PUGET SOUND ENERGY

Manufactured Home Duct Sealing Program: Impact Evaluation for Program Years 2012-13, Process Evaluation for Program Year 2014

Contents:

- DNV GL - Impact and Process Evaluation Report
- PSE - Evaluation Report Response

This document contains DNV GL's Impact Evaluation for Program Years 2012-13, and Process Evaluation for Program Year 2014, for Puget Sound Energy's Manufactured Home Duct Sealing Program (MHDS). It also contains an Evaluation Report Response (ERR) authored by PSE program staff.

In accordance with WUTC conditions, all PSE energy efficiency programs are evaluated by an independent, third party evaluator.[1] Evaluations are planned, conducted and reported in a transparent manner, affording opportunities for Commission and stakeholder review through the Conservation Resource Advisory Group (CRAG) and reported to the UTC.[2] Evaluations are conducted using best-practice approaches and techniques.[3]

PSE program managers prepare an ERR upon completion of an evaluation of their program. The ERR addresses and documents pertinent adjustments in program metrics or processes subsequent to the evaluation.

Please note that this is an evaluation of the program as it operated during the 2012 – 2013 program years, and does not necessarily reflect the program as currently implemented, or measures currently deployed by the program.
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[1] **(6)(c.) Approved Strategies for Selecting and Evaluating Energy Conservation Savings, Proposed Conditions for 2016-2017 PSE Electric Conservation.**
[2] **PSE 2016-2017 Biennial Plan, Exhibit 8: Evaluation, Measurement & Verification (EM&V) Framework, revised August 6, 2015.**
[3] **Ibid.**

Puget Sound Energy's Manufactured Home Duct Sealing Program Evaluation

Impact evaluation for Program Years 2012-13, Process for Program Year 2014

Prepared by DNV GL

11-13-2015

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1 EXECUTIVE SUMMARY

Puget Sound Energy's Manufactured Home Duct Sealing (MHDS) program provides eligible electric customers with duct sealing and direct install measures at no charge. UCONS, as a sub-contractor to PSE, has been delivering the program since 2010. The program's goals are to cost effectively save energy while delivering services to an underserved population. Since 2010, the program has treated more than 20,000 manufactured homes

This evaluation addresses both impact and process evaluation issues. The impact evaluation focuses on estimated savings for duct sealing measures installed in 2012 and 2013. The process evaluation, completed by Btan Consulting, looks at the current program to assess program implementation, participants and other related issues. It relies on feedback from 2014 participants.

1.1 Program Summary

The MHDS program offers no-cost duct sealing services, as well as direct install efficient lighting and showerheads, to PSE customer living in manufactured homes. Duct sealing primarily saves energy by avoiding leakage of heated air to spaces outside the home shell. Additional savings may be gained by more even distribution of heated air. Low flow showerheads save energy by reducing use of the hot water heater if less water is used with the new showerheads. Efficient light bulbs save energy when they replace less efficient bulbs and usage characteristics remain the same.

The MHDS program is marketed directly by the implementer, UCONS, and through marketing efforts by PSE. Door knocking is a primary mode of getting program participation. By working with park managers and associations, UCONS obtains access to mobile home parks to promote the program through meetings and door knocking. Where no one answers the door, UCONS personnel leave pamphlets in a protected spot, if available. This one-page program description includes a toll free number to call UCONS and schedule an appointment.

PSE supports UCONS marketing efforts through periodic press releases, public service announcements, and program information on the PSE website. In 2014, PSE sent direct mailings (postcards) to customers to reduce program costs. (UCONS mailed them in previous years.) UCONS provides PSE with direction on where and when to send the mailers.

The program has three levels of service that relate to the level of service possible given the ducting system in the home. Those levels are defined in the impact and process evaluation sections because the definitions changed slightly between the 2012-13 program years that are the focus of the impact evaluation and the 2014 to current program that was the focus of the process evaluation. All evaluated homes received duct sealing services. In addition to duct sealing, lighting is installed, and residents are provided showerheads and furnace filters, where applicable.

In 2012-2013 the program targeted manufactured homes in parks. The program implementer works through park managers to get access to park residents. Once provided access to the park, they can knock on doors and present the program at park meetings (if they are held). Besides the benefit of a geographically clustered set of participants, this increases participation through multiple contacts with the program, and validation of the program through participation of neighbors. Out-of-park homes are more widely dispersed, so more difficult to direct market, but they tend to offer more savings.

1.2 Impact Evaluation

1.2.1 Objectives

The impact evaluation conducted a billing analysis to quantify gross program savings.

Specifically, the objectives of the impact evaluation were:

1. Estimate participants' energy savings from the duct sealing program?
2. Determine how energy savings vary by duct sealing type and mobile home location between in-park and out-park?
3. Determine how other efficiency measures distributed during duct sealing impact energy consumption?

