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1992-1993 Bonneville Appliance Efficiency Program: Showerhead Evaluation Volume I - Report

W. M. Warwick

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Pacific Northwest Laboratory
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Summary

The Bonneville Power Administration (Bonneville) provides wholesale electric power to over 100 retail distribution utilities in the Pacific Northwest. Bonneville is faced with meeting growing loads from these utilities. It acquires conservation as one means of meeting this load growth. Bonneville has offered a variety of conservation programs since 1980. Efficient showerheads have been a feature in residential conservation programs ever since. Bonneville launched the Residential Appliance Efficiency Program to focus on water-heater energy conservation opportunities in 1992. The Residential Appliance Efficiency Program consists of two parts, a water-heater efficiency program, and a hot-water efficiency program. This report evaluates the savings and costs of the first two years of the *showerhead portion* of the Residential Appliance Efficiency Program (the showerhead program). Although it is not a formal evaluation of the program limited to implementation or a "process" evaluation, observations about program design and implementation are included as appropriate. Results of this evaluation are limited to program participants within the Bonneville service territory.

Overview

The showerhead program design was more innovative than most Bonneville programs, because it provided utilities with a menu of program delivery options instead of a single, prescribed program design. This approach was adopted to increase utility acceptance of the program and the associated conservation acquisition goals. In addition, the program included a variety of brands and models of efficient showerheads and faucet aerators. The end result was a program that followed several paths to achieve installation of a variety of conservation measures, each of which performed differently. This variety significantly complicated program evaluation due to variations in measure installation from each delivery path and savings from each showerhead model. The complex nature of the program resulted in a program evaluation approach that continued to evolve during its implementation.

Initially, the evaluation approach was based on an engineering model of showerhead savings that included a number of behavioral variables, such as number of showers per household member and shower length. Bonneville contracted with Pacific Northwest Laboratories (PNL) to conduct a field study to verify the assumptions Bonneville used in its engineering model. The results of the field study called into question both Bonneville's initial assumptions and the usefulness of an engineering model that relied heavily on occupant data, which is highly variable, difficult to obtain, and often unreliable. This launched a series of related studies to explore various facets of hot-water use and energy savings ultimately resulting in a new engineering model for evaluating the program. The final program evaluation algorithm relies on the relationship between monitored energy savings from the program and conditions that vary from site to site, such as water pressure and retrofit showerhead performance. This model provides a more reliable means for estimating program savings because site conditions are easier to measure, more stable, and can be supplemented with laboratory studies to project program savings.

Program and Measure Results and Savings Estimates

During its first two years the showerhead program achieved the following:

- Attracted 557,483 participants.
- Distributed almost 2 million measures, including over 500,000 showerheads.
- Acquired savings over the next 12 years of 859,020 MWh of electricity.
- A program cost to Bonneville of 18.4 million dollars (4.8 million was for measures and nearly 13 million was for installation costs and incentives to participants and utilities).
- Energy savings at a real, levelized cost of about 39 mills/kWh, or 3.9 cents/kWh, which is within Bonneville's cost-effectiveness criteria.
- Reduced showerhead flow rates an average of .9 gpm and energy use 337 kWh.
- First year savings included an estimated 153kWh savings per house due to a regionwide drought. Thus, net energy savings averaged 184 kWh the first year, in homes where all showerheads were replaced. Only half of the energy savings were obtained when participants were required to install measures themselves.
- Projected savings at each participant site totalling an average of 1,541 kWh over 12 years, or average 128 kWh per year once measure persistence is considered.

In addition to these significant energy savings, the showerhead program was also among the most popular Bonneville ever offered, in terms of the number of utilities who offered it and consumers who participated. The innovative program design complicated the final evaluation; however, the evaluation approach may significantly reduce the cost and time involved in other program evaluations and permit cost sharing through collaborative effort. This approach relies on small-scale, in-depth field studies to fully explore energy-savings dynamics and the development of models of energy savings that can be adapted to a wide variety of conditions using local data. This contrasts with the most current evaluation approaches that require expensive customization of evaluation methods for each utility or extensive data collection and analysis. These conventional approaches may not be cost-justified in a more competitive utility environment.

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Mr. Bavry was instrumental in the initial analysis of REMP socioeconomic data. Mr. Hardin was primarily responsible for the REMP energy savings analysis and the initial draft of Appendix E. He would also like to acknowledge the following PNL staff members for their efforts: Sharon Bailey for managing the REMP field study; Annet Dittmer, Anita Lauhala, Jan Schwab, Linda Seidel for support conducting the REMP field study; Andrea Wood, Rob Pratt and Gordon Haber for their help with the REMP energy saving analysis; and Terri Gilbride, Mary Ann Thornburgh, Karen Cole, and Diane Purser for preparing this report.

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1.0 Introduction

The Bonneville Power Administration (Bonneville) provides wholesale electric power to over 100 retail distribution utilities in the Pacific Northwest. Bonneville adopted conservation as a resource alternative in 1980 when it faced growing power demands and increasingly expensive conventional generating resources. Bonneville has offered a variety of conservation programs since 1980. Its aggressive approach to conservation typically includes full cost reimbursement for the installation of conservation measures expected to be cost-effective.

Efficient showerheads have been a feature in residential conservation programs since 1980. Bonneville launched the Residential Appliance Efficiency Program to focus on water-heater energy conservation opportunities in 1992. At this writing, Bonneville continues to operate this program. The Residential Appliance Efficiency Program consists of two options, a water-heater efficiency option and a hot-water efficiency option. The *water-heater* efficiency option offers rebates to encourage consumers to replace failed electric water heaters with models that are among the most energy-efficient on the market. This portion of the Residential Appliance Efficiency Program is the subject of another Bonneville evaluation report (PECI 1994). The *hot-water* efficiency option, called the "showerhead" program for short, is designed to save water-heating energy by reducing household demand for hot water through retrofitting efficient showerheads and faucet aerators. This report evaluates the savings and costs of the first two years of the showerhead portion of the Residential Appliance Efficiency Program. It is not a formal program process evaluation. However, the complicated program design presented impact evaluation challenges that resulted in observations about program implementation. These challenges are noted when appropriate.

1.1 Program Summary

Bonneville has included hot-water conservation devices in its residential conservation programs since 1980. Initially, these devices were limited to showerhead flow restrictors, which were often simply left for consumers to install. Results from these devices were not encouraging. There were many complaints about the poor quality of both the devices and the shower they provided. Follow-up visits to homes where devices were retrofit documented high removal rates and/or low initial installation rates. In time, manufacturers began to produce showerheads that were designed to provide both a satisfactory shower and reduce water use. By the late 1980s these showerheads began to attract renewed attention as conservation measures. Bonneville and other regional utilities commissioned studies to review the performance and consumer acceptance of efficient showerheads (Katzev 1991). The results were encouraging enough that Bonneville included efficient showerheads and faucet aerators in its residential program offerings in January of 1992.

Electric water heating is common in the Pacific Northwest due to historically low, stable power prices (approximately 85% of the region's homes have electric water heaters [Northwest Power Planning Council 1986]). It is the second largest power user in homes that heat with electricity and the largest user in those that have other energy sources for home heating (Pratt et al. 1989). Significant savings result from reduced water-heating demands.

Bonneville is a wholesale power provider. It sells bulk power to over 100 local utilities who sell it to retail consumers. Bonneville acquires conservation from these utilities to defer the construction of new generating resources. These acquisitions are governed by contracts between Bonneville and the local utility. Generally, these contracts specify the conservation program design including incentives to be paid to consumers and utilities for participating.

The showerhead program was one option included in the Residential Conservation Agreements (RCA) offered by Bonneville to all of its utility customers in 1991. Nearly all of Bonneville's utility customers adopted the showerhead program element, making it one of Bonneville's most popular programs.

Bonneville was implementing a more flexible approach to conservation acquisition when the RCA was negotiated. With this new approach in mind, Bonneville permitted local utilities to select from a menu of program delivery alternatives or even to design their own. This contrasts with Bonneville's traditional approach, which is more restrictive. The result was a variety of showerhead and faucet aerator distribution methods (sometimes at the same utility). Bonneville provided most of the utilities with efficiency measures (showerheads, aerators, and associated installation materials). However, these were not all from the same manufacturer, so that utilities could have their choice of models. Although the measures were designed to meet Bonneville's specifications, each model had unique performance characteristics which affected savings. Combining a variety of delivery mechanisms and showerhead models was a unique approach for Bonneville. This participant-friendly program design complicated the subsequent program evaluation. A unique program required an equally unique program evaluation design.

1.2 Overview of the Evaluation

Household electricity savings from the installation of efficient showerheads were initially estimated using engineering models with assumptions about dwelling and participant characteristics, bathing habits, and manufacturers' showerhead performance estimates. This was adequate to design and implement Bonneville's residential retrofit program but not to substitute for a formal program evaluation (Appendix A, Keating memo).

Bonneville subjects most of its conservation programs to formal, objective evaluations of performance and cost. Typically, these are based on a defensible estimate of savings per participant, which are multiplied by the number of participants to estimate program savings. Participant savings are estimated by the evaluator using engineering and statistical methods. Program records provide the evaluator with the number of participants and costs. This was the approach initially expected by Bonneville for evaluating the showerhead program.

At the onset of the program evaluation, Bonneville assumed that each program measure performed according to program specifications. During the first field study conducted for the evaluation, this assumption was challenged. Each model of each measure had performance characteristics that produced different savings. As the unique nature of the program design became apparent during the evaluation, it dictated radical changes in the evaluation approach. The primary driver for these changes was the customer-oriented program design that gave utilities more freedom to choose their own showerhead distribution and installation methods. As a result, over 20 showerhead models and over 500,000 showerheads were distributed, using both professional and occupant installation methods.

Each model of measure and distribution method needed to be explicitly addressed to provide a representative estimate of program results.

Uncertainties about some of the underlying savings assumptions were also raised. To resolve these issues, Bonneville initiated several related research studies to collect data on field conditions that affect the performance of energy-efficient showerheads; these included the collection of data on program participation, program penetration, measure penetration, measure persistence, water-flow rates, and showerhead energy savings.

The showerhead field studies were designed to narrow the scope of the actual program evaluation to reduce data collection from utilities and participants, which is both costly and intrusive. These studies proceeded in a serial manner, with each study responding to new information as it became available. They resulted in identification of key variables that affect the performance of hot-water efficiency devices and savings. The studies also caused Bonneville to modify its initial evaluation approach. Field study results provided the foundation for a new evaluation algorithm, which was used with available program data to evaluate the program. Using focused field research to develop a reliable, nonintrusive evaluation equation was an unexpected result. This approach has the potential to be a model for future conservation programs, especially those that rely more heavily on marketing mechanisms and consumer action rather than on standardized, tightly controlled program designs.

1.3 Organization of the Report

This evaluation rests on a series of related studies. Some of these were not conducted by Pacific Northwest Laboratory (PNL). Most have been documented in separate reports. Although detailed descriptions of the major studies and their results support the assumptions used in this evaluation, including these details in this text would distract readers from the principal topic. Accordingly, information on key aspects of the field studies and their results has been placed in appendices. These are organized with an introductory appendix (Appendix B) that provides an overview of each of the critical field studies. Subsequent appendices highlight the major studies and their results. Interested readers should consult the appropriate reports referenced in this report and appendices for a complete description of each major study.

2.0 Program Description

Bonneville offered the Residential Appliance Efficiency Program to its customer utilities in the winter of 1991. Contracts for the program were negotiated, and the program began operating in the spring of 1992. The program was implemented through Exhibit G and associated references in the RCA. The RCA is the primary contracting vehicle for Bonneville's programs in the residential sector. The Appliance Efficiency Program in 1992 consisted of two components, the "water-heater option" and the "showerhead option." Briefly, the water-heater and showerhead options were designed to encourage replacing electric water heaters, showerheads and faucet aerators with energy-efficient models in residential buildings using electric energy for water heating. Bonneville supplied all the necessary resources to implement the program and it was up to Bonneville customer utilities to conduct the program according to the needs of their service territory. Bonneville provided local advertising, program administration support, and payments for implementation costs.

