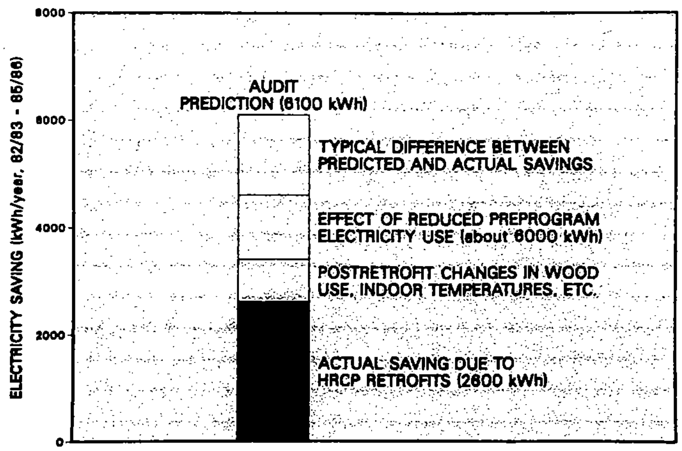

Fig. 15. Rough accounting of differences between actual and predicted electricity savings caused by HRCP retrofit measures.

These results suggest that the modest savings attributed to HRCP were caused partly by pre-HRCP changes and partly by household increases in comfort and convenience. Roughly one-fourth of the technical improvements produced by HRCP measures was taken in comfort and convenience, and the remaining three-fourths was taken in reduced electricity bills. It is likely that much of the pre-HRCP electricity savings and the post-HRCP behavioral changes are reversible. The savings stimulated by the retrofits, on the other hand, are more dependable and permanent. Thus, if electricity prices remain stable and households relax their energy conservation behaviors, the savings caused by HRCP retrofits could increase. In other words, the HRCP retrofits provide, in addition to immediate savings, "insurance" against rapid long-term load growth.

Finally, HRCP showed the feasibility of reducing residential electricity use to very low levels. Specifically, post-HRCP consumption averaged 16,000 kWh, of which space heating accounted for only 5000 kWh. Post-HRCP levels of space-heating electricity use were lower than those in typical new homes constructed during the early 1980s and far below levels achieved in other retrofit programs throughout the U.S.

LOAD REDUCTIONS

Retrofit measures (as well as other electricity-efficiency actions) affect peak demands (kW) as well as annual electricity use (kWh). Data from the 320 EUM homes were used to examine daily load shapes (the hour-by-hour pattern of electricity use) and demands at the time of system and area peaks. System refers to the Pacific Power & Light Company system, and area refers to the Hood River area. These load data were collected for a year before and a year after installation of retrofits; therefore, the analysis considers demands before and after HRCP and the effects of HRCP on loads (Stovall 1987).

Weather-normalization of the load data was essential because no local control group was available for comparison. (Load-metering a sample of homes in nearby communities would have been very expensive and time consuming.) Two weather-normalization methods were employed. The first is a regression modeling technique, which involved the development of statistical models that explain variations in total hourly load as functions of outdoor temperature, wind speed, solar radiation, and time of day. Separate models were developed for weekdays, weeknights, weekend days, and weekend nights. These models predict hourly load for the average of the EUM homes for the winter months (December through February). The second weather-normalization method involved comparison of loads on "similar" days for the two years. Similar days were matched on the basis of day of the week, average daily outdoor temperature, and minimum (winter, spring, fall) or maximum (summer) daily outdoor temperature.

During the second heating season (1985/86), the Hood River area peak occurred on November 25, 1985. The reduction in diversified load across the EUM homes at the time of this peak was almost 0.6 kW/house (Fig. 16). The Pacific peak occurred three weeks later, on December 13. The reduction in diversified load at the time of this peak was just over 0.5 kW/house.