1.2.2 Impact Findings

The billing analysis evaluated the impact of duct sealing on annual electricity consumption of residents living in manufactured homes. The final analysis sample consisted of 4,102 premises in a participant group that installed duct sealing measures in 2012 and 2013. The comparison group was constructed of 3,731 premises that received duct sealing measures in the subsequent years, after the evaluation timeframe. The analysis applied a difference-in-difference method to weather-normalized annual consumption to estimate program savings.

The program provides three different levels of duct sealing to two different populations of manufactured homes, homes in- and out-of-parks. The level of savings is closely related to these two characteristics, so savings were estimated by subgroup. The savings estimates represent total savings for these homes including the direct install lights and showerheads. We made a concerted effort to isolate the direct install savings, but could not get separate savings estimates that were statistically significantly different than zero.

Table 1 provides the average annual savings along with confidence interval and level of significance. Five of the six subgroups provided statistically significant savings; that is, five of the six subgroup estimates' confidence intervals do not include zero. In particular, Level 3 savings were high for both in- and out-of-park. Level 1 out-of-park savings were also high. The savings represent from 1.9% to 6.7% savings as a percent of pre-period consumption.

Table 1: Annual Savings by Level and In/Out-of-Park[4]

Customer Groups/ Impact (kWh/year)	Average Participant Savings (kWh)	90% Lower Limit (kWh)	90%[5] Upper Limit (kWh)
Duct Sealing Level 1- In-Park	388.6**	94.6	682.6
Duct Sealing Level 1- Out Park	1,175.2***	745.0	1,605.4
Duct Sealing Level 2- In-Park	404.5**	128.7	680.3
Duct Sealing Level 2- Out Park	358.1	-27.9	744.1
Duct Sealing Level 3- In-Park	930.1***	554.3	1,305.8
Duct Sealing Level 3- Out Park	1,316.6***	943.3	1,689.8

*Note: The asterisk symbol (*) represent statistical significance level: * p<0.1, **p<0.05, ***p<0.01*

The process evaluation came to the conclusion that there is no evidence of free-ridership with this program, so these savings estimates represent both gross and net savings. Table 2 summarizes net savings estimates for the 2012 and 2013 MHDS program. In particular, Levels 1 and 2 for out-of-park homes did well. Overall, however, the realization rate was just 51% compared to deemed savings estimates from those program years.

Table 2 MHDS Program Savings for 2012 and 2013 with Realization Rate

Customer Groups/ Percent Savings	Average Participants' Savings (kWh)	Total Participants: 2012 & 2013	Total Estimated Savings (kWh)	Total Tracked Savings (kWh)	Realization Rate
Duct Sealing Level 1- In-Park	388.6	2,433	945,550	2,202,349	42.9%
Duct Sealing Level 1- Out-Park	1,175.2	674	792,084	719,609	110.1%
Duct Sealing Level 2- In-Park	404.5	2,961	1,197,713	3,346,482	35.8%
Duct Sealing Level 2- Out-Park	358.1	1,305	467,359	1,781,328	26.2%
Duct Sealing Level 3- In-Park	930.1	1,233	1,146,756	1,730,396	66.3%
Duct Sealing Level 3- Out-Park	1,316.6	861	1,133,580	1,389,716	81.6%
Total		9,467	5,683,042	11,169,880	50.9%

There are no conclusive explanations for the low savings estimates relative to the tracked (expected) savings. The billing data used for the analysis, a combination of monthly and daily reads, were complete and used consistently across treatment and comparison groups. The savings estimation process that was used is well-established and widely used this kind of program. Possible explanations include a combination of unreasonable savings expectations given the nature of ducts being sealed and other factors (participant behaviors, broken heating systems, etc.) that overwhelm the modest positive effects from the duct sealing.

[4] Definitions of Level 1-3 are provided in section 4.1

[5] The 90% confidence intervals and the asterisks representing statistical significance level are parallel means of expressing the confidence that the estimates are within a certain range. The 90% confidence upper and lower limits indicate that given the nature of the data, we are 90% confident that the true answer falls somewhere within this range. The P-values are an indication of the probability that the true answer could be zero. That is, a p-value of <0.05 indicates that there is a less the 5% chance that the indicated savings are actually zero.

Additional analysis was performed on participant data provided by PSE later in the evaluation process. These data included general site information such as square-footage, year built and number of occupants as well as duct-related characteristics such as number of endcaps, presence of crossover, etc. These data were analysed to see if they provided any further insight into different levels of saving in the different level/location combinations. There is no evidence that any single characteristic such the age or size of the home explained the relatively low savings for in- and out-of-park Level 2 customers and Level 1, in-park customers.