This report evaluates the energy savings and cost-effectiveness of the showerhead program option only. However, payments for program promotion could be used to advertise either program option. Generally, these expenses were ascribed to the "water-heater option." Similarly, program staffing could be allocated to either or both program options, obscuring direct attribution of the costs and resources needed for the showerhead program. Finally, the program targeted hot-water savings in both existing and new buildings. Cost records for implementing the program did not distinguish between them, some costs, for instance measure costs, could be apportioned based on participation records, however, others like marketing cannot. Accordingly, this evaluation includes program costs for both program options (except water-heater incentives) and savings estimates for both new and existing homes as well as for commercial buildings. Savings estimates are based on results from field studies of existing residences rather than from specific statistics for new residences and commercial sites, because the bulk of program participants were existing residents.

2.1 Five Program Options

When this program was introduced, Bonneville was beginning to re-evaluate the way it delivered its conservation programs. Typically, Bonneville designed and implemented programs centrally, following a uniform design. Bonneville's regional support offices (area offices) assisted local customers with program implementation. In 1991, Bonneville's management began encouraging utilities to assume greater responsibility for program success and permitted each utility more flexibility in program implementation. This change in philosophy was characterized by Bonneville management as a "paradigm shift." It also increased responsibility among the area offices for program design and implementation and was characterized internally as "decentralization." The showerhead option embraced this new philosophy within the program design by providing customers with a menu of methods for distributing showerheads and faucet aerators. This contrasted with a typical program design with only a single implementation scheme. Customers selected the distribution method from the following five options permitted: direct installation, customer demand, canvassing, inventory/depot, and the customer-designed option (Bonneville 1991, RCA, Exhibit

H). These options are described (based on the RCA [a]) in Sections 2.1.1 through 2.1.5[b].

2.1.1 Direct Installation

This method required the utility (Bonneville's customer) to install the measures, rather than to rely on installation by program participants (consumers, or the utility's customer). Replacement of *all* showerheads and aerators in each home was specified under this method. Showerheads could be installed in the consumers' homes during an energy audit or by plumbers as part of a marketing program for water heaters. The local utilities could make the energy-efficient showerhead mandatory for consumers to get the water heater incentive. The devices could also be sent through the mail with a return mailer provided for the consumer to send back their old, inefficient showerhead and still qualify as being directly installed. (Bonneville 1991, RCA, Exhibit G, p. 6).

2.1.2 Consumer Demand

This method relied on consumers installing measures themselves. Measures were distributed based on consumer requests. The utilities could adopt their own methods for encouraging consumers to request measures, such as coupons in newspapers and notices in power bills. There were no distribution mechanisms required in the RCA, so utilities used a variety of methods; for example, mailing them. This approach was used with great success by Seattle City Light, the region's largest municipal utility.

2.1.3 Canvassing

This method also relied on consumers installing measures. Since the RCA did not specify what distribution methods could be used, common distribution methods consisted of canvassing, or door-to-door solicitation, followed up by doorstep distribution of showerheads.

2.1.4 Inventory/Depot

This method used a central distribution point for consumers to pick up showerheads that they installed themselves. This could be done over the counter at the utility or whenever utility personnel went to a consumer's home. They could also be distributed when consumers bought water heaters from retailers. Utilities could furnish retailers with the showerheads. Bonneville did not provide utilities with faucet aerators under this alternative, although utilities could distribute aerators they purchased themselves. Utilities were required to monitor the distribution of measures and to attempt to recover old showerheads.

2.1.5 Customer Designed

This name was applied to programs that did not fall into one of the four main categories. It was intended to facilitate utility innovation in program design. Consistency with program objectives was assured by requiring written proposals to area office staff and written authorizations. To the best recollection of Bonneville program staff, no customer-designed programs were authorized; however, Bonneville's records indicated that some utilities *did* use this method. These records are thought to be erroneous area office records. Bonneville's central staff continues trying to correct these records.

(a) Utilities could choose more than one distribution method, although direct installation, using professionals, was the most popular (Table 2.1). Bonneville reduced the number of options, effective January 1994, when the RCA was amended in 1993.

(b) The experience of a variety of utilities (most outside the region) with each method is summarized in Appendix H.

2.1.6 Implementation by Individual Utilities

Utilities were required to submit a description of the distribution method they intended to use and their implementation plan to the appropriate Bonneville area office. Utilities were not prohibited from using more than one method or from switching from one method to another. Altogether the utilities distributed over 500,000 showerheads (Table 2.1). A total of 90 utilities participated in the showerhead program from January 1, 1992, to September 30, 1993. Direct installation was the most popular way of dispensing, followed by consumer-demand, canvassing, and inventory depot. There were no recorded customer-designed disbursement programs.

2.2 Measures

Generally, Bonneville provided participating utilities with showerheads and faucet aerators. The hardware was selected from a list approved by Bonneville as being certified to be energy-efficient (Bonneville 1991, RCA, Exhibit G, Reference 19). The actual brands and models were selected by Bonneville with the participation of utilities through meetings and demonstrations by product vendors. Bonneville required vendors to certify measure performance in independent laboratories; however, Bonneville did not verify the performance of products itself until this evaluation (Appendix F).

Utilities were free to select specific brands and models of showerheads and faucet aerators from the approved list. Utilities' requests for measures were submitted by area office staff to Bonneville's procurement staff for purchasing. Utilities were also free to purchase measures on their own from the approved list and get reimbursed from Bonneville (Bonneville 1991, RCA, Exhibit G, Reference 7).

2.3 Reimbursement

Bonneville reimbursed utilities for direct program implementation expenses based on the type of distribution method used. Reimbursement for aerators was capped at $3.50 for kitchen faucets and $1 for bathroom faucets. Direct installation methods resulted in a $37.00-per-unit reimbursement for single-family residences including

Table 2.1 Showerhead Distribution Method

	Direct Install	Consumer-Demand	Canvass	Inventory/Depot
Number of Utilities[a]	79	48	7	5
Number of Showerheads[b]	349,967	44,058	163,458	1,714

[a] Utilities could use more than one method.
[b] Excludes those noted as "customer-designed."
These numbers are not the same as those in 5.2 due to differences in Bonneville's program database.

condominiums, $18.00 per unit for multifamily residences, including motels and hotels, and $37.00 per shower room for nonresidential buildings, such as schools and health clubs. The consumer-demand method provided the utility $10.50 and canvassing $8.50 for each showerhead. No reimbursement was provided by Bonneville for the inventory/depot method. Aerators were not tracked by distribution method for reimbursement purposes. Instead, it was assumed aerator installations followed the same pattern as showerheads. Reimbursements under the customer-designed method were negotiated separately. Bonneville payments did not distinguish between new and existing buildings (Bonneville 1991, RCA, Exhibit X, Reference 7). In addition, if Bonneville customers purchased the showerheads instead of Bonneville, they were reimbursed actual costs up to $10.00 per unit.

Bonneville also provided utilities with payments for indirect program costs, including advertising, program start-up costs, and program administration related travel. The advertising allowance for the program (both options) was fifty cents per customer, with a minimum of $2,000 and a maximum of $150,000, per utility. Advertising allowances could be increased through separate negotiations with Bonneville, budget permitting (program staff were not aware of any increases). Program start-up costs consisted of a one-time start-up payment designed to cover the utility's initial administrative costs. No administrative costs were provided for the showerhead option, although such payments were offered for the water-heater option. These were based on the number of residential consumers served by each utility. Some of the administrative and start-up costs for the program were common to both program options. As a result, some of these funds typically covered some of the costs of the showerhead option at each utility (Bonneville 1991, RCA, Exhibit X, Reference 5).

Bonneville's Appliance Efficiency Program customers were required to maintain certain types of records to be eligible for reimbursement. They included paid receipts for promotions, a Bonneville-approved written description of the distribution method(s) they selected, paid receipts for materials they purchased in lieu of measures purchased by Bonneville, and a list of "unique Identifiers of Consumers" who received qualifying showerheads under each of the selected distribution methods (Bonneville 1991, RCA, Exhibit G, p. 7). Bonneville required this documentation at least quarterly, along with a quarterly financial summary statement (Bonneville 1991, RCA, Exhibit X, Reference 11, Schedule G-2). Financial summary statements provided the basis for Bonneville's utility cost reimbursements. As a result, utilities could submit them as frequently as once a month rather than quarterly to accelerate repayment. Each of the area offices entered these paper reports into a central database. This provided Bonneville's headquarters staff with data to track program accomplishments, although the accuracy of the data in the database rested on the utilities' prompt reporting and the area office staff's prompt, accurate data entry. In the spirit of decentralization, headquarters staff were not expected to oversee the program.

2.3.1 Payment Plans

There were three different payment plans available to the Bonneville customers under the RCA. The first was the cost-reimbursement method, which issues a treasury-check or vendor-express wire transfer. The second was a revolving working capital advance, which also uses a treasury-check or vendor-express wire transfer for payment. The third was a letter of credit. (Bonneville 1991, RCA Exhibit X, Reference 14). Each method is described below.

Cost Reimbursement - The cost reimbursement method reimbursed the customer after the fact for their costs incurred in the showerhead program under the Exhibits of the RCA agreement. Payments were made on the basis of completed financial summary statements with the appropriate schedules.

Revolving Capital Advance - The revolving capital advance approach had Bonneville advancing funds to the customer during the first two months of the RCA Program. These funds were estimated. Subsequently, Bonneville replenished funds based on current RCA Program needs. This payment method required customers to file monthly financial summary statements.

Letter of Credit - The last payment option was a letter of credit. It was also an advance payment system, where Bonneville provided funds through the United States Department of Health and Human Services, Payment Management System (DHHS-PMS). The customer withdrew cash when needed for their showerhead conservation activity. This option required the utility to comply with requirements of the DHHS program, complete a quarterly OMB Standard Form 272 and return the original to DHHS-PMS, complete a quarterly financial summary statement, return to Bonneville any interest income earned, establish an effective financial management system, and submit a reconciliation of advances upon termination of the program in a timely manner.

2.4 Advertising

Promotional activities are necessary in a program like this for consumer awareness and participation. Local utilities were encouraged to advertise efficient showerheads aggressively in their service territory. Bonneville's customers were encouraged to publicize cooperatively with showerhead manufacturers. Suggested activities included mass-media advertising, direct mailings, local home shows and fairs, and other promotional events. All advertisements were to acknowledge the Bonneville Power Administration as a co-sponsor (Bonneville 1991, RCA, Exhibit G, p. 8). Bonneville purposely allowed their customers flexibility in promotion and distribution to enhance the success of the Appliance Efficiency Program.

Bonneville stated its intention in RCA Exhibit G to perform an evaluation for each of the five distribution methods to determine if the showerheads given out under each method were installed and were still being used. They also planned to do follow-up home visits or telephone confirmations with consumers to obtain the needed information for the evaluation. They intended to use the results to adjust the payment level for each method of distribution in subsequent years (Bonneville 1991, RCA, Exhibit G, p. 8). Early results from this evaluation called into question Bonneville's early assumptions about measure performance, measure-installation rates, and potential cost-effectiveness. Bonneville reviewed the program in 1993 in the context of an agency-wide budget review. Funding exigencies along with evaluation results led Bonneville to announce in midyear that it would no longer reimburse utilities for showerheads with flow rates equal to or greater than 2.5 gallons per minute (gpm). This was also due, in part, to the recent adoption of water-efficiency codes in the states of Oregon and Washington and the pending federal codes that prohibited the sale of showerheads rated by the manufacturer as higher than 2.5 gpm. Utilities were permitted to exhaust their current stock of 2.5 gpm showerheads, but new showerhead purchases were required to be rated at 2.0 gpm (or better) after January 1, 1994.