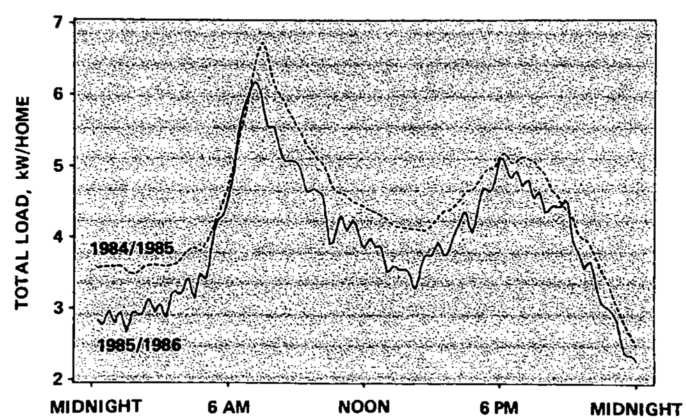

Fig. 16. Diversified total residential load on the peak day (11/25/85) for the Hood River area. The year 1 (1984/85) load profile is computed using the regression model weather-normalization method.

Analysis of these load data suggest that the peak load reductions produced by the HRCP retrofits increase with decreasing ambient temperature. Thus, the Project reduced the electric system's sensitivity to extremely cold weather (which is precisely when system demands peak).

Both weather-normalization methods were used to assess the reductions in average and peak seasonal loads and showed close agreement. During the winter, the average reduction was 0.4 kW, while the peak reduction was 0.5 kW (Table 20). The amount of time during which the diversified load exceeded 5.4 kW/house decreased by more than a third between the two heating seasons. Reductions in loads during the other three seasons were much less than during the winter, which reflects the fact that the HRCP retrofits focused on space heating. The average reduction in water-heating load was just under 0.1 kW/house.

Table 20. Electricity demands in Hood River, by season

Season	Period	Total load (kW/house) Average	Total load (kW/house) Maximum	Load factor (%)
		Total sample of monitored homes		
Spring	Before	2.0	4.6	45
	After	1.9	4.1	47
Summer	Before	1.4	2.4	61
	After	1.4	2.2	64
Fall	Before	1.9	4.3	44
	After	1.8	4.1	44
Winter[a]	Before	3.4	6.1	55
	After	3.0	5.9	50
		Single-family electrically heated homes		
Winter	Before	4.0	6.2	65
	After	3.4	5.4	61

Source: Stovall (1987).

[a]Use of the regression-model method gave the same average winter loads but very different peak loads: 6.7 and 6.2 kW/house. Thus, the regression method shows a reduction in peak load of 0.5 kW/house in contrast to the 0.2 kW/house shown above.

Load factors decreased from 1984/85 to 1985/86 because the percentage reduction in peak load was less than the percentage reduction in average savings (Table 20). To a large extent, peak loads are defined by the capacity of the heating equipment. The HRCP retrofits affected the building shell but not the heating equipment.

HRCP measures affected peak demands (kW) as well as annual electricity use (kWh). The reduction in demand at the time of Pacific's system peak averaged 0.5 kW/house (about 10%).

The average winter weekday profiles were quite similar for the two heating seasons, with the profile for the second year lower by a nearly uniform amount over the entire day (Fig. 17). Peak loads occurred in the morning (generally between 8 and 9 am); a secondary peak occurred late in the afternoon (around 6 pm).

Table 21. Diversified loads on selected similar cold days

	Total load (kW/house) Average	Total load (kW/house) Maximum
Total sample of monitored homes		
Regression model		
January 15, 1986[a]	3.3	5.2
January 15, 1986	2.9	4.7
Savings	0.4	0.5
Similar days		
January 16, 1985	3.4	5.4
January 15, 1986	2.9	4.7
Savings	0.5	0.7
Single-family electrically heated homes		
Similar days		
January 16, 1985	4.2	6.2
January 15, 1986	3.2	4.8
Savings	1.0	1.4

Source: Stovall (1987).

[a]These loads were estimated for this day with the pre-HRCP regression model.

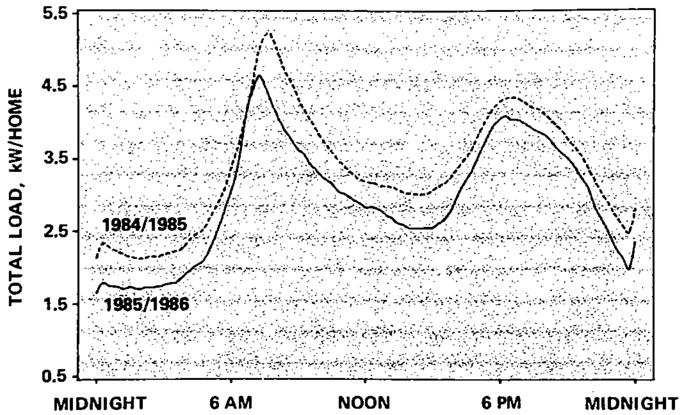

Fig. 17. Average winter weekday diversified total residential load.