1.3 Process Evaluation

1.3.1 Process Evaluation Objectives

Btan Consulting conducted the process evaluation with a focus on 2014-2015 program processes. The 2014 -2105 program provides the same duct sealing measures to manufactured homes in PSE's electric service territory as previous years of the program.[6] The program has a new emphasis on duct sealing in out-of-park homes, with a goal of 60 percent of participants being out-of-park. The objectives of the process evaluations were to:

1. Identify and document program implementation processes.
2. Assess participant satisfaction with the MHDS program and measures.
3. Assess (qualitatively) the extent of free-ridership in the program.
4. Identify any take-back behaviors that may reduce savings.

To meet these objectives the evaluation team completed a variety of tasks. These included in-depth interviews (IDIs) with the PSE program manager and program implementation staff (11) with roles throughout the program delivery process. The team also interviewed 16 program participants, reviewed the results of participant satisfaction surveys, and reviewed program materials and data.

1.3.2 Key Process Findings

The process evaluation found the MHDS program to be operating smoothly, with each entity – PSE, UCONS (the program implementer) and Efficiency Services Group (the verification contractor) – being responsible, qualified, and motivated to do their parts. In 2014, UCONS installed duct sealing in 3,411 homes. With new deemed savings estimates in place, they achieved 79% of the 2014 – 2015 contract period kWh goal with 59% of the budget.[7] The majority of the homes treated (68 percent) were out-of-park.

The program has well established processes for marketing, scheduling, installation, verification and handling of customer complaints. Roles across the partners are clearly defined. Communication between program partners (PSE, UCONS and Energy Services Group) is regular, and both formal and informal (as needed). Although the PSE Program Manager is new to the MHDS program, most other staff interviewed have been working on the program for multiple years. Participant recall of program experience is mostly consistent with program staff's description of the process.

[6] Prior program years included PSE natural gas customers in manufactured homes.
[7] 2014 deemed savings levels were increased from the levels used during the 2012-13 program years on which this evaluation focused.

UCONS handles two functions that are typically not the responsibility of program implementers due to conflicts of interest: installation verification and participant satisfaction surveys. While program implementers often have *internal* quality control procedures that include on-site verifications, most utilities or other program funders contract directly with independent firms for verification services to avoid these conflicts of interest.

Program implementers may also conduct limited participant satisfaction surveys, but none have sole responsibility for data collection and data entry. For MHDS, the installer provides participants with a paper satisfaction survey (or a link to a web survey) for return to UCONS. The data collection processes used are prone to low response rates, selection bias, and result in data that is limited in its usefulness.

Program participants appear to be very satisfied with the program, as well as with the LED lighting that is installed. These findings are based upon responses to the 2014 participant survey implemented by UCONS and 16 participant interviews completed as part of this evaluation. The 2014 participant survey had a very low (6 percent) response rate[8], and the data collection procedures preclude assessing how well the respondents represent the participant population.

The evaluation participant interviews also indicated high measure retention. Most interviewed participants reported that the installed lighting and showerhead are still in use. Very few participants, however, noticed a difference in home comfort after duct sealing, and few reported a noticeable difference in their energy bill, despite savings claims of up to 30% in the program flyer and post card.

Free ridership in the MHDS program is likely to be near zero. Almost all interviewed participants were unaware of the need for duct sealing in their home before participating in the program. Most of the target population is low or fixed income.[9] During interviews, many explicitly or implicitly indicated that they did not have sufficient money to make home repairs. Program staff reported that there is no market for retrofit duct sealing. They report that retrofit duct sealing is driven by incentive programs, such as the duct sealing and insulation rebate offered by PSE.[10] Without awareness that duct sealing is needed, and sufficient disposable income to pay for it, it is unlikely that participants would have their ducts sealed without the PSE program. This is the implied logic in the program design, which provides the service a no cost to participants.

The MHDS program may result in limited "take-back." When asked in evaluation interviews if they had changed their "winter temperature settings since the duct sealing was installed," only one respondent indicated a substantial change. His response was that they "use the heat more." The installer had repaired a cross-over, which allowed heat to flow to rooms that previously were too cold. This respondent reported both increased comfort and lower energy bills.

[8] Telephone survey response rates for program participants, even low income, range from 20 to 60%, depending upon data collection methods and location.

[9] The 2009 American Housing Survey reported median household incomes for owners of manufactured housing to be $30,000, compared to a national median income of $49,777. The 2013 American Housing survey shows 25% of households in manufactured housing below the poverty level (compared to 11% in single family detached homes.

[10] This PSE program requires customers to pay 50% of the costs for duct sealing and insulation. Other retrofit duct sealing programs in the NW also require customers to pay a portion of the cost.

1.4 Recommendations

PSE should continue to prioritize out-of-park homes. The savings levels are substantially higher (for Levels 1 and 3).

PSE should re-assess the process for prioritizing homes with more extreme duct leakage issues. A subset of the manufactured homes in the program has sufficient savings to make this program cost effective.