2.5 Implementation Issues

Program reimbursement and payment options reflect how Bonneville evolved toward programs that appear to be more responsive to utility needs and easier for them to manage. This is consistent with the philosophy of utility responsibility and decentralization that was in vogue at Bonneville during this program evaluation period. However, from an evaluation perspective, these myriad options significantly complicated both monitoring program performance and collecting program-cost data. Further, the decentralized operation of the program resulted in split documentation responsibilities between the Bonneville area office and headquarters program staff. The lack of clear accountability and priorities among responsible staff for these functions was reflected in significant lag times in resolving data-quality problems with the central database. For example, separate program summaries compiled for this evaluation revealed significant differences in program participation and costs from one month to the next even though these summaries were for a common, previous period.

3.0 Evolution of the Evaluation

The evaluation approach for Bonneville's showerhead program evolved as data became available.

3.1 Initial Evaluation Assumptions

The overall approach to this evaluation was guided by standard practices followed by Bonneville and its consultants for the evaluation of large-scale programs and by initial assumptions regarding savings potential.

Typically, Bonneville evaluations for large-scale programs employ a quasi-experimental research design using a sample of program participants and another sample of nonparticipants as a comparison group. This is often coupled with a pre- versus post- analytical approach that is used to compare energy use among participants prior to installing conservation measures with energy use after the measures are in place (Bronfman et al. 1991; Mohr 1988). A similar comparison is performed for the nonparticipant sample, and between the participant and nonparticipant groups. One-year observation periods are commonly used for the pre-post comparisons. Samples of participants and nonparticipants are drawn to provide statistically representative estimates of energy use among participants and among the comparison group. The size of the sample is determined using estimated savings and the variance around that estimate (Bronfman et al. 1991; Mohr 1988).

In May of 1991, Bonneville estimated savings to be 400 kWh annually (Appendix A). The variance of this estimate was unknown, in part, because it was based on an engineering model of hot-water use for showering. The model used the following assumptions to generate the savings estimate:

- Post-retrofit showerhead flow rate: 2.5 gpm or less at 65 pounds per square inch (psi)
- Flow rate reduction from retrofit showerhead: 1 gpm
- 100% replacement of showerheads at each participant site
- Average shower duration: 6.5 minutes per shower
- Average number of showers per day, per person: .77
- Average shower temperature: 103°F
- Ratio of hot to cold water for showering: 50/50.

These assumptions have corollaries that also guided the initial evaluation. These include

- Pre-retrofit showerhead flow rates of 3.5 at 65 psi: This is derived from the assumed 1 gpm flow-rate reduction for efficient, 2.5 gpm showerheads and the assumption that bathers do not use full volume when showering with current showerheads.
- Adequate water pressures - The 65 psi assumption is consistent with showerhead design conventions, and provides for adequate showers. Significant deviations from that pressure will affect showerhead performance.

- Effective program designs: The assumption was that the program would achieve 100% installation or that program tracking systems would monitor actual installation rates.

3.2 Initial Evaluation Approach

Bonneville's initial approach to evaluating the program was to conduct a pre-post analysis of participants and nonparticipants using utility billing records or other easily obtained data. However, uncertainties about the reliability of assumptions used to estimate savings and their variability in local populations led to a recommendation that Bonneville conduct a field study in the region to validate or replace these assumptions.

The initial evaluation plan was to proceed with a field study of a sample of homes participating in the Regional Energy-Use Metering Program (REMP) followed by a large-scale billing data analysis of single-family homes to evaluate the program. This would be followed by a supplementary field study and billing data analysis for multifamily structures to complete the program evaluation (Appendix A, Keating memo).

3.3 Revised Evaluation Approach

As is often the case in research studies, the results from the first field study raised unanticipated questions that led to an unexpected series of new studies to address them. These studies follow in the order in which they were initiated.

1. The REMP field study (Warwick and Bailey 1993).
2. The Puget persistence study (Bailey and Warwick 1993).
3. The REMP energy savings analysis study (Warwick 1993).
4. Showerhead Savings Algorithm Development and Documentation (in Warwick 1993).
5. Review of participation and installation rates for other showerhead programs (Appendix H).
6. Puget water-metering study (SBW Consulting, Inc. 1994).
7. Program evaluation development (documented in this report).
8. Bonneville Showerhead and Aerator Flow Testing (Matthews 1994).
9. Program evaluation (documented in this report).

These studies covered the following issues (sometimes the same issues were addressed in multiple studies):

- field conditions and their effect on showerhead retrofits and savings potential
- showerhead installation rates, persistence, measure penetration field conditions, and telephone survey reliability

- program participation and showerhead retrofit rates for different distribution mechanisms

- representative energy savings from retrofit showerheads and key variables that affect savings

- showerhead savings-estimation equations and assumptions

- water-flow rates for showerheads and faucet aerators, water-flow reductions and estimated energy savings (primary source of faucet aerator data)

- program evaluation methodology and sources for program evaluation data

- monitored performance of showerheads and aerators under simulated field conditions

- energy savings from the program, program costs, and cost-effectiveness.

In addition to the program evaluation, this research also produced a new protocol for doing evaluations and a robust, general-purpose hot water efficiency evaluation equation that could be applied elsewhere.

3.4 Evolution of the Evaluation

Although the initial program evaluation plan was based on the expected results from a large-scale billing data analysis, there was concern that the expected savings might be too small a fraction of the energy bills to identify using statistical methods. The annual change expected in power bills of 400 kWh per home of 20,000 kWh could be difficult to detect statistically, especially if weather extremes affected electric heating demands in the pre- and post-periods. As a result, Bonneville approached PNL about the feasibility of using an existing sample of homes equipped with end-use meters to explore this issue. These homes were participants in Bonneville's End-Use Load and Conservation Assessment Project (ELCAP), which was implemented previously by PNL (Appendix A, Bonneville Power Administration showerhead proposal cover letter).

The ELCAP study measured major household energy uses of electricity on an hourly basis. Data was collected from over 300 single family homes and stored for later analysis. At the time of Bonneville's request, the original ELCAP sample had been reduced to about 150 single family homes for which over three years of load data had been collected. Bonneville renamed this reduced sample the Regional End-Use Metering Project (REMP). Monitoring data from the REMP sites constituted a readily available source of pre-retrofit end-use data for both water heating and total energy use.

The initial scope for the REMP analysis was to recruit REMP sites to participate in a showerhead field study involving replacement of showerheads with efficient models and the collection of site and occupant data. The goal of the field study was to assess the key factors thought to affect the performance of efficient showerheads (the assumptions in the engineering model) and the variance these factors might contribute to savings estimates from pre-post or other analysis methods. Energy use at the sites continued to be monitored through the REMP project. This preserved the option to expand the scope of research to include analysis of energy-use data to estimate savings, if warranted by the results of the field study.

In effect, the REMP field study results were expected to dictate future evaluation actions. If the first phase of the field study indicated that the variance in showerhead performance was too great to be addressed through the REMP sample, an alternative approach would have to be adopted using a larger sample. Alternatively, if the variance in use and other factors supported statistically robust estimates of use and savings, the REMP results could substitute for the estimated savings from Bonneville's engineering model. In either case, Bonneville expected billing data analysis to be used to evaluate the program, due to the relatively small size of the REMP sample.

The field study was initiated in the fall of 1991. The initial results challenged many of the assumptions used in the engineering model, although the expected reduction in showerhead water-flow rate was supported. Certain assumptions could not be measured with any reliability or incorporated into a workable evaluation equation (e.g., shower-valve settings for temperature and force for each occupant). When the field study data were substituted in Bonneville's engineering model, the results exceeded Bonneville's savings estimates significantly (Table 3.1).

PNL had conducted an earlier analysis of water-heater energy use for Bonneville (Pratt 1991). This study was conducted using the larger ELCAP sample from which the REMP sample used in the field study was drawn. The objective of the study was to disaggregate the total water-heating energy use data collected by the ELCAP meters into two major components. These components were *stand-by* and *demand* energy use. Water heaters operate by warming incoming cold water to a preset temperature (demand energy use) and storing it. During storage, the heated water cools off. As a result, the water heater has to reheat the stored water periodically to maintain the desired temperature. This reheating energy compensates for stand-by losses (stand-by energy use). PNL developed a method to identify these stand-by losses in the ELCAP data and developed estimates of both stand-by and demand energy use for water heaters.

Demand energy use is the focus of hot-water efficiency devices like showerheads and faucet aerators. PNL's estimate of total household water-heating energy demand was 1,191 kWh per occupant annually. The REMP participant sample and regional average number of occupants per

Table 3.1. Comparison of Engineering Estimates with Field Data

Factor	Bonneville Assumption	Field Data
Showerheads Retrofit	100%	90%
Shower Duration	6.5 min.	7.4 min.
Water Flow Reduction	1 gpm	1.4 gpm
Hot/Cold Water Mix Ratio	50% hot	70% hot
Showers/Person/ Day	.77	.95
Person/Home	2.3	2.8
Estimated Savings	400 kWh	1,225 kWh

home was 2.8. Accordingly, the expected average water-heating energy demand for the REMP sites would be about 3,200 kWh per year. PNL's estimate of average stand-by losses was about 1,200 kWh per year, for an estimated total water-heating energy use of 4,400 kWh annually (pre-retrofit monitored water-heating energy use for the REMP field study participants averaged 4,489 kWh annually). Water-heating demand energy savings of over 1,200 kWh annually, or 38% of total hot-water energy use were predicted by employing Bonneville's engineering model with actual field data for the REMP sites (Table 3.1). This implies that showering is *the* major use of hot water.

These results made it apparent that the engineering model lacked critical variables to predict showerhead energy savings accurately. This outcome led to the second phase of the REMP field study, which was an analysis of actual energy savings. This analysis was done to identify the sources of error in the initial engineering model, and to provide an initial estimate of statistically reliable showerhead energy savings. The analysis was not included in the scope of the initial research project because the statistical validity and usefulness of results from the REMP sample were uncertain. These doubts were resolved through the field study. Also, analysis of end-use records tends to be expensive compared to billing data due to the large volume of data.

The energy savings analysis for the REMP sites required load data for (water heating and total household-energy use [billing data]) for each of the 150 sites. Data for each end use consisted of 8,760 records per year (one observation for each hour in the year). The analysis period covered about 2.5 years. As a result, nearly 40 million data points needed to be cleaned, managed, and analyzed! Bonneville did not want to commit to this expense until it was assured of the value of the outcome. The energy savings analysis of REMP sites achieved both of its initial objectives. It identified a number of factors that did not appear to be correctly represented in the initial engineering model of savings, and it produced a robust estimate of first-year savings from showerhead retrofits.

The first-year savings estimate for the entire retrofit REMP sample (85 homes) was 515 kWh. This was based on a measured flow-rate reduction of 1.4 gpm and compared favorably with the savings Bonneville initially expected; namely, 400 kWh from a reduction in flows of 1 gpm. However, Bonneville's estimate was based on an engineering model with assumptions that were discredited by the REMP field study. In other words, the REMP field study results and the Bonneville results were similar due to compensating errors in Bonneville's assumptions. The source of these errors had to be in the behavioral variables in the initial engineering model (shower number, duration, and temperature), because of the rough comparability with the pre/post REMP flow-rate results (expected reductions of 1 gpm and observed reductions of 1.4 gpm in the field study). In addition, the REMP field study highlighted a number of conditions that were taken for granted in the engineering approach. Prior to the REMP field study these conditions were, in fact, uncertain. Key findings included:

- Actual performance of the retrofit showerhead - The REMP field study used two brands of showerheads and found that the manufacturers' flow ratings were not necessarily accurate. Bonneville's engineering model assumed they were.