As expected, the load reductions differed by housing type, as was true for energy savings. The average and maximum (peak) load reductions for single-family homes that used only electricity for heating were double those of the average (Tables 20 and 21). The reduction in demand for these all-electric, single-family homes was about 1.0 kW at the time of system peak.

Loads were also monitored on a three-phase feeder line serving mostly residential customers. The purpose of this monitoring was to measure the effects of HRCP at the feeder level (i.e., to assess the effects on a utility's distribution system). Unfortunately, the presence of many small commercial customers on this feeder, which were not separately monitored, made it impossible to isolate the effects of the retrofits. Also, many of the participant homes on this feeder received some measures before and during the first heating season, further complicating analysis of data from the feeder.

Project Economics

A critical issue in assessing conservation programs is their overall worth. In other words, are the costs of implementation justified by the program's benefits?

Assessing benefits and costs is difficult because some benefits are hard to quantify. HRCP retrofits made it feasible for households to raise indoor temperatures and reduce the amount of wood they use; placing a value on this increase in "well being" is difficult. Other hard-to-quantify benefits include increased local employment caused by greater retrofit activity, increases in the value of participant homes, reductions in the environmental problems associated with electricity production and wood use, and improved relations between utilities and their customers.

Examining HRCP economics is further complicated because HRCP was an experiment designed to test the reasonable *upper* limits of a retrofit program. By design, HRCP was more expensive than other programs because of its emphasis on superweatherization and 100% participation (see discussion of costs in Chapter 3). Project management sometimes consciously sacrificed cost-minimization to other objectives. The need to complete all retrofits within two years, coupled with the decision to rely as much as possible on local contractors, produced higher than necessary costs. Some of the retrofits involved levels of insulation and glazing with which the contractors were initially unfamiliar; HRCP costs include the initial "learning curve" that involved mastery of new installation techniques.

In examining HRCP cost-effectiveness, we adopt a broad regional view (Northwest Power Planning Council 1986) rather than the narrower perspectives of participants, nonparticipating ratepayers, or the Pacific electric system. The regional view computes benefits on the basis of total electricity savings valued at the region's marginal cost of electricity. Regional costs, all of which occur at the time of program participation, include those borne by participating households as well as HRCP.

The cost-of-conserved energy (CCE) is used to assess the economic worth of HRCP. CCE computes the annualized cost of the program (retrofit plus administrative costs) per unit electricity saving. In essence, this method considers conservation an energy resource, comparable to supply resources. Both types of resources are examined on a similar basis. The annualization process permits one to convert a one-time capital cost (for either conservation or a power plant) to a uniform stream (in constant dollars) of annual payments over the lifetime of the investment.

Two perspectives (analogous to the two views of HRCP's effects on electricity use) are used to assess the economics of HRCP electricity savings. One is retrospective and focuses on the measured savings for the retrofit homes. An alternative approach uses the perspective of a utility planner who is deciding among alternatives for meeting long-term electric-power needs. The first approach understates HRCP benefits, while the second approach overstates benefits.

RETROSPECTIVE (RESOURCE) VIEW

Averaged over all 2989 homes retrofit by HRCP, the savings were 2600 kWh/year. The average cost to achieve these savings was $4400/house (Table 10). This cost includes the small payments by Hood River homeowners and the Project's administrative expenses, but excludes air-to-air heat exchangers.