The program should have a fully transparent and clear set of decision rules that decide the Level of service for each home. Rules should be based on verifiable measurements and consistently applied across all levels to minimize implementer discretion

PSE should consider using an independent firm to conduct participant satisfaction surveys to increase the quality and usefulness of the data, and to avoid any conflict of interest.

PSE should consider taking responsibility for the verification contract with Efficiency Services Group to avoid the inherent conflict of interest with the existing arrangement

PSE should obtain more complete program data collected by UCONS to increase program transparency, as well as to have a more complete picture of the participant population.

PSE should explore additional marketing opportunities to reach out-of-park and other potentially underserved (such as Spanish language) MH homes.

2 INTRODUCTION

Puget Sound Energy (PSE) has offered duct sealing and direct installation of low-cost measures to customers in manufactured homes since 2009.[11] The services are provided at no cost to participants. In addition to duct sealing, the 2014 program provides up to 5 LED lights, up to 2 low-flow showerheads, and several furnace filters. The primary marketing approach has been door-to-door promotion, supplemented by direct mail and press releases in targeted areas. Starting in 2014 MHDS duct sealing eligibility was limited to PSE manufactured home customers using electricity as their primary heat. Since 2010 PSE has contracted with UCONS to provide program implementation throughout their service territory. Duct sealing helps reduce energy required for heating/cooling purposes, thus lowering residents' energy bill. Since 2010, PSE has provided duct sealing measures to more than 20,000 customers. This impact evaluation focuses on customers installing duct sealing measures in 2012 and 2013. The process evaluation focuses on customers from program year 2014. The outcomes of the Manufactured Home Duct Sealing (MHDS) evaluation report are quantifying gross energy savings from the program and qualitatively assessing customer satisfaction, free-ridership, and take-back behaviors.

2.1 Evaluation Objectives

The evaluation of Manufactured Home Duct Sealing primarily consists of two major components.

Impact Evaluation: For the first component of the evaluation, the evaluation team conducted a billing analysis to estimate program savings of 2012 and 2013 duct sealing participants. The team utilized a difference-in-differences modelling approach to estimate residents' weather-normalized annual energy savings. The analysis dataset was created combining consumption, weather, participation, duct sealing type and CFL bulb and efficient showerhead information. Specifically, the impact evaluation focussed on following questions:

1. What is the average participant's energy savings from the duct sealing program?
2. How do energy savings vary by duct sealing type and mobile home location between in-park and out-park?
3. How do other efficiency measures provided or installed during duct sealing impact energy consumption?

Process Evaluation: For the second component of the evaluation, the evaluation team focussed on process issues to identify what is working well and to provide recommendations for program improvement. The process evaluation team reviewed key program documents and conducted in-depth interviews with the PSE Program Manager, UCONS program implementation and Efficiency Services verification staff and participants in the 2014 program. The process addressed the following four objectives:

1. Identify and document program implementation processes.
2. Assess participant satisfaction with the MHDS program and measures.
3. Assess (qualitatively) the extent of free-ridership in the program.

[11] The program was piloted in 2008.

4. Identify any take-back behaviors that may reduce savings.

2.2 Overview of the Report

The remaining sections of the report are organized as follows. Section 3 briefly describes impact and process evaluation methodologies. We discuss data sources and summary in Section 4. Section 5 presents the impact evaluation results. In Section 6, we discuss findings from the process evaluation. We conclude the report with the summary and recommendations in Section 7 and appendix in Section 8.

3 EVALUATION METHODOLOY

The DNV GL team employed a two-step statistical regression method for the billing analysis. The impact evaluation utilized premise-level regression models to predict weather-normalized annual consumption in the first step. The second step used a difference-in-differences approach to estimate the gross program savings.

The process section focussed on detailed review of program materials and in-depth interviews with staffs and participants.

3.1 Impact Evaluation

3.1.1 Construction of Comparison Group

The typical difference-in-differences approach uses a comparison group with similar energy consumption characteristics to control for the non-program, exogenous change in energy consumption through the evaluation period. In a randomized control trial experimental setting, where customers are randomly assigned to the control and treatment groups, this allows for an unbiased measure of program savings, by design. However, the MHDS program is an opt-in rebate program where it is not feasible to obtain randomly selected customers in control and treatment groups. In this case, it is necessary to construct a comparison group. Following the guidance of DOE's Universal Methods Project, the analysis uses subsequent years' participants to populate the comparison group.[12] This approach puts a premium on matching the full range of participant characteristics with the comparison group. In this case, the comparison group are manufactured home occupants in homes that will be considered for participation in subsequent years. It is reasonable to expect that the comparison group homes face the same kind of duct system degradation for which the participants' homes are being treated.

The evaluation used 2013 installers as the comparison group for estimating energy savings of 2012 participants while 2014 installers were used as the comparison group for 2013 participants. For the comparison group, DNV GL constructed a two-year pre-installation period that mirrors the pre- and post-installation of the participants being evaluated. The first of the two pre-installation years of the comparison group corresponds to participant's pre-installation period while the second pre-installation year of the comparison group corresponds to the post-installation period of the participants. The year over year change in comparison group's consumption during the two years of pre-program consumption data provide a basis for addressing non-program change in the estimates of savings.