- Standard water pressure of 65 psi - Bonneville's engineering equation used 65 psi as a benchmark for measuring flow-rate changes. The 65 psi assumption was close to the regional average from the REMP field study (60 psi); however, there were many REMP sites with much lower water pressure and, consequently, significantly less energy savings. These sites were associated with domestic water wells, which typically operate in the 25 to 45 psi range. Approximately 20% of both the REMP sample and single-family homes in the region have domestic water wells.

- Number of showers per day - This figure is normally based on occupant surveys. Exploratory analyses of the REMP end-use data indicated that these responses may overstate the number of showers taken in the home, either because people skip showers or because they include showers taken outside the home. (This finding has been corroborated by other studies [Proctor et al. 1994; SBW 1994]).

The conclusion drawn from these findings was that some of these factors would need to be recognized explicitly in the program evaluation. Both the billing data approach (which was expected to rely on survey data about shower use) and engineering models had significant shortcomings. The evaluation approach shifted at this point to estimating energy savings *directly*, and using engineering models and survey responses to tailor savings estimates to fit program data. Bonneville continued pursuing two evaluation approaches. The first was expected to use billing data methods to capture the variety of field conditions and showerheads installed in the program. Bonneville also directed PNL to continue using REMP data to refine an alternative evaluation equation that estimated regional savings using REMP field conditions that were known to vary, such as showerhead flow and replacement rates.

Bonneville continued to plan for a billing data analysis using a large sample, in part, to assure stakeholders concerned about the small size of the REMP sample. These concerns were heightened by the REMP pre-retrofit water-flow measurements, which indicated average flow rates were considerably lower than initially expected (3.2 gpm instead of the 4 to 5 gpm expected). Anticipating this billing analysis, Bonneville initiated a study with Puget Sound Power and Light (Puget Power) to assess the reliability of telephone interviews for collecting data on showerhead installation rates (Puget persistence study). PNL conducted this study (Appendix C). Telephone surveys are less expensive than in-person inspections, but it is still necessary to conduct on-site inspections of survey subjects to verify the accuracy of their responses. PNL took advantage of the on-site inspections to collect water flow and pressure data, as well as to verify the presence of efficient showerheads distributed by Puget Power.

The Puget persistence study included a post-retrofit measurement of showerhead flow rates. Consequently, the flow rates for the showerheads that were replaced were unknown. However, the retrofit rate, or fraction of showerheads replaced in each home, was not 100%, in part, because no more than two showerheads were distributed to any one home. A total of 98 homes in the sample of 101 Puget persistence study participants actually received at least one showerhead (some through the mail, some through professional installers). There were 166 showers among these homes, because some had up to four showers. However, the restriction on the number of showerheads distributed resulted in only 144 showerheads being received, for an 86% program penetration. Not all of the showerheads were installed. The PNL inspection was able to identify Puget showerheads in 87% of the homes. The actual *measure penetration* rate, or fraction of showerheads replaced in each home, was probably between 66 and 75% because of noninstallation and the restriction on the number of shower-heads distributed. Verifying that the showerheads distributed by Puget were actually installed was one of the primary objectives of this study, so finding less than a 100% installation rate for distributed showerheads was significant.

The incomplete replacement rate enabled PNL to measure flow rates for showers that were not replaced. The flow rates observed at these sites was 2.7 gpm, which compared favorably to the 3.2 gpm flow rates observed in the REMP field study when the characteristics of the two samples are considered (Appendix D). The flow rates for the showerheads distributed by Puget averaged 1.8 gpm, which again, confirmed the REMP field study results that indicated manufacturers' flow ratings are not necessarily accurate. The difference in flow rates in the Puget persistence study averaged 0.9 gpm, for a relative flow rate reduction of about 33%. The Puget persistence study also included a small number of homes with domestic wells. The water pressure and showerhead flow rates at these sites were lower than at other sites, also confirming the results from the REMP field study (Appendix D).

Although the primary objective of the Puget persistence study was to confirm the reliability of telephone surveys for verifying showerhead installations, its major contribution was lending credibility to the results of the REMP field study. The results from the two studies reinforced critical conclusions from the REMP field study, including:

- Current showerhead flow rates are much closer to 3 gpm than to the 4 or 5 gpm initially expected.
- Domestic wells affect savings because they have inherently lower water pressure, and hence, existing flow rates.
- Manufacturers' flow ratings (2.5 gpm or 2.0 gpm) are not accurate predictors of performance under field (rather than laboratory) conditions.

The Puget persistence study also validated telephone surveys as a means of verifying *program penetration but not measure penetration.* Additionally, the study introduced the retrofit rate of showerheads in homes as a new issue, particularly when installation is left to the occupant.

These results cast doubt on the potential value of a large-scale billing study, because key findings from the REMP field study were confirmed and questions were raised about the reliability of surveys to gather critical data like measure penetration and retrofit rates necessary for billing analyses. Further analysis of the REMP records using the billing data analysis approach did not inspire great confidence in results from the billing data methodology (Appendix E). Eventually, Bonneville decided to forego a large-scale billing analysis.

4.0 Program Evaluation Algorithm

The final program evaluation algorithm evolved based on the factors described in sections 4.1 and 4.2.

4.1 Evaluation Algorithm

Support for the REMP field findings from the Puget persistence study led PNL to develop an evaluation algorithm designed to extrapolate results from the REMP field study to mirror the conditions for the showerhead program. This algorithm is essentially an improved engineering model based on the observation that energy savings are proportional to changes in showerhead flow rates. The final evaluation algorithm is based on the observed relationship between monitored energy savings and measurable site conditions. This contrasts with the initial engineering model that relied on behavioral factors, such as shower number and length, which are highly variable and difficult to measure. The program evaluation algorithm rests on the assumption that household energy savings from showerhead retrofits are proportional to showerhead flow-rate changes and retrofit rates. The final form for the energy savings estimation algorithm is as follows:

> Showerhead Program Savings = REMP Showerhead Savings per Household * Adjustments for Flow-Rate Change * Number of Participants * Fraction of Homes on Wells * Retrofit Rates * Persistence

The various parameters, and their source, are described in the following sections.

4.1.1 REMP Showerhead Savings per Household

Average household energy savings from the REMP sites, and factors that affect them, were known (Warwick 1991). As a result, they were used as a benchmark to estimate program savings. They were selected for a benchmark because they were developed from the regional population targeted by the program, the savings estimates were statistically robust, and savings were measured concurrently with the implementation of the program. Substituting observed savings eliminated the need to identify and include the behavioral factors used in Bonneville's initial engineering model, such as shower number and duration, which appeared to be the source of its errors. The REMP savings reflected savings per home rather than per showerhead. As such, they were sensitive to differences across households. The critical differences identified through the REMP field and Puget persistence studies were relative change in showerhead flow rates and the rate of retrofit of showerheads in the home. These, along with other factors, make up the balance of the savings equation parameters.

4.1.2 Adjustments for Flow-Rate Changes

If the proportional changes in flow rates for the Bonneville program were the same as those in the REMP field study, there would be no need to adjust the REMP savings benchmark. However, the Bonneville program used over 30 models of showerheads with different flow ratings (The program required showerheads to flow at no *more* than 2.5 gpm. Approved models were designed to flow at rates between 1.5 gpm and 2.5 gpm.). In contrast, the REMP field study used primarily one of two models. The sheer variety of showerhead brands and models offered to the participants complicated the program evaluation because, at the same water pressure, each showerhead model may have a different flow rate. As a result, the proportional change in flow rates needed to be estimated for each showerhead model under simulated field conditions to estimate the proportion of REMP savings that were achieved for each showerhead model.

The reduction in water flow rate, and hence, energy savings, varies locally based on the type of water supply (city versus domestic well), local water pressure, and the flow rates of the stock of existing and replacement showerheads. Although the pre-existing showerhead flow rates were lower than expected in the REMP field study, they were confirmed by other regional utilities in their own tests. There was no clear correlation of pre-flow rates with other obvious factors (other than with domestic wells). The REMP flow rates (3.2 gpm) were adopted as the basis to estimate showerhead savings on each model of showerhead used in the program for the evaluation. Local flow-rate data can be substituted in the energy savings equation if they are available.

If the initial flow rate is assumed from the REMP field study, the primary determinant of the *expected performance* of retrofit showerheads is *their* flow rate. However, the REMP field study indicated these may vary from the manufacturers' rating due primarily to differences in performance at various water pressures and showerhead design practices. For instance, some manufacturers may design their showerheads not to exceed a specific rate, whereas others may design for average performance at that rate. As a result, Bonneville conducted performance tests for each of the 20 brands and models of showerheads distributed in its program over a broad range of water pressure settings (Appendix G). Water pressure measurements from the REMP sample were used to represent regional conditions (Table 4.1). This distribution of water pressures was used to weight the Bonneville showerhead flow-rate results for each of the program showerhead models (Actual weights were based on a sixth order curve fit to this data [Appendix F]).

In other words, the flow rate for each pressure category in Table 4.1 was correlated with the proportion of the REMP sample with that pressure (the weight factor from Table 4.1). The resulting flow-rate estimate represents a pressure-weighted flow rate that is representative of the region as a whole.

Table 4.1. Distribution of REMP Water Pressures and Associated Weighting Factors

Pressure category (psi)	No. of REMP sites	Weight
0-15	0	0
16-25	0	0
26-35	9	.094
36-45	15	.156
46-55	15	.156
56-65	18	.188
66-77	21	.219
78-92	15	.156
93-107	2	.021
107+	1	.01
Total	96	1.00

The average change in flow rate resulting from the program also needed to reflect the proportion of each showerhead that was distributed in the Bonneville program. This is a simple weighted average of each showerhead model distributed in the program, as constructed from Bonneville program data (Table 4.2 on the following page).

4.1.3 Number of Participants

Total savings is also a function of the number of program participants. This variable in the evaluation algorithm is based on utility records. Although a variety of program delivery methods were used, all of them were supposed to include some form of customer registration. These records also categorized each participant by the type of delivery method. Bonneville's program recognized four program delivery mechanisms,[a] as follows:

- professional installation
- canvassing
- consumer demand
- inventory/depot.

It also permitted one other option called "customer-designed," which did not use a specific delivery mechanism. The customer-designed label applies to showerheads that were distributed through programs designed by Bonneville's customers rather than by Bonneville. Delivery mechanisms that do not explicitly track participants, such as handing out showerheads at energy fairs, were not credited with any program savings.

(a) Bonneville's names differ from the names for the delivery mechanisms covered in Appendix H.

4.1.4 Retrofit (Measure Penetration) Rates

Retrofit rates (the fraction of showerheads replaced in each home) are expected to vary based on the following: 1) whether the showerhead is professionally installed or installed by the participant; 2) how many showerheads are provided to each site (one for each shower versus one or two regardless of the number of showers); and 3) physical barriers (e.g., nonstandard showerhead necks, plumbing, or fixtures).

This variable was included in the estimation equation based on the REMP field and Puget persistence studies The REMP study design had a target of 100% retrofit. The retrofit rate achieved in the REMP field study was actually about 90%. We expect this retrofit rate to be the maximum achievable. The Puget Power showerhead program used both professional and occupant installation methods. Occupant installation was the most common. In homes that received showerheads through the mail, 87% installed at least one. The retrofit rate was 44% in homes where at least two showers were present and two showerheads were distributed.

Further, many of the Puget Power installations were found to have preceded the PNL site visit by a short time, although the showerheads had been distributed up to a year before. This led to speculation that the site inspection triggered the showerhead installations, thereby inflating "normal" installation rates. Consequently, a 50% retrofit rate was assumed for homes where occupants were required to install their own showerheads. (A 50% retrofit rate for self-installation is applied to the maximum retrofit rate of 90% from REMP, producing an overall retrofit rate of 45%, consistent with the 44% rate found in the Puget persistence study.)