Thus, the cost was $1.70/first-year actual saving, substantially higher than the audit-based cost-effectiveness limit ($1.15/kWh, exclusive of administrative costs). Annualizing the initial cost of $4400 at a real interest rate of 3% over the assumed 35-year lifetime of the measures yields an annual cost of $206. The annualized cost of conserved energy for HRCP is then 7.9¢/kWh. Using assumptions on retrofit lifetimes developed by the Council yields an average lifetime of 44 years for the HRCP measures; the annualized cost is then 7.1¢/kWh. Both results are above the

5.3¢ implied by HRCP's $1.15 limit and above the 5.0¢ limit used by the Northwest Power Planning Council (1986) to assess conservation programs. (The Council's limit is for the marginal, not the average, measure and does not include administrative costs. Also, their limit credits conservation savings with reductions in transmission losses and the 10% credit specified by the 1980 regional power act, and is therefore comparable to the 4.5¢/kWh cost of a new coal plant.)

Two perspectives are used to assess the economics of HRCP electricity savings.

The foregoing calculations give no credit to HRCP for the latent savings embedded in behavioral changes made in response to the retrofits (i.e., increases in indoor temperatures and reductions in wood use). Also, no credit is taken for peak reductions, which might reduce the losses in and costs of constructing transmission and distribution facilities. (Assuming a $300/kW cost of transmission and distribution reduces the cost of conserved energy given above by 0.3¢/kWh.) Finally, environmental benefits associated with the substitution of conservation for generation are excluded.

PROSPECTIVE (PLANNING) VIEW

An alternative to the retrospective view is that of the utility planner who is deciding among alternative strategies for meeting long-term system needs. This planning perspective might yield results that are more stable and more easily transferable than those obtained with the retrospective view discussed above. Retrospective measurements of energy savings depend strongly on the external environment, especially changes in electricity prices and household incomes. When prices rise and/or incomes fall, pre-retrofit electricity use declines and program-induced savings are lower than expected; the reverse occurs when prices fall and/or incomes rise. If systemwide consumption shifts upward (e.g., in response to stable electricity prices), electricity savings will increase just as the system's need for them increases.

The value of such planning contributions can be approximated for HRCP by comparing utility estimates of space-heating electricity use at the time the Project began with the post-retrofit consumption that the Project and rising electricity prices produced. Estimates of annual space-heating electricity use averaged almost 13,000 kWh/single-family home during the early 1980s (Watson 1986). Post-HRCP, single-family homes that relied primarily on electricity for heating used 7,000 kWh. The 6000 kWh difference can be attributed to HRCP in this planning perspective.

Utilities did not predict the pre-retrofit decline in electricity use that occurred in Hood River and other Northwest communities during the early 1980s. That is no indictment; in planning for future generation, utilities cannot count on reversible customer actions that result collectively in large savings. Indeed, this is a major reason why utilities invest in customer conservation measures; they are converting what would otherwise be a speculative and possibly temporary saving into a planned resource that comes "on line" in a predictable fashion. In other words, the savings caused by the HRCP retrofits (technical efficiency improvements) are much more durable and long-term than savings caused by behavioral changes.

The 6000 kWh planning savings were purchased at a cost of $5600 (Tables 10 and 19) per single-family house heated primarily with electricity. Thus, the planning cost to achieve these savings was $0.93/first-year kWh saved, below the $1.15 limit. Annualizing the initial cost over the assumed 35-year lifetime of the measures yields a cost of 4.2¢/kWh (3.7¢ at 44-year lifetime), less than the allowable 5¢ suggested by the Council.

Supplemental Studies

HRCP's focus on providing information to support decisions about residential conservation programs led to the collection and management of an extensive and high-quality data base. This enormous data base turned out to be valuable for purposes that go beyond the original HRCP objectives.

This chapter discusses several studies that used (and continue to use) HRCP-generated data. The first three studies (performed by Pacific) dealt with the energy-saving effects of the "House Doctor" approach to residential retrofit, the inputs to a widely used heat-loss methodology, and the extent to which HRCP results can be generalized to the Pacific Northwest as a whole. The second set of studies (performed by ORNL) used the load-research data to examine electricity use for water heating and the electricity savings caused by the HRCP water-heating retrofits, examine pre-HRCP vs post-HRCP levels of indoor temperature and wood use, and validate a weather-adjustment method. The final studies (conducted by Pacific) continue monitoring post-HRCP levels of electricity use to measure the durability of these savings.