The use of subsequent participants addresses self-selection concerns in ways that a comparison group constructed from the general population cannot. Also, the use of subsequent participants lowers the likelihood of non-program duct sealing activity in the comparison group.

Table 3 provides a diagram of how the difference-in-differences approach works after constructing comparison groups. For households that installed duct sealing in 2012, the difference in consumption between the pre- and post-periods provides an estimate that combines program-related effect and exogenous (non-program-related, natural trend) change. Their comparison group is made up of

[12] *Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol*. Chapter 8 of The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. NREL April, 2013. http://energy.gov/sites/prod/files/2013/07/f2/53827_complete.pdf

households that became program participants a year later. The consumption difference from their two year-long pre-program period captures only exogenous changes. Removing the comparison group's pre-post difference (exogenous, natural trend only) from the 2012 participants' group pre-post difference (program + exogenous, natural trend) provides an estimate of change in consumption due to the MHDS program.

Table 3: Pre- and Post- Differences of Participants and Comparison Groups

Group	Pre	Post	Pre-post difference within group	Pre-post difference between groups
2012 Installers (Participants)	Non-program trend	Non-program trend + Program effect	Program impact + Non-program impact	Program impact
Future participants 2013* (Comparison)	Non-program trend	Non-program trend	Non-program impact	
2013 Installers (Participants)	Non-program trend	Non-program trend + Program effect	Program impact + Non-program impact	Program impact
Future participants 2014* (Comparison)	Non-program trend	Non-program trend	Non-program impact	

*Installed more than a year **after** the households with which they are matched for comparison purposes

The process is the same for estimating energy savings of households installing duct sealing measures in 2013. Removing the comparison group's pre-post difference (exogenous, natural trend only) from the 2013 participant group (program + exogenous, natural trend) provides an estimate of savings that is due to the program.

3.1.2 Analysis Method

Gross program savings are estimated using a two-stage billing analysis approach where the first stage involves site-level modelling and the second stage applies a difference-in-differences method to measure program savings.

Site-level Modelling: DNV GL conducted site-level modelling[13] to estimate: (a) individual outdoor temperatures that trigger cooling and heating for each program participant, and (b) a weather-adjusted consumption that reflects a typical weather year for each site.

The site-level modelling covers a range of cooling and heating degree day bases to estimate normalized annual consumption for pre- and post- installation periods of each household in the participant and comparison groups. This modelling approach searches for the optimal reference temperature that yields the best model fit, separately for each household during the pre- and post-periods.

Using the coefficient estimates of the best model selected for each site, we then calculated normalized annual consumption using the parameter estimates (see Equation 2 in appendix). Weather normalized annual consumption is particularly important for application of billing results to deemed unit savings estimates that can be used for program planning and administration.

[13] The site-level modeling approach was originally developed for the Princeton Scorekeeping Method (PRISM™) software.

Difference-in-Differences: The second stage follows a difference-in differences method that compares the change in the average normalized consumption of the participant group during pre- and post-program period with the change in usage during the same period for the comparison group.

The difference-in-differences approach is a simple, robust approach to measuring program-related savings. The participant group pre-post difference captures all changes between the two periods including those related to the MHDS program. The comparison group captures all changes between the two periods with the exception of those related to the MHDS program. Removing the non-program differences, as represented by the comparison group difference, from the treatment difference produces an estimate of the MHDS program's isolated effect on consumption.

An important part of the difference in difference approach used for this evaluation was making sure that participant premises with particular characteristics were compared to comparison group premises with similar characteristics. Most importantly, this refers to premise location (in- or out-of-park) and the level of duct sealing. The level of duct sealing is, in part, an indication of home size, with level 1 homes comprised of primarily single-wide manufactured homes, while level 2 and 3 are comprised primarily of double-wide homes. Because all comparison group premises were ultimately participants, we know both whether the comparison group homes were in- or out-of-park, and what level of duct sealing for which they ultimately qualified. This matching of the comparison premises with like participant premises is built into the specification of the second stage regression.

Finally, The MHDS program combines the major duct sealing measures with additional direct install measures like CFL and LED lights as well as low-flow showerheads. We attempted a number of different second-stage model specifications with the intent of isolated the savings effect of the direct install items. Invariably the results indicated saving estimates that were statistically non-significant. This is not uncommon with savings measures that almost every home received and are, with respect to magnitude, smaller than the major measures. In this case there is the added challenge that during the heating season at least some of the overall savings would be reduced due to interactive effects with the heating system. The solution, in both cases is to include the direct install savings with the duct sealing savings. The final specification used for the evaluation estimates savings in this way.