Table 4.2 Bonneville Program Showerhead Brands, Models, and Proportions

Manufacturer	Model	Flow Control	Purchase Totals: Showers	Purchase Totals: Shower Fraction	Included in Testing: Test	Included in Testing: Shower Fraction
ONDINE	Ondin25	Regulator	100	0.02%		0.00%
	OndineA	Regulator	10000	1.58%		0.00%
	284460T	Regulator	119930	31.59%	119930	36.34%
	28802	Regulator	300	.06%		0.00%
	28802		600	0.09%		0.00%
	28804		200	0.03%		0.00%
	28805		220	0.03%		0.00%
	29446	Regulator	17300	2.74%	17300	3.14%
	28446/27418		900	0.14%		0.00%
	933A	Regulator	21000	3.32%	21000	3.82%
BRASS CRAFT	BC2527	Regulator	6063	0.96%	6063	1.10%
	2530		700	0.11%		0.00%
	2531		12600	1.99%		0.00%
	BC2475	Regulator	180071	28.45%	180071	32.73%
			39900	6.30%		0.00%
			400	0.06%		0.00%
	BC2610	Regulator	3250	0.51%	3250	0.59%
	BC2611	Regulator	19200	3.03%	19200	3.49%
	BC2612	Regulator	8400	1.33%	8400	1.53%
	BC2613	Regulator	4561	0.72%	4561	0.83%
NIAGARA	N2131	Restrictor	600	0.09%	600	0.11%
	N2132	Restrictor	130	0.02%	130	0.02%
	N2133	Restrictor	3665	0.58%	3665	0.67%
			2612	0.41%	2612	0.47%
	N2151/2153	Restrictor	526	0.08%	526	0.10%
	2900	Regulator	29850	4.72%	29850	5.43%
	4101		2150	0.34%		0.00%
	4104		5000	0.79%		0.00%
ETL	ETL2001	Restrictor	8615	1.36%	8615	1.57%
	AS			0.00%		0.00%
ALSONS	672BX	Regulator	1689	0.27%	1689	0.31%
	682BX		20	0.00%		0.00%
	670BX	Regulator	10020	1.58%	1000	0.18%
CEW				0.00%		0.00%
	CEW2000	Restrictor	16525	2.61%	16525	3.00%
	CEW2010	Restrictor	4320	0.68%	4320	0.79%
	CEW24CV	Regulator	1319	0.21%	1319	0.24%
	PF1			0.00%		0.00%
WHEDON	DS2B	Restrictor	850	0.13%	850	0.15%
	AS1B		100	0.02%		0.00%
RESOURCES CONSERVATION	ES270	Regulator	17340	2.74%	17340	3.15%
	ES410B	Regulator	1365	0.22%	1365	0.25%
	PP315		300	0.05%		0.00%
TOTALS			632991	100	550181	100
		Fraction of Total Population			0.8691767	

4.1.5 Fraction of Homes on Wells

Low water-flow rates were correlated with low water pressure in both the REMP and Puget Persistence studies. Low water pressure was, in turn, correlated with sites using domestic wells as a water source. The savings evaluation equation includes a parameter to adjust for low water pressure and reduced savings from lower flow rates based on the fraction of participants on domestic wells compared to the fraction (20%) of REMP sites. Coincidentally, the average number of households on domestic wells was the same in the REMP sample as the regional average, so no adjustment was necessary for estimating regional savings. Data on domestic wells are readily available from census data, as well as from local surveys. The parameter is retained in the equation for subregional (individual utility) showerhead savings estimation; however, it is set to 1 for this evaluation and has no effect. This adjustment is also unnecessary if pre-flow rate data is available.

4.1.6 Measure Persistence

How long efficient showerheads stay in place is hotly debated because this factor has a major impact on the expected lifetime savings of the program. There is very little data on the expected life of installed shower-heads, and the interpretation of that data is open, due to many new products without track records entering the showerhead market. As a result, measure persistence was broken into two components, first-year retention rates, which are better documented, and "replacement rates," a term meaning the time over which almost all of the showerheads in normal use were replaced.

A variety of factors may cause a showerhead to be replaced before it wears out. Logically, these include, but are not limited to, dissatisfaction with performance, leakage, and replacement as a result of remodeling. The probability that a showerhead will be replaced for one of these reasons varies with the age of the existing showerhead, the number of years the occupant has been in the home, and so on. These factors are difficult to sort out. Occupants can also exercise their preference for specific showerhead features, like massage flows, and energy savings. Replacement for these reasons is more likely to be linked to turnover in housing rather than in the age of the showerhead. Similarly, many homeowners remodel one or more bathrooms after they have lived in a home a few years. The showerheads in place at that time are likely to be replaced with new plumbing fixtures regardless of their age. Finally, the showerheads may fail, either because they become fouled, and the occupant replaces them rather than cleaning them, or they fail because of old age. Fouling can occur at any time in the life of a showerhead. Replacement at that point depends on the response of the occupant.

Accordingly, each of these potential risks to showerheads were debated with Bonneville staff. No compelling data were offered to challenge Bonneville's initial 12-year measure-life assumptions. Bonneville adopted a first-year retention rate of 90% based on the REMP study and assumed a replacement rate of 11 years as a straight line after the first year, for an assumed total measure life of 12 years. To simplify utility reimbursements to program savings, Bonneville apportioned the benefits evenly over the first seven years of participation.

4.1.7 Faucet Aerator Savings

The Bonneville program included efficient faucet aerators as a measure along with efficient showerheads. Bonneville's initial estimate of savings for aerators was zero. Aerators were not included in the REMP study, but were included in a later study of water flow at Puget Power (the Puget water-metering study). The Puget water-metering study included direct measurements of hot-water use in kitchen and bathroom faucets, so it is the best, and probably only primary data on aerator performance (Table 4.3). The primary data from the study indicated that flow *rates were reduced* but *use actually increased*, although observed differences were not statistically significant (SBW Consulting, Inc. 1994). The increased use for kitchen faucets was assumed to be the result of the novelty of the aerators, which had a swivel on them. Bonneville interpreted these results as confirmation of its assumption of no savings from aerators. As a result, no variables are included in the evaluation algorithm for faucet aerator savings.

4.1.8 Other Factors

The REMP field study and the Bonneville program were implemented during a multi-year drought that reached its peak during the program. Reactions to the drought included water rationing as well as exhortations to reduce water use. Concerns about the drought were region-wide, even though the effects were not uniform across the region. As a result, attempts were made to gauge the effect the drought might have on showerhead savings. The REMP sample included about 50 homes that chose not to participate in the showerhead study. These were used to examine changes in water-heating energy use during the drought. The results suggest voluntary reductions in hot-water use equal to 153 kWh in energy savings. Closer examination of this effect indicated that it was stronger early in the year when public concerns about the drought were first raised. However, the effect was not noticeable after midsummer (Appendix I). As a result, the first-year energy savings for program participants will be reduced by 153 kWh per participant to capture this drought effect. Savings will not be reduced after the first year.

4.1.9 Corroboration

One way to build confidence in analytic methods is to compare them to the results of similar studies (Table 4.4). In this case, the REMP field and Puget Water-Metering studies of showerheads are roughly comparable (Appendices D and E). Both studies were based on direct measurement of showerhead water flows and hot-water use (water use in the Puget

Table 4.3. Faucet Use and Savings (Puget Water-Metering Study)

Measurement	Pre-period Result	Post-period Result	Change	% change
Kitchen flow rate (gpm)	1.98	1.63	-3.58	-18
Kitchen use (gal/day)	10.36	10.58	+.22	+2
Bathroom flow rate (gpm)	2.18	1.72	-.457	-21
Bathroom use (gal/day)	3.13	3.31	+.18	+6

Table 4.4. Comparison of Showerhead Findings from the Puget Water-Metering and REMP Field Studies

Finding	Change	Percent Change	Adjusted Change*
REMP water-flow rate	-1.41 gpm	44%	
Puget water-flow rate	-1.14 gpm	37%	46% hot water only
Puget shower use	-6.33 gal./day	25%	31%
REMP energy use	-515 kWh /yr. -1.4 kWh/day	11.6%	
Puget hot-water use	-4.65 gal./day	7.5%	-9.3%
Puget energy use	-.09 kWh/day	0.7%	
(a) Adjustments applied to shower hot water uses only.			

study and energy use in the REMP study). The Puget water-metering study period was roughly 28 days prior to and 28 days after retrofits of both showerheads and faucet aerators, whereas the REMP field study covered over two years. Energy use and savings in the Puget water-metering study were derived from estimated water-heater energy use, rather than direct measurement of energy use. Finally, the Puget Power showerheads did not reduce showerhead flow rates as much as those used in the REMP field study. This required an adjustment to the Puget Power results to facilitate direct comparison (Column 4 in Table 4.4). The results from the two studies support each other except for the Puget energy savings estimate. The Puget water-metering study pre- and post-retrofit periods were short and the temperature and inlet water temperatures were cooler in the post-period than in the pre-period. In addition, there was a difference in efficient showerhead flow rates and retrofit rates between the REMP field and Puget water-metering studies. When the Puget water-metering study results are adjusted for these effects, the showerhead savings from approximately 325 kWh increase to 558 kWh per home annually.

4.2 Caveats

The expected program energy savings are based on measured energy savings from the REMP sites extrapolated to reflect estimated flow-rate changes at nonREMP sites. This method rests on an assumption that there is a linear relationship between changes in showerhead flow rates and energy savings. In other words, one can assume that changes in flow rates will save an average of 37 kWh per 0.1 gpm change when flow rates are reduced by up to 2 gpm (515 kWh average savings for an average flow-rate change of 1.4 gpm yields 36.78 kWh of savings per 0.1 gpm change.) It is not clear that the assumption of a linear relationship is valid for more extreme flow-rate reductions or for low post-retrofit water flows. There is *weak* evidence in the REMP and Puget Power data that showerhead flow rates below 2 gpm *may not* produce proportionate savings. Speculating, people may respond by taking longer showers to compensate for the reduced water volume at very low flow rates.

The Puget water-metering study highlighted the variability of energy use and savings due to the impact of weather on inlet (cold) water temperature. Because the Puget water-metering study was based on short-term monitoring, this factor had to be taken into account. The correction factors used resulted in significant changes in hot-water use and energy savings estimates. The REMP field study did not collect comparable data on inlet water temperature.

Weather effects are less pronounced for long-term monitoring of end uses that are not primarily temperature-sensitive. However, the REMP energy-savings benchmark should be adjusted to compensate for different inlet water temperatures in other regions. This is especially true for areas in the South with moderate temperatures and areas in the North with extremely cold temperatures.

5.0 Program Impact Evaluation

This chapter presents the program impact evaluation results. The impact results rest on the data and assumptions summarized in the previous chapters and described in detail in the appendices. Cost data were provided by Bonneville staff in Portland. This impact evaluation consists of the following three parts:

- program savings
- program costs
- program cost-effectiveness.

Program savings are derived from the evaluation equation described in the previous chapter. Program cost data were collected from program records as discussed in Chapter 2. The cost-effectiveness of the program was calculated using the estimated savings from the evaluation equation and Bonneville cost data.

5.1 Energy Savings Estimation Equation Parameters and Assumptions

Energy savings from the program were estimated using the equation discussed in Chapter 4:

Showerhead Program Savings = REMP Showerhead Savings Per Household * Adjustments for Flow-Rate Change * Number of Participants * Fraction of Homes on Wells * Retrofit Rates * Persistence

The data for this equation came from a variety of sources, as described in Chapter 4 and summarized in Table 5.1.