HOUSE DOCTOR STUDY

The House Doctor approach, developed at Princeton University and Lawrence Berkeley Laboratory, is designed to identify and reduce infiltration of outside air into a house. The house doctor uses a "blower door" fan to pressurize the house and thereby locate sources of air leakage. Caulking, weatherstripping, and other remedies are then applied to reduce infiltration at the sites identified with the blower door.

The incremental effects of the House Doctor treatment on electricity savings and infiltration were measured in Hood River (Engels et al. 1985). A random sample of 75 homes received blower door tests before and after retrofit, the House Doctor treatment, and the usual HRCP retrofits during the 1983/84 heating season. Other random samples of participants were used as control groups. These groups of homes were compared in terms of electricity use and infiltration (based on measured air changes per hour and effective leakage area). Implementation of these comparisons was straightforward and inexpensive because so much relevant data were already being collected for HRCP.

Analysis of monthly electricity bills for the 1982/83 and 1984/85 heating seasons showed that no measurable electricity savings could be attributed to the incremental House Doctor measures. The absence of incremental savings might have been caused by the much larger effects of the HRCP measures, use of wood for space heating, or both. The House Doctor measures did yield small (but statistically insignificant) incremental reductions in air infiltration; the effective leakage area dropped by 20% in homes that received HRCP measures only, compared with 25% in homes that received both HRCP measures and House Doctor treatment.

HEAT-LOSS STUDY

The energy audits used in retrofit programs are generally based on engineering models that simulate energy flows into and out of a house. A fundamental assumption of these programs (including HRCP) is that the audits yield accurate estimates of the energy savings that can be achieved by installation of individual measures. The detailed end-use data, energy audit results, and survey information for the EUM homes offered the opportunity to examine the relationship between model predictions and actual space-heating electricity use for a sample of homes.

Yoder (1987) compared SUNDAY predictions with monitored space-heating electricity use for 20 of the EUM homes. SUNDAY (Palmiter and Straub 1984) is a one-zone, thermal-load simulation model used to analyze space-heating energy use in single-family homes. SUNDAY was selected for comparison because it is used by the Council to estimate long-term conservation potentials in the region. Although SUNDAY had been checked against data for unoccupied structures, HRCP provided an opportunity to compare SUNDAY results with actual electricity use for occupied homes.

The 20 homes chosen for analysis were all single-family homes without unheated basements that relied exclusively on electricity for space heating; 18 of the homes had individual-room baseboard heaters and the other 2 had central furnaces. These criteria yielded a set of homes with the fewest confounding factors (e.g., none of these homes used wood for space heating).

Parametric analysis showed that the overall building heat-loss rate and the thermostat setpoint were the two most important input parameters to SUNDAY. Three estimates of setpoint temperature and two estimates of heat-loss rate were used to define six sets of plausible inputs for the SUNDAY simulations. The SUNDAY predictions of annual space-heating electricity use exceeded actual electricity use by an average of 34% for these six runs (with 20 homes in each); the discrepancy between predicted and actual electricity use ranged from a 68% overprediction to a 1% underprediction.

Apparently, much of the difficulty in obtaining close agreement between data and model simulations is caused by variations in occupant behavior. For example, the heat-loss rate is affected by unheated rooms in a house, and the average indoor temperature is a function of temperature in each of the rooms. These comparisons of space-heating electricity *use* suggest that occupant behavior might have accounted for much of the variation found among HRCP homes in the relationship between actual and predicted electricity *savings* (Fig. 18).

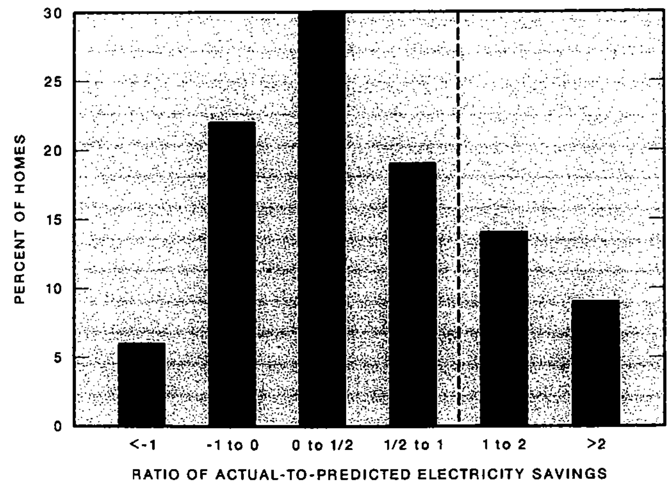

Fig. 18. Distribution of the ratio of actual-to-predicted savings for HRCP homes. A ratio of 1.0 means that the actual saving equals the predicted saving. More than 25% of the homes increased electricity use between 1982/83 and 1985/86.