3.2 Process Evaluation

The process evaluation relied on multiple approaches and sources to meet the process evaluation objectives. These included:

In-depth interviews (IDIs) with program related staff. The IDIs with program related staff were designed to understand how the program is delivered, including the roles and communication across the organizations responsible for the program. Interviews with UCONS staff included the Director, Marketing Manager, Field Supervisor, Scheduler and three installers. The PSE Program Manager and two staff from Efficiency Services Group (verification firm) were also interviewed. The interviews also addressed, when appropriate, opportunities for other energy efficiency improvements in manufactured homes, and discussion of the market for duct sealing in PSE service territory.

Review and analysis of the 2014 participant survey. UCONS, the program implementation contractor, provides participants with a satisfaction survey designed by PSE for return to their offices. UCONS enters the data into the survey database. PSE provided the evaluation team with excel files of the survey responses.

In-depth interviews with 16 program participants. In order to better understand how the program looks to the participants, the evaluation team completed in-depth interviews with 16 program participants who participated in the program between January and October 2014. The respondents were split evenly between in- and out-of-park households.

Review of program data. PSE provided program data to the evaluation team for sampling and other evaluation purposes. While using these data, we noted some opportunities for improved clarity of the data.

Review of program materials. The evaluation team reviewed materials provided by PSE, such as marketing postcards and other marketing materials, invoices, the PSE website, data collection forms (implementation and verification), and internal planning documents to get a broader picture of the program.

4 IMPACT DATA SOURCES AND SUMMARY

This section provides a summary of the data used for the evaluation of the Manufactured Home Duct Sealing (MHDS) program. The section discusses data issues such as data availability, exclusion criteria, and provides summary statistics of the final data used in the evaluation.

4.1 Program Description 2012-13

The MHDS program in 2012 and 2013 had specific definitions of the Levels of service. These are from the Field Specification Manual[14] :

- Level 1 - Ducts are sealed from the interior (boots, registers, end caps). Cross-over duct is inspected and if no air leaks are found, no exterior treatment of the crossover duct is done.
- Level 2 - Ducts sealed from the interior (boots, registers, end caps). Plenum is sealed. Cross-over duct is inspected and if determined to still be in good condition but air leaks are identified at the crossover duct connections to the collars, the collar connections to the main duct runs, or there are air leaks in the crossover duct that are repairable. The identified air leaks are sealed with mastic and/or repairs are made to crossover duct as required.
- Level 3 – Ducts are sealed from the interior (boots, registers, end caps). Cross-over duct is inspected and if found to be disconnected and in good condition, the crossover will be reconnected and all connections shall be sealed with mastic If the cross-over is damaged and in need of replacement, a new R-8 crossover duct shall be installed, and crossover duct connections sealed with mastic.

4.2 Data Sources

Puget Sound Energy (PSE) provided DNV GL with four different data types – participant tracking information, monthly billing usage, daily billing usage, and weather data. We discuss each of these four data types briefly in the following paragraphs.

4.2.1 Tracking Data

Puget Sound Energy provided DNV GL with customer participation information for the MHDS program from January 2010 to October 2014. The tracking dataset included both measure and premise specific information such as program type, measure name, measure costs, savings, installation date, premise address, and zip code.

DNV GL only received electricity consumption information – from monthly billing and daily usage - for participants installing duct sealing measures on 2012-2014. As a result, the impact evaluation will focus on estimating 2012 and 2013 participant energy savings utilizing duct sealing and usage information of customers installing efficiency measures in 2012 – 2014. We discuss the billing data in detail in next section.

4.2.2 Additional Participant Data

Additional analysis was performed on participant data provided by PSE later in the evaluation process. These data included general site information such as square-footage, year built and number of

[14] Attachment C to the 2012-2013 contract between PSE and UCONS.

occupants as well as duct-related characteristics such as number of endcaps, presence of crossover, etc. More fields capturing the condition of many aspects of the home such as insulation, vapor barrier, etc. were not apparently available for much of 2012 and 2013. They were analysed with the intent of better understand the impact evaluation outcomes.

4.2.3 Monthly and Daily Billing Data

DNV GL used both monthly billing cycle and daily data to obtain participants' electricity consumption information. Monthly billing data were available for the target program participants (2012 and 2013 duct sealing installers) from January 2010 to August 2014. However, a significant number of participants' billing records were not provided for the time period after the change in PSE's data management system in March 2013.