Table 5.1. Evaluation Data Sources

Equation Variable	Data Source
Benchmark savings	REMP
Benchmark for pre-retrofit flow	REMP
Benchmark for post-retrofit flow	(Bonneville 1994; Appendix F)
Retrofit rate with professional installation	REMP
Retrofit rate with self-installation	Puget persistence study
Number of participants	Bonneville data
Low water pressure (well adjustment)	REMP
Retention rate (1st. yr.)	REMP
Persistence	12-yr. life (Bonneville assumptions)

The key to this equation is using results from REMP and other sources as benchmarks to adjust measured savings to conform to observed program conditions. For example, the measured REMP savings only represent hot-water savings for selected showerheads under specific conditions. To extrapolate the results to the program, these savings need to be adjusted to mirror actual program conditions. To illustrate, if the program showerheads reduced hot-water use only half as much as the REMP showerheads, only half of the REMP savings would be expected among program participants. The values used in the equation are listed in Table 5.2.

Program inputs include cumulative program savings from the beginning of the program and expected over the life of the measures installed. The life of installed measures was assumed to be 12 years. Ninety percent of the REMP showerheads were retained at the end of the first year, when replacement is generally the highest.

Accordingly, the showerheads that remained were assumed to be replaced over the remaining 11 years of their projected life at an even rate of approximately 8% per year. Therefore, household savings are projected to decrease over time. This effect for the REMP sites is illustrated in Table 5.3. Results for the program are somewhat different, reflecting differences in the performance of program showerheads and measure installation rates.

The decreases in Table 5.3 are for savings *directly attributable* to the program. This assumes program measures are replaced with showerheads that are similar to those that were removed. If program participants replace program measures with showerheads that perform better than the original ones, some function of the savings will be retained. Recently adopted energy codes require new showerheads to be efficient (flow rates cannot exceed 2.5 gpm). This results in more savings than expected. However, this energy code went into effect in 1994, which is *outside* the time period covered by this evaluation.

Implementation of the energy code will, by itself, achieve household savings that are similar to those being attributed to this program. These savings would be "free riders" because they are not directly attributable to the program. This is not an issue for *this evaluation* because program participation preceded the new energy code, but it needs to be addressed by any *future evaluation* of this program.

The energy savings benchmark for the equation is from the REMP results. The REMP savings estimate is 515 kWh annually in the first year. These reflect savings per home rather than savings per showerhead. As such, they are sensitive to differences across households. Differences identified as critical to estimating savings compose the balance of the savings equation parameters. Program savings or the savings attributable to the installation of the program showerhead may deteriorate over time due to several factors including persistence. Therefore, the savings are not constant.

Table 5.2. Evaluation Equation Inputs

Equation Variable	Inputs
Benchmark savings	515 kWh/year
Benchmark for pre-retrofit flow	3.2 gpm
Benchmark for post-retrofit flow	2.28 gpm
Retrofit rate with professional installation	100% of REMP (90% net)
Retrofit rate with self-installation	50% of REMP (45% net)
Number of participants (pro-install)	349,967
Number of participants (self-install)	207,516
Low water pressure (well adjustment)	0 (REMP = regional average)
Retention rate (1st. year)	90% (REMP savings include this effect)
Replacement rate (remaining measure life)	Straight line based on 12-year life (Bonneville assumptions)

Table 5.3. Potential Savings per REMP Household Over the Life of a Showerhead (based on REMP savings and Bonneville measure life assumptions)

Year	Potential Savings (kWh / year)	Fraction of Potential First Year Savings
1	515	100
2	436	85
3	396	77
4	357	69
5	317	62
6	277	54
7	238	46
8	198	38
9	158	31
10	119	23
11	79	15
12	40	8
Lifetime Savings	3,130 kWh	50%
Average Annual Savings	261 kWh	

Further, the region was in the grip of a seven-year drought that resulted in widespread programs and appeals to conserve water in the 1992 water year (October to September). This effect was incorporated into the evaluation by reducing expected first-year savings by 153 kWh to 362 kWh (Appendix E describes how these savings were derived). This was a one-time-only adjustment that was not repeated for subsequent years because the emergency public actions taken during the drought were suspended within a year.

The reduction in water-flow rate, and hence, energy savings, varies locally based on the type of water supply (city versus domestic well), local water pressure, and the flow rates of the stock of existing showerheads. The REMP field study provided a benchmark for pre-retrofit flow rates of 3.2 gpm, which was confirmed in studies by several utilities. As a result, the evaluation assumes the average pre-retrofit flow rate is that of the REMP sites, although local data can be substituted in the energy savings equation if they are available. The primary determinant of post-retrofit water flow is the retrofit showerhead design flow rate. The post-retrofit flow rates for showerheads in the REMP field study are only representative of the two models of showerheads used in the study and their associated flow-rate reductions. For example, the REMP field study resulted in an average flow-rate reduction of 1.4 gpm. If program showerheads only reduced flows an average of .7 gpm, savings would be proportionately lower (50% less). The measured flow rates for the efficient showerheads installed in the REMP field study were different from the manufacturers' ratings. As a result, Bonneville conducted performance tests for each of the brands and models of showerheads distributed in its program over a broad range of water pressure settings to identify the actual performance of each shower-head model rather than rely on manufacturers' ratings.

Each showerhead model flows at a different rate depending on water pressure. This affects the savings potential of each showerhead. To account for these differences in this evaluation, the water-pressure measurements taken during the REMP field study were used to estimate the flow rate of each showerhead. These results were averaged to reflect average regional water pressure using REMP data.

To illustrate, assume that a showerhead flows at 1 gpm at 40 psi and 2 gpm at 65 psi. The average flow rate would be 1.5 gpm only if there were an equal number of homes with water pressure of 40 psi and 65 psi. If the number of homes with 40 psi were actually 25 percent of the total and the balance were at 65 psi, the "average" flow rate would be 1.75 gpm, which is higher than the simple average. This weighted average is based on the proportion of homes with water pressures at 40 psi and at 65 psi (e.g., 25% to 75%).

The REMP field study provided data on the proportion of homes with water pressures from 10 psi up to 110 psi. These proportions were used to weight the Bonneville showerhead flow test results to project typical regional savings for each model of showerhead. Different numbers of each showerhead model were distributed in the program. Consequently, the post-retrofit showerhead flow rates needed to be weighted, once again, to reflect the proportion of *each showerhead model* distributed in the program. The resulting estimate is 2.28 gpm, which is lower than the program maximum of 2.5 gpm (Appendix F).

The flow-rate change was calculated by subtracting this brand-weighted, water-pressure adjusted, post-retrofit flow rate (i.e., 2.28 gpm) from the average pre-flow rate observed in the REMP study (3.2 gpm). The resulting average

.9 gpm flow rate reduction was used with the flow rate reduction observed in the REMP study (1.4 gpm) to develop a ratio of expected program flow rate change to REMP energy savings. This ratio (.9 gpm/1.4 gpm = 0.65) assumes that water and energy-use changes are proportional to changes in water-flow rates. It also assumes these changes are linear in the range of changes observed in the REMP study. In other words, we assume that changes in flow rate will save an average of roughly 37 kWh per 0.1 gpm change when flow rates are reduced by up to 2 gpm (515 kWh average savings for an average flow-rate change of 1.4 gpm yields 36.78 kWh of savings per 0.1 gpm change.)

The number of program participants cited in this study is based on available Bonneville records. Although a variety of program-delivery methods were used, almost all of them included some form of customer registration. Utilities participating in Bonneville's showerhead program distributed showerheads to a total of 557,483 customers. These records also categorized each participant by the type of delivery method (e.g., professional installation, self-installation, etc.). This information was used to classify program participants by one of two installation methods: professional versus self-installation. According to Bonneville records, showerheads were distributed to 207,516 participants for them to install, and professionals installed showerheads for 349,967 participants. Delivery mechanisms that did not explicitly track participants, such as handing out showerheads at energy fairs, were not credited with any program savings. Program documentation isolated installations at commercial sites from those at residential sites. However, program cost data did not include this level of detail. Commercial installations are a small fraction of the total number of installed showerheads (and none of the faucet aerators) so the 2,005 commercial participants are treated as residential participants in this evaluation.

The program participation rate is the number of participants in the program compared to the number of customers who could potentially participate in the program. Although the number of participants is known from program records, the number of eligible consumers is not. Regional planning documents show that Bonneville serves roughly half of the regions's 3 million electric customers. About 90% of these have electric water heaters. Consequently, the showerhead program reached about 40% of dwellings with electric water heaters in the first two years. For comparison, the REMP study identified a program participation rate of 66% using a professional installation approach.

The retrofit rate (fraction of showerheads replaced) is expected to vary based on whether the showerhead was installed by the participant or professionally and how many showerheads were provided to each site (one for each shower versus one or two regardless of the number of showers). The REMP study design had a target of 100% replacement. (Due to technical barriers, the retrofit rate achieved was actually about 90%.) The retrofit rate of 90% found in the REMP study is expected to be the maximum utilities will average using professional installation techniques. Utilities that relied on participant installation were credited with a retrofit rate equal to 50% of the REMP retrofit rate and a proportionate fraction of the associated energy savings. The lower retrofit rate for self-installation was based on the results from the Puget participation study and a review of the literature from other programs (Appendices C and H). This translates into an actual retrofit rate of 45%, because the REMP retrofit rate was 90% (forty-five percent is 50% of 90%).

Low water-flow rates were correlated with low water pressure in the REMP field study. Low water pressure was, in turn, correlated with sites using domestic wells as a water source. The savings evaluation equation adjusts for low water pressure and reduced savings from lower flow rates based on the fraction of participants on domestic wells compared to the fraction of REMP sites. This adjustment is to be used only when REMP pre-retrofit flow rates are used instead of local data. Locally collected data on pre-retrofit flows includes the affect of low water pressure on flow rates.

Program savings are a function of both annual savings and the number of years measures remain in place to produce savings. Measure persistence was broken into the following two components; first-year retention rates, which were well documented in the REMP field study; and replacement rate, a term meant to capture the period over which almost all of the showerheads in normal use were replaced. This evaluation adopted a first-year retention rate of 90% based on REMP study results and assumed a replacement rate of 12 years as a straight line after the first year.

5.2 Program Savings

Program savings are a function of average household-level savings for program-installed measures multiplied by participants in each of the two major delivery approaches, professional- and self-installation. Energy savings are discounted for self-installation to reflect the fact that only about half of the showerheads are replaced by occupants and thus, only half of the potential savings are achieved. Projected savings for each method over the 12-year life of these measures is shown in Table 5.4.

Savings per participant based on REMP pre-flow rates and energy savings and actual program measures (rather than REMP post-flows) are 1,893 kWh annually for professionally installed measures and 947 kWh annually for self-installed measures. Year 1 includes a one-time reduction in savings to reflect actions taken during the regional drought. As a result, projected savings in year 2 increase over year 1. However, savings in year 2 do not return to pre-drought levels to reflect the fact that roughly 8% of the program showerheads are expected to be removed. This removal rate is applied to the savings for years 2 through 12 to adjust for measure persistence.

According to Bonneville records, there were 557,483 participants in the program. Of these, 349,967 participated in programs using professional installers and 207,516 participated in programs that required self-installation of measures. Savings for the program as a whole and for each of the two installation options are shown in Table 5.5.

Table 5.4. Projected Savings per Participant

Year	Projected Savings (prof-install) (kWh/year)	Projected Savings (self-install) (kWh/year)
1 (adjusted for drought)	184	92
2	285	142
3	259	130
4	233	117
5	207	104
6	181	91
7	155	78
8	130	65
9	104	52
10	78	39
11	52	26
12	26	13
Average Annual Savings	158	79
Lifetime Savings	1,893	947

Table 5.5. Program Savings Estimates

Estimate	Estimated Savings (Professional Install)	Estimated Savings (Self-Install)	Estimated Savings (Total)
Savings per Participant:			
Net First-Year Savings (kWh)	184	92	150
Lifetime (12-yr.) Savings (kWh)	1,893	947	1,541
Annual Average Savings (kWh)	158	79	128
Program Savings:			
Participants	349,967	207,516	557,483
Net First-Year Savings (MWa and Mwh)	64,298 MWh 7.34 MWa	19,063 MWh 2.18 MWa	83,361 MWh 9.52 MWa
Lifetime (12 yr.) Savings	662,579 MWh 75.64 MWa	196,441 MWh 22.42 MWa	859,020 MWh 98.09 MWa
Average Annual Savings	55,215 MWh 6.3 MWa	16,370 MWh 1.87 MWa	71,585 MWh 8.17 MWa
MWa = average megawatts = mWh / 8,760 hours/year			

5.3 Program Costs

Program costs include the following three categories: 1) measure costs, 2) utility program costs, and 3) Bonneville direct program costs. In addition, Bonneville's program database tracks total program expenditures, which includes costs in these three categories for the program.