TRANSFERABILITY STUDY

Because HRCP results were meant to inform the entire Pacific Northwest about retrofit programs and their effects, a study was conducted to determine the extent to which (and how) HRCP results could be generalized to the region as a whole (French et al. 1985). The first phase of this study compared results from the 1983 pretest survey and the 1984 onsite interview conducted among EUM households with comparable data for Hood River from the 1980 Census of Population and Housing. This comparison suggested that the two Hood River surveys accurately represented the community (i.e., the samples were properly drawn for these two surveys).

The second phase compared Hood River households (based on the two surveys mentioned above) with data from the 1983 Pacific Northwest Residential Energy Survey, conducted by Bonneville. The third phase examined differences and similarities among the electrically heated homes in the aforementioned three surveys; this phase also examined levels of electricity use among these households.

The largest difference between electrically heated homes in Hood River and those in the region was in the age of houses. Roughly half the Hood River homes were built after 1970, compared with only 12% for the region as a whole. The Hood River and region homes showed other differences, but these were small and generally not statistically significant: a larger fraction of homes in Hood River were single-family and owner occupied, and larger fractions of Hood River households reported use of wood as the primary or secondary heating fuel. Differences in annual electricity use between Hood River and the region were also small, regardless of type of utility (Fig. 19) and house type.

The primary conclusion from the transferability study is that "Hood River is indeed representative of the Pacific Northwest region, with very few exceptions" (French et al. 1985). The study suggests several modeling approaches to apply Hood River results to other locations.

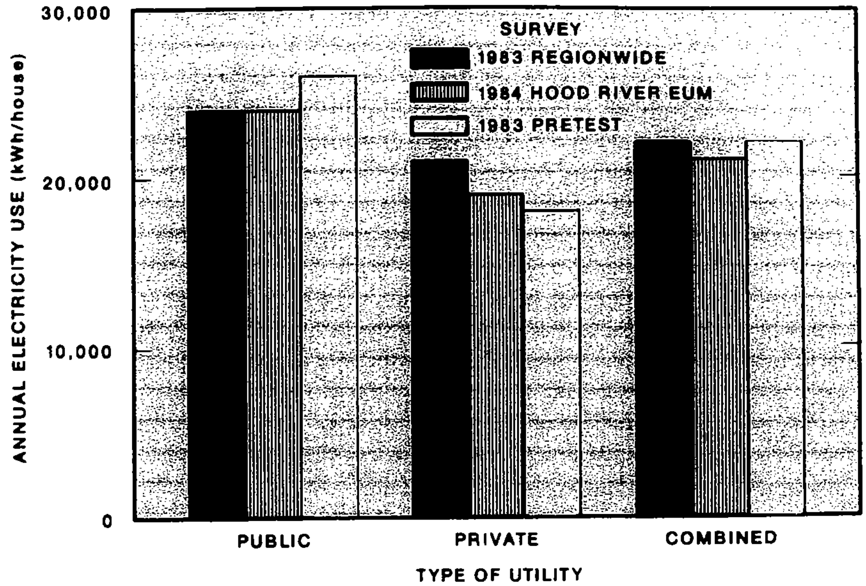

Fig. 19. Annual electricity use for single-family homes in the Pacific Northwest (1982 kWh/year), by type of utility.

COMPARISON OF PRISM WITH LOAD RESEARCH DATA

The Princeton Scorekeeping Method (PRISM) is a widely used technique to adjust residential energy-use data for differences in winter severity (Fels 1984). Indeed, PRISM results form the basis for our analysis of HRCP electricity use and savings (Chapter 5). The load-research data available from the EUM homes made it feasible to compare PRISM estimates of total and space-heating electricity uses with annual sums of the whole-house and space-heat loads (Hirst and Goeltz 1986a).