The analysis team used monthly billing data for years 2011 and 2012. Then, we leveraged daily PSE consumption data of 2013 and 2014 to create monthly consumption for years 2013 and 2014 of MHDS participants. We also compared daily-aggregated monthly usage with monthly billing information for participants that had billing data for 2013 and 2014. We found that the monthly usages from both sources were comparable and thus utilized daily-aggregated billing for 2013 and 2014. The use of daily data substantially increased the number of MHDS participants that could be used for the impact evaluation, especially for estimating 2013 energy savings.[15]

4.2.4 Weather Data

PSE provided hourly weather data from January 2005 to December 2014 for nine weather stations and a weather station lookup file that contains a list of zip codes covered by each station. These data were matched to each site, by zip code, for the site-level modelling. For the purpose of normalizing the results, DNV GL produced a file of ten-year average annual degree days at the range of degree day bases found in the site-level modelling. The purpose of using TMY or normal weather data is to estimate program savings under typical conditions, or the most likely conditions to occur in upcoming years. The TMY and normal datasets that are available from the National Renewable Energy Laboratory (NREL) or the National Oceanic and Atmospheric Administration (NOAA) use longer data series that can get out of date. When ten years of local data are available, then constructing a typical whether data set of degree days is the best approach.[16]

4.3 Data Summary

4.3.1 Data Disposition

DNV GL carefully examined the tracking, billing, and weather datasets before using it for evaluation. Specifically, we looked for missing data, discontinuity, duplicates, zero usage, negative usage, potential outliers, and premises with multi-meters. After the quality check of the data, we included only premises meeting the following criteria.

- Premises should have billing data for at least 11 months in the pre- and post-installation periods.
- Premises with only positive reads, non-zero usage.

[15] DNV GL received daily data for 2013 and 2014 that facilitated this supplementation of the monthly billing data MHDS participants. A full history of daily data facilitating an evaluation at a higher level of resolution was not available.

[16] Specifically, using the average degree days over the time period, as opposed to averaging the temperatures first, is the best way to capture the natural variability in the weather data while producing a "typical" weather scenario with which to normalize.

- Premises with only one meter.
- Premises with site-level model results with an R-square of greater than 0.6.

These criteria, in combination will tend to remove households with extended vacancies. The minimum of almost two years of data under a single account number will remove vacancies related to change in occupancy. In addition, limiting the set to non-zero usage means that homes that have been completely shut down for just one bill period, would also be removed. Finally, remaining extended vacancy households could fail the R-squared requirement if the model was trying to characterize consumption over periods of occupancy and non-occupancy with a single model. These criteria help to remove pre-post changes that reflect changes in occupancy in addition to changes in duct sealing. Otherwise, households that are low consumption through the evaluation period, perhaps because of limited occupancy, are appropriate to include in the analysis.

Moreover, we exclude billing information of the month during which duct sealing installation took place.

Table 4 and Table 5 provide the number of unique premises that appear in each criterion and also contain the final count of premises used in the evaluation analysis. In Table 4, we present participation group premises, whereas Table 5 includes premises used in the comparison group. The comparison group consists of future installers of duct sealing measures, 2013 installers form comparison group for 2012 participants and the comparison group for 2013 participants consists of 2014 installers.

Table 4: Data Disposition Table of Participation group for MHDS Impact Evaluation

Description/ Year	Participation - 2012	Participation - 2013	Total
Initial Unique Premises	4,731	5,581	10,312
Premises without Billing data	447	771	1,218
Premises without 11 months of billing data from Pre- or Post-Install month	2,220	1,841	4,061
Premises with negative usage for any month	15	28	43
Premises with zero usage	40	45	85
Premises with multiple meters	205	24	229
Premises with PRISM adjusted R square less than 0.6	167	199	366
Premises used for Billing Analysis	1,653	2,449	4,102

The initial tracking data set included information of 10,312 unique premises in the participation group. First, we checked if the duct sealing participants had billing information. We found that 1,218 participants did not have usage information. For duct sealing participants with billing data, DNV GL checked if the premises have consumption information for at least eleven months in the pre- and post-installation periods. We found that 2,220 premises among 2012 installers and 1,841 of 2013 installers had less than eleven months of billing data in either pre- or post-installation periods. We did not consider these premises in the impact evaluation.

Moreover, we excluded premises with negative and zero values for the usage. Negative bill reads frequently indicate a bill correction which could make the data unsuitable for analysis. There were 15

premises with at least one negative usage among 2012 installers and 28 premises among 2013 participants. Similarly, there were total of 85 premises with at least one zero electricity usage.

We checked premises with multiple meters. Premises with multiple meters may have received duct sealing measure corresponding to one of their meter locations. Since there is no way to identify the meter corresponding to duct sealing installation, including billing information of both meters would undermine the impact of the program. In particular, we dropped 229 premises from participation group that have multiple meters.

Finally, after running the site-level models, we remove households with model R-square of less than 0.6. This is a standard cut-off for site-level models and removes households with highly variable data that is poorly characterized by the site-level models.[17] 356 premises failed this criterion.

Table 5 provides the exclusion criteria for comparison group premises. As discussed in section 3.1.1, the comparison premises participated in the following year. The initial tracking dataset consisted of 8,163 unique premises to be used in the comparison group. We dropped 901 premises that are missing billing information. Similarly, 3,046 premises do not have complete billing dataset for 11 months of pre- and post-installation periods. Moreover, we also exclude 28 premises with negative usage information, 76 premises that have at least one month with zero usage, 35 premises with multiple meters and 356 premises with R-square less than 0.6.