Measure costs consist of the direct costs for the purchase of measures to be installed under the program. These costs, in turn, consist of direct procurement costs for measures purchased by Bonneville's central procurement staff in Portland, items purchased by area office staff directly, and measures purchased by utility participants directly and reimbursed by Bonneville. Procurement requests in excess of $50,000 were processed by Portland staff. Although area office staff were authorized to procure measures directly, our review of program documents does not indicate that any of them actually did. These procurement records were reviewed for this evaluation. Attempts to obtain area office procurement records were unsuccessful, however; if these costs occurred, they would be included in Bonneville's program database. The Bonneville procurement records we reviewed reflect procurement requests, rather than actual orders. However, our copies included hand-written notations in the procurement log indicating the quantity of items that were purchased and the utility to which they were delivered. In addition, program staff provided fiscal-year summaries of orders sorted by utility and within each utility by order date. This spreadsheet includes counts of showerheads and aerators, although these counts also include accessory hardware in addition to the showerhead and aerator measures (Table 5.6). Bonneville reimbursements for utility purchases for measures were tracked individually. These various data sources provide a composite picture of the number and kind of measures that were requested for this program. For the sake of completion, this analysis should have included a reconciliation of measures ordered that remained in inventory at the end of the program as a cross-check on the number of measures actually distributed throughout the program. However, this data was only available from the area offices, and our requests for it went unanswered. The number of showerheads ordered (905,194) divided by the number of program participants (557,483) produces an average of 1.62 showerheads per participant. This is comparable to 1.7 showers per household observed in the REMP field study, which indicates these records are reasonable, assuming few showerheads remained unmeasured at the end of FY 93.

Table 5.6. Showerhead Program Procurement Summary

Fiscal Year	Showerhead items ordered	Aerator items ordered	Showerhead costs	Aerator costs
FY 92	491,329	490,111	$ 269,659	$556,912
FY 93	413,865	583,942	$ 3,004,595	$ 923,735
Subtotal	905,194	1,074,053	$ 3,274,254	$1,480,647
Total				**$4,754,901**

In addition to measure costs, the program also reimbursed utilities for program-related costs, including advertising, start-up expenses, and implementation costs. Generally, implementation costs were tied to participation rates and varied depending on the distribution method used by the utility (Chapter 3). These costs are reflected in Bonneville's program database. Expenditures in the program database include promotional and other expenses associated with the program, showerheads purchased by utilities and associated installation expenses, aerators purchased by utilities, and sales taxes (Table 5.7). Summaries from the program database do not normally distinguish between reimbursements for administrative costs and those for measures purchased directly by utilities; however, that level of detail is included in the database. As a result, the summaries in Table 5.7 for nonhardware expenses also include some costs for reimbursement to utilities for direct procurement of hardware. For this evaluation, these details are not necessary, especially since direct purchase of measures was thought to be a small fraction of the total measures installed. Similarly, the "promotional" expense line in Table 5.7 includes all of the promotional costs for the Appliance Efficiency Program, not just the showerhead option. The costs for the promotion of each program option cannot be separated readily because generally, both program options were promoted together. The showerhead option was the most significant portion of the Appliance Efficiency Program. For comparison, the direct program expenses for the water heater option for the same period were $ 2,082,419, or roughly 14% of total direct, non-hardware expenses for the Appliance Efficiency Program.

Table 5.7. Summary of Showerhead Program Direct Expenses (FY 1992 and 1993)

Expenditure	Amount
Promotion and Public Relations	$315,039
Non-hardware Showerhead Expenses	$12,697,495
Non-hardware Aerator Expenses	$188,302
Local Sales Taxes	$6,968
Total	**$13,207,803**

Bonneville also incurred indirect costs for staff time associated with the implementation of this program. Bonneville tracks staff time using time sheets that are entered into a database used by the entire organization called the PACS system. Discussions with program staff indicated that they keep tract of their own time, and there is a tendency toward expediency rather than toward accuracy in these records, which may undermine their reliability. They also indicated the project breakdowns in the PACS system may group program elements into a single large category. This is especially true during the early stages of program design and contract negotiation when a formal program may not be recognized by the PACS system. As a result, Bonneville's program staff generated staffing estimates as a substitute for data from the PACS system. They assumed that the program required 2.5 full-time equivalent (FTE) staff during each of the two years covered by this evaluation, or a total of 5 FTE. Bonneville has used a value of $70,000 per FTE for previous internal planning exercises. Thus, this evaluation will assume an additional cost of $350,000 for Bonneville staff support.

A summary of all cost elements for the program is provided in Table 5.8.

Table 5.8. Showerhead Program Cost Summary

Expenditure	Amount
Measure Procurement	$4,754,901
Direct Costs	$13,207,803
Bonneville Staff Costs	$350,000
Total	**$18,312,704**

5.4 Program Cost Effectiveness

Cost-effectiveness is one way of assessing the monetary value of program achievements. Its chief benefit is that it can help predict changes in the monetary value of energy savings over a future period. This allows ready comparison with alternative investments that could be made over the same time period. Utilities use cost-effectiveness calculations to compare concurrent conservation programs with each other and with alternative generating resources. Bonneville uses a standard formula and set of assumptions for calculating cost-effectiveness in these comparisons. Currently, these assumptions include the following:

- Energy savings for Bonneville only (water savings are not included)
- Bonneville finance rate of 8.35%
- discount rate of 3%
- finance life, or amortization rate, of 20 years.

Bonneville's cost-effectiveness calculations also include a factor for measure life. However, this factor is not necessarily comparable to the expected lifetime of a measure or to measure persistence. Instead, it is a reflection of the economic life of a measure in a program setting. For this program, measures are assumed to have a seven-year lifetime. Similarly, the cost-effectiveness calculation is based on first-year savings. Using these assumptions with the results from this evaluation produces the levelized costs for the program indicated in Table 5.9. These are within Bonneville's current cost-effectiveness criteria. Consequently, the program is cost-effective. Costs would be even lower if the water savings and water- and sewer-treatment cost savings were included.

Table 5.9. Program Cost-Effectiveness (1993 base year, cost in mills/kWh)

Nominal Cost	Levelized Cost			
	Nominal Dollars		Real Dollars	
First Year	Base Year (1992)	Current Year (1993)	Base Year (1992)	Current Year (1993)
22.96	44.82	44.82	38.92	38.92

6.0 Conclusions and Recommendations

This report describes the impact of Bonneville's showerhead program during 1991 and fiscal year 1992. The program design and the evaluation approach followed for this program were both somewhat unusual for Bonneville. The program design included a menu of program implementation options for utilities to choose from, instead of a single, prescriptive program design. In addition, responsibility for program implementation was largely transferred to Bonneville's area offices. The design complicated the impact evaluation by introducing a broad range of program-delivery mechanisms and measures, each of which resulted in a different impact on savings and cost. The area office implementation of the program further complicated evaluation by introducing four area offices into the data collection process and diffusing responsibility among staff in the area, at utilities, and within Bonneville's headquarters staff. This evaluation is based primarily on data (which may not be complete) provided by Bonneville headquarters staff. Finally, the focus of this program was energy savings from reduced use of hot water in showers and faucets. During the course of the program the states of Oregon and Washington, as well as the Federal government adopted energy codes that mandated maximum flow rates for showerheads and faucets. Fortunately, these new energy codes did not affect this evaluation because the effective date for them was outside the evaluation period. However, their impact will need to be considered in future evaluations.

The impact evaluation for this program was implemented in stages, with each succeeding stage of the evaluation dependent on the issues raised in the preceding one. Each stage of the evaluation was not conducted by the same contractor. Instead, various topics were researched by different parties, including utilities, Bonneville staff, consultants, and PNL. This, along with the decentralized nature of the program, also required a collaborative approach to the program evaluation.

The evaluation has spanned three years. As a result of the novel approach followed for the evaluation and the time spent evaluating the program, we have developed insights into the implementation of the program and the evaluation approach. These insights are normally the outcome of a process evaluation, and based on in-depth interviews of participants, program staff, and others. A process evaluation of this program has not been requested and hence, is not the subject of this report. Nevertheless, it seems appropriate to present the most important insights we gained in this chapter as findings or recommendations even though they are *not* the result of structured interviews.

6.1 Conclusions

This section presents our findings. Section 6.2 lists recommendations.

6.1.1 Program Impacts

Pacific Northwest Laboratory (PNL) had two major findings about impacts (savings) from the program.

6.1.1.1 Utility and Consumer Participation Success

The program was successful in terms of utility and consumer participation. Program records indicated over 90 of Bonneville's utility customers participated in the program. These utilities recruited participation by over 550,000 households during the first two years of the program. These are impressive statistics for the first two years of a program. In fact, Bonneville utilities serve roughly half of the region's 3 million households and about 90% of these have electric water heaters. Accordingly, the program reached about 40% of the eligible population in less than two years.

6.1.1.2 Energy Savings Success

The program was also successful in terms of energy saved, both on a household and on a program basis. The average savings per household projected in this evaluation, 150 kWh in the first year, represent significant savings. The large number of program participants increases the these savings to 9.52 average megawatts the first year and 98 average megawatts over the projected 12-year life of the measures.

6.1.2 Program Cost-Effectiveness

There were four major findings regarding program cost-effectiveness.

6.1.2.1 Cost-effectiveness

The program was expensive, at $18.3 million for the 1992 and 1993 fiscal year period. The resultant savings made the program cost-effective, 22 mills per kWh, or 2.2 cents per kWh, nominal cost in the first year (39 mills per kWh in real, levelized costs).

6.1.2.2 Future cost-effectiveness

The new energy code undermines the future cost-effectiveness of the program. Federal energy codes now mandate maximum flow rates for showerheads and faucets. As existing showerheads and faucets are gradually replaced, savings similar to those found in this program will be achieved, without any cost to Bonneville or utilities. Consequently, continuing to acquire savings from these measures may not be cost-justified unless there is a near-term need to accelerate the acquisition of these savings, or, unless the retrofit measures have significantly lower flow rates than required by the energy codes and generate additional savings.

6.1.2.3 Incentives

Current program incentives may be higher than necessary. Bonneville continues to acquire savings from showerheads and aerators in addition to those included in the current energy code by requiring the installation of very low-flow showerheads (less than 2 gpm). However, Bonneville's flow tests indicate that current models of showerheads that meet the current code perform at rates similar to the very low-flow showerheads Bonneville now specifies, making the incremental savings much less than expected. The pressure-weighted average flow rate for showerheads rated at 2.0 gpm is only .2 gpm less than those rated at 2.5 gpm. As a result, the likely savings are far less than the .5 gpm indicated by manufacturers' ratings and expected by Bonneville. Moreover, the *measured* flow rates for models rated at 2.5 gpm averaged 1.95 gpm, or less than Bonneville's program target. Therefore, Bonneville may be offering incentives for these savings that are not necessary, and not cost-justified.