Results showed that PRISM estimates of total electricity use are in almost perfect agreement with load-research data. Discrepancies occur only when there are errors in the monthly electricity bills. On the other hand, PRISM estimates of space-heating electricity use are generally higher than actual consumption (Fig. 20). On the average, PRISM overestimates space-heating use by 29%. Use of wood for heating, actual space-heating electricity use, use of air-conditioning equipment, and PRISM parameters are all statistically significant determinants of the discrepancies between actual use and PRISM estimates. Differences are larger for homes that use wood, and smaller for homes that use large amounts of electricity for heating or that have air conditioners. These data and analyses were used to develop a simple method to adjust PRISM results to yield more accurate estimates of average space-heating electricity use for Hood River homes.

WATER-HEATING ELECTRICITY USE

Water heating is the second most important residential electricity end-use (after space heating); electricity use for water heating averaged 5000 kWh/year in 1984/85 among the roughly 180 EUM homes with monitored water-heater use. The availability of detailed end-use data on electricity use for water heating plus results from the onsite home interview made it feasible to analyze residential electricity use for water heating (Hirst, Goeltz, and Hubbard 1987). These data were also used to measure the energy-saving effects of the HRCP water-heating retrofits (water-heater wraps, cold and hot water pipe insulation, and low-flow showerheads) (Brown et al. 1987).

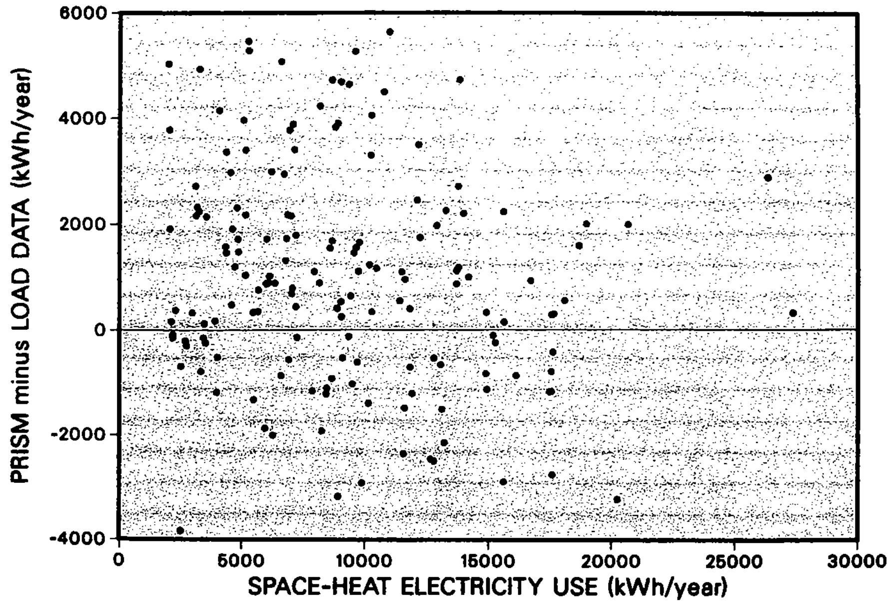

Fig. 20. Differences between PRISM estimates of space-heating electricity use and load data vs load data from homes in Hood River. The mean value of space heating use was 9100 kWh/year for these homes, all of which used more than 2000 kWh/year for heating. The mean value of the discrepancy between actual and predicted consumption was 1600 kWh.

Analysis of the annual aggregates of the water-heating electricity-use data showed that the number and ages of household members are the primary determinants of electricity use (Table 22). Electricity use increases by about 1000 kWh/year with each additional member. Adults (18 to 65 years old) have more influence on electricity use than do older residents or children. Hot water temperatures also affect electricity use; each 1°F decrease in temperature reduces electricity use by 35 kWh/year. Finally, electricity use is higher in single-family homes than in mobile homes and higher for units located in unheated spaces of the home.

Indoor temperatures increased by an average of 0.6°F after weatherization. This increase cut electricity savings by 300 kWh/year.