Table 5: Data Disposition Table of Comparison group for MHDS Impact Evaluation

Description/ Year	Comparison - 2012	Comparison - 2013	Total
Initial Unique Premises	5,581	2,582	8,163
Premises without Billing data	771	130	901
Premises without 11 months of billing data from Pre- or Post-Install month	2,454	592	3,046
Premises with negative usage for any month	28	0	28
Premises with zero usage	35	41	76
Premises with multiple meters	22	13	35
Premises with PRISM adjusted R-square less than 0.6	158	198	356
Premises used for Billing Analysis	2,127	1,604	3,731

As a result, the final impact evaluation dataset consists of 4,102 premises in participation group and 3,731 premises in comparison group. Among premises in the participation group, 1,653 installed duct sealing in 2012 whereas 2,449 are 2013 installers. Among comparison group premises, 2,127 belong to 2013 participants and 1,604 installed duct sealing measures in 2014. Next, we present distribution of premises by efficiency measure combinations, duct sealing levels, and installation months.

[17] PRISM (Advanced Version 1.0) User's Guide. Fels, Margaret F. et al. Center for Energy and Environmental Studies, Princeton University. January 1995.

The attrition rate for this evaluation is high but common for this kind of program. The manufactured home population generally has higher mobility leading to the limited number of sites that had effectively two full years of data with the same occupant in place. The other issues that caused sites to drop from the analysis were also typical of other billing analysis evaluations. It is believed that the remaining households are suitably representative of the MHDS program population for the purpose of this evaluation. The following section shows that the data removals are general proportional across the important characteristics for the MHDS program.

4.3.2 Summary of MHDS measures

DNV GL created three measure groups – duct sealing, lighting, and showerhead - based on the detailed measure type information included in the tracking dataset. Even though the primary treatment of the project is duct sealing, the majority of participants also received other energy efficiency measures such as lighting and showerhead. Among premises in the tracking dataset, we found that few premises did not receive any duct sealing measures. These customers only received lighting measure or showerhead direct installs or both measures. Table 6 provides the number of premises receiving unique combinations of different efficiency measures. The table is further divided by participation and comparison groups of 2012 and 2013. The comparison group measures would not have been installed until after the evaluation period (in 2014). They are included here to demonstrate the similarity between the characteristics of treatment and comparison groups.

Table 6: Measure Group Combinations Using Initial and Final Tracking Data

Measure Group Combination/Installation Year	Initial		Final	
	N	% of total	N	% of total
2012 Participation Group				
Duct Sealing	350	7.4%	156	9.4%
Duct Sealing, Lighting	1,021	21.6%	419	25.3%
Duct Sealing, Showerhead	414	8.8%	144	8.7%
Duct Sealing, Lighting, Showerhead	2,484	52.5%	926	55.9%
No Duct Sealing	462	9.8%	11	0.7%
2013 Participation Group				
Duct Sealing	232	4.2%	109	4.5%
Duct Sealing, Lighting	767	13.7%	408	16.7%
Duct Sealing, Showerhead	403	7.2%	189	7.7%
Duct Sealing, Lighting, Showerhead	3,796	68.0%	1,743	71.2%
No Duct Sealing	383	6.9%	0	0.0%
2012 Comparison Group				
Duct Sealing	232	4.2%	94	4.4%
Duct Sealing, Lighting	767	13.7%	347	16.3%
Duct Sealing, Showerhead	403	7.2%	161	7.6%
Duct Sealing, Lighting, Showerhead	3,796	68.0%	1,466	68.8%
No Duct Sealing	383	6.9%	64	3.0%
2013 Comparison Group				
Duct Sealing	9	0.3%	8	0.5%
Duct Sealing, Lighting	889	34.4%	567	35.3%
Duct Sealing, Showerhead	7	0.3%	3	0.2%
Duct Sealing, Lighting, Showerhead	1,653	64.0%	1,011	63.0%
No Duct Sealing	24	0.9%	15	0.9%

The table includes unique premises in both initial tracking data provided and the final count used for impact evaluation. We include proportions for both the initial and final datasets to facilitate two comparisons: 1) Initial vs. Final for each year and group and 2) by installation year across treatment and comparison groups. The former comparison, initial vs. final, is important to assure the subset of data on which we will perform the analysis is representative of the full population. The latter is important to show that the comparison group is similar to the treatment group despite participating in subsequent years.

The majority of participants for both 2012 and 2013 received the lighting and showerhead direct installs in addition to the duct sealing measures. Within each year, the proportion of premises installing each efficiency combination between initial tracking and final sample differs by less than three percent. Across the program years, there is more change. In the final sample of participation group of 2012, 55.9% out of total participants obtained