6.1.2.4 Trade-off between Resource Quantity and Quality

The Bonneville program was geared toward getting the maximum amount of savings available. This is a quantitative objective and requires maximum program participation rates. However, there is a trade-off between quantity and quality in showerhead retrofit savings. Other regional utilities, such as Portland General Electric (PGE), have chosen to pursue a qualitative objective and expressly limit participation to homes with showerheads determined to be inefficient during a site inspection. In PGE's case, the cut-off is showers that flow at 3 gpm or less. This approach trades maximum program savings for maximum savings per participant. If the REMP sites are used to define potential, the effect of screening participants, as PGE does, reduces total savings *potential* by 41%, but it reduces the number of sites that need to be retrofit to capture these savings by 57%. The net effect on savings per home is to increase savings.

6.1.3 Program Design and Implementation

There are three findings regarding program design and implementation.

6.1.3.1 Increased Program Options Increase Participation

Increased participation by utilities and customers was the expected outcome of decentralized program implementation and it seems to have been borne out in the participation statistics for both utilities 90% and 557,000 customers.

6.1.3.2 Record-keeping a Weak Point

Record-keeping systems for the program were not accurate or timely. Decentralization of program implementation to the Bonneville area offices appeared to diffuse accountability for program management and success. The RCA included a variety of reporting requirements, for reviewing and approving utility plans for program implementation, facilitating the procurement of program measures, and monitoring the delivery and installation of measures. Also included were monitoring the return to the utility of showerheads that were replaced, ensuring that utilities kept accurate records of participants to prevent double counting and over-payments, and so on. In the course of this evaluation we attempted to access these records from the area offices and headquarters staff. We were unable to obtain timely answers to our data requests from the area offices, with the exception of the Puget Sound area office. Even then, we were unable to obtain detailed data on the number of homes contacted by the program and number of showerheads remaining in inventory at utilities at the end of the 1993 fiscal year. This evaluation was for the January 1992 through September 1993 period, and completion was delayed from January 1994. However, participation records we received for the program continued to be revised through May of 1994. Headquarters staff attributed these changes to ongoing corrections in the field data by area office personnel.

Our discussions with area office staff left us with the feeling that they were knowledgeable about what each of the utilities was doing in the program, in terms of distribution methods employed and general program success. However, the poor condition of the program database leads us to conclude that area office staff did not monitor the program using formal procedures or written records or in a timely manner. Moreover, it appeared that much of the responsibility for tracking program progress was delegated to nongovernment contractors whose performance was not directly linked to the cost or success of the program. This casts doubt on the accuracy of the program participation records. We were unable to determine exactly how many measures were actually installed by the program. We have procurement logs that indicate how many measures were purchased, and program records that document customer-participation incentives in the program. However, we have no idea how many measures were installed in each home. We also do not know how many measures purchased in 1992 and 1993 remained *uninstalled* by the end of September 1993.

6.1.3.3 Decentralization Not Successful

The diffusion of responsibility that resulted from decentralization and the division of tasks in the program among various Bonneville offices created a situation where things fell between the cracks. This conclusion is potentially significant for Bonneville as it decentralizes further with the adoption of dozens of account executives with authority to custom-design transactions between Bonneville and its customers. Programs that permit many variations and reduce direct oversight need to include alternative reporting mechanisms to ensure that the benefits assumed from them are, in fact, obtained and provide traceable records.

6.1.4 Evaluation Design and Implementation

There are five findings about the design and implementation of the program evaluation itself.

6.1.4.1 Increased Program Options Increase Evaluation Complexity

Increasing the number of program options and the number and kind of measures that can be installed complicated program monitoring and subsequent evaluation. This required either the collection of more data on each option and measure or the substitution of an alternative that permitted less detailed record-keeping. In this evaluation, a thoroughly researched engineering model significantly reduced the kind and amount of data that needed to be collected. Similarly, weatherization and building-code programs have substituted heat-loss models using prototypical buildings in the evaluation for collecting detailed audit data on a large sample of participant and nonparticipant homes. Emphasis on engineering-model-based approaches increased the significance of assumptions about measure performance. These assumptions were a weak point in the initial evaluation of this program. Bonneville staff could have minimized this problem by requiring vendors of measures to submit detailed laboratory tests to verify the performance of each showerhead model and aerator sold to Bonneville. This problem would also have been minimized by stockpiling a sample of each model for later testing by Bonneville.

6.1.4.2 Initial Preparation for Program and Evaluation Needs Inadequate

Program and evaluation needs should have been anticipated so that improved record-keeping systems and research plans were in place. Bonneville's Appliance Efficiency Program did not adequately anticipate the needs of the showerhead evaluation in the contract or in the design of the program. The RCA appeared to require records that were not kept, or at least, not centrally collected and reviewed. Even if they had been, the contract did not distinguish between reimbursement for expenses for portions of the program, such as the showerhead portion, as opposed to the program as a whole. This prevented us from isolating the costs of each portion for cost-effectiveness analyses.

The research that went into this evaluation was unnecessarily complicated by problems in the design of the program. However, had this research been conducted prior to the design of the program, the data collection needs could have been accommodated in the program easily, and most likely, would have reduced the reporting requirements and costs of the program. This finding is significant as Bonneville and other utilities move away from prescriptive program designs. The movement toward market-based approaches lends itself to collaborative research in advance of program introduction to reduce the uncertainty in program potential and reduce the costs of both the research and the program.

6.1.4.3 Collaboration on Evaluation Worked

Collaborative evaluation worked well, resulting in timely input to the program, lower cost, greater participation, and better results, and could be expanded to include nonregional players. Although this evaluation followed an indirect path to achieve its ultimate goal, the process seemed to result in a better product. Typically, Bonneville evaluations are conducted in relative secrecy and the results are presented without much audience preparation. This tends to foster an environment of skepticism.

This evaluation, in contrast, was conducted fairly publicly with results presented, reviewed, and debated serially, as they became available. This often redirected the evaluation in different directions than expected, based primarily on what seemed to have the greatest effect on savings. The first example of this was found with the discovery that existing flow rates for showerheads were less than expected. It was followed by concerns about how to incorporate the impact of expected changes in energy codes into the evaluation and the unresolved debate about showerhead measure life.

The results from the various research studies cited in this report and included in the appendices were used by the collaborators to revise the program as they became available, rather than waiting until they became available through more typical evaluation reporting mechanisms. In addition, utility and program collaborators were able to consult with evaluators on how new results should be used to modify ongoing programs. The collaborative approach also seems to have increased the credibility of the evaluation assumptions, methods, and results, because several regional utilities and regulators, as well as Canadian utilities, are using them to monitor their own programs.

6.1.4.4 Evaluation Costs and Delays Greater than Expected

Collaboration involved costs not normally included in evaluation contracts or bids. Collaborative research required more flexibility on the part of contractors than typical two-party contracts. Results had to be presented in-process, rather than at the end of the study, resulting in more briefings, more preparation, and more opportunities for redirection away from the initial scope of work. This increased the cost of each task. This evaluation provided for that flexibility by dividing each stage of the evaluation into a separable contract. Although this approach worked well, it created additional contracting burdens on Bonneville and contractor staff, as well as uncertainty for contractors about future work.

6.1.4.5 Accountability for Evaluation Unclear

Piecemeal contracting for the evaluation did not provide for overall "management" of the evaluation. It defused accountability of various collaborators, and thus, shifted the evaluation management burden to Bonneville staff. In a typical, two-party evaluation contract, the prime contractor is responsible for managing the evaluation and delivering a finished report to Bonneville on a negotiated schedule. The collaborative nature of this evaluation and the serial research that supported it, did not include an overall "evaluation manager" role among the contractors or a realistic schedule for completing the evaluation. As a result, Bonneville staff had to assume responsibility for successful completion of the evaluation in addition to their other duties. This was unanticipated and had the effect of slowing the process.

6.2 Recommendations

The following seven recommendations are ways to improve the showerhead program and the design of other Bonneville programs offered in a decentralized manner in the future. These suggestions may help to avoid the kinds of problems we faced, including inadequate records and untimely access to program information, which delayed this evaluation.

6.2.1 Declare Success for Showerheads

Program records indicate that over 40% of the eligible market for efficient showerheads and aerators was reached in the first two years of the program. The program has continued an additional year, and must be close to saturating the market. Based on the achievements to date, and the new energy codes for showerheads, Bonneville should stop further showerhead-acquisition activities.

6.2.2 Incorporate a Forward-looking Element in Program Design

The pending energy codes for showerheads and aerators were not addressed in the initial program design and should have been. The collaborators in the evaluation were not uniformly aware of the pending codes during early meetings; thus, the codes seemed to come as a surprise. This should be prevented in future programs by incorporating an early warning system into the resource-acquisition process that monitors national, regional, and state code and standard activities that may affect the market for efficiency measures. This recommendation may be in the process of being addressed already. Bonneville has undergone a reorganization designed, in part, to increase communication among staff so that this kind of information flows more freely. In addition, Bonneville is active in market-transformation activities, such as participation in the Consortium for Energy Efficiency, that monitors changes in codes and markets. These activities should be continued and explicitly linked to future program-design efforts.

6.2.3 Conduct Research in Measure-performance and Energy-use Dynamics Prior to Program Design

Much of the research conducted during the evaluation of this program could have been conducted earlier. If the information on current showerhead flow rates, regional water pressure, number of showers per household, and hot-water energy use practices had been available prior to the design of the program, program implementation could have been streamlined further, appropriate record-keeping systems could have been put in place, and program incentives could have been more closely linked to energy savings potential. This might have reduced the cost of the program by up to half.

6.2.4 Encourage Research Collaboration in Measure-performance and Energy-use Dynamics

There is nationwide interest in the performance and potential of energy-efficiency measures. Generally, each utility has pursued answers to questions about performance and potential independently. This often limits the depth of research to the budgets available at each utility. We suggest pursuing a more ambitious research agenda supported by several utilities, following the serial pattern established by this evaluation. Without this level of cooperation at the outset, Bonneville should consider conducting in-depth research on these topics and selling the results to other interested parties. The level of interest in this evaluation provides ample evidence that a market for this research exists. To some extent, Bonneville is already doing this through tailored collaboratives with the Electric Power Research Institute (EPRI) and through activities in the Consortium for Energy Efficiency (CEE).

6.2.5 Improve Quality and Timeliness of Record-keeping Systems

This evaluation was significantly hampered by a lack of detailed, timely information on efficiency measures (how many of which were ordered, when they were ordered, when and where they were distributed, and how many remain in inventory). Program costs (costs specific to each portion of the Appliance Efficiency Program, staff costs, and costs for each distribution method for each utility) and utility implementation plans also needed to be documented in greater detail. Utilities were required to file implementation plans with Bonneville area office staff, but these plans were not available for review from any central source. The lack of accurate and timely data from the central database has already been noted. Based on this experience, Bonneville should implement program-monitoring systems that provide convenient, central access to all program data and records. These systems should be under the control of individuals who are held accountable for the quality, accuracy, timeliness, and completeness of program records.

6.2.6 Clarify Accountability for Program Success

Even decentralized programs should have clear lines of authority backed up by a chain of accountability for program success. This concept was evident in the program because area staff were accountable for program success. However, their accountability was not supported by record-keeping systems that could be accessed easily to audit the claims from the field or by a clear chain of command. The chain of command should lead to one person who is responsible for directing area staff and for providing accurate record-keeping.

6.2.7 Improve Efforts to Establish Measure-performance Benchmarks

The measures procured for this program had to meet specified performance criteria (i.e., showerheads to flow less than or equal to 2.5 gpm at 80 psi). These kinds of criteria are essential. However, program or procurement staff should have taken advantage of this requirement to require potential vendors to submit laboratory test data that went beyond minimum criteria to establish performance across a broad range of water pressures. In the absence of this information, Bonneville's laboratory was required to conduct these tests two years later. By that time, some of the vendors had changed the design of their showerheads, without changing their model numbers, which complicated establishing performance benchmarks. If Bonneville is unable to require vendors to provide this kind of documentation, a sample of each brand and model should be stockpiled for testing later.

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