Comparison of pre- vs post-HRCP water-heating electricity use showed an average reduction of 540 kWh/year. Savings were larger for units located in an unheated area of the house, probably because the water-heater wrap saves more energy when the unit is exposed to colder temperatures. The annualized cost-of-conserved energy for the water-heating conservation measures (which cost an average of $20/home) was 0.4¢/kWh, much less than the cost of space-heating measures.

INDOOR TEMPERATURES

The behavioral response (e.g., changes in indoor temperatures) to residential technical efficiency improvements (e.g., attic insulation and storm windows) is very important. Although the extent to which households "take back" some of the energy savings caused by efficiency improvements in increased comfort is often discussed, almost no empirical evidence exists on the subject. HRCP may be the first project to provide data on indoor temperatures rather than household self reports.

Collection of 15-minute data on indoor temperatures at one location (generally the living room) among the EUM homes permits analysis of the determinants of indoor temperatures and the pre- vs post-HRCP changes in temperatures. Dinan (1987) analyzed monthly average temperatures for the heating season as functions of electricity price, household income, house size, pre-HRCP structure efficiency, and other variables collected during the 1984 onsite interview.

Results showed that low-income households have lower indoor temperatures than either middle- or

Table 22. Water-heating electricity use as a function of household size in Hood River

Number of household members	Electricity use (kWh/year)	
	Mean	Standard deviation
1	2600	880
2	4290	1560
3	5460	1260
4	6190	1920
5	7400	2430
6 or more	9270	3720
Average	5040	2320

Source: Hirst, Goeltz, and Hubbard (1987).

high-income households, by almost 2°F. Homes served by HREC had temperatures about 0.5° higher than those served by Pacific, probably because HREC electricity prices were lower. Homes that used wood for space heating had temperatures that averaged 2.4° higher than those that relied solely on electricity for heating.

On the average, indoor temperatures increased by almost 0.6°F between 1984/85 and 1985/86. The increase was higher (almost 1°) for low-income households. Homes that used only electricity for heating showed a smaller increase, only 0.2°. The average increase of 0.6°F is equivalent to a 300 kWh/year loss of electricity savings. Thus, the takeback effect cut HRCP electricity savings by 10 to 15%.

WOOD USE FOR SPACE HEATING

Use of wood has substantial effects on residential electricity use throughout the Pacific Northwest as well as in Hood River. ORNL recently analyzed data from the wood-stove monitors and the onsite surveys from the EUM homes. This project continues and expands upon earlier analysis of wood use in the Pacific Northwest (Tonn and White 1986 and 1987).

Initial results from analysis of HRCP data show that wood users in Hood River have larger and older homes with more occupants than do electrically heated homes that do not use wood. Wood generally contributes more energy for space heating than does electricity in wood-heated homes. Similarly, the HRCP retrofits saved more energy (electricity plus wood) but less electricity in wood-heated homes. On the average, about three-fourths of the space-heating energy savings in wood-heated homes was attributed to reductions in wood use, and only one-fourth to reductions in electricity use.

CONTINUED MONITORING OF HRCP HOMES

Because the data from HRCP are so rich and extensive, Bonneville and Pacific agreed to continue collection of data from Hood River, especially the load-research data. Pacific will analyze electricity savings for a second year (1986/87) to improve our knowledge of the long-term durability of the conservation resource obtained by HRCP. In addition, Pacific

The lessons learned from HRCP can be applied to energy planning in other U.S. weatherization programs.

will examine changes in Hood River and the two comparison communities; update the ORNL analysis of peak loads; and examine the effects of electricity use on air quality, wood use, room closures, and indoor temperatures. Finally, the HRCP data will be used to help refine the regional conservation supply curve for residential retrofit.

Additional efforts are being planned to extend data collection through the winter of 1989/1990. These data would be used to update ORNL analyses of electricity use and savings (both kWh and kW); to suggest methods for increasing savings among the homes that experienced little or no initial electricity savings; to develop an improved method of generalizing results from Hood River to the region as a whole; and to examine the interactions among air-to-air heat exchanger performance, household behavior and indoor air quality. It is likely that additional relevant studies will be suggested and pursued with the rich HRCP data base.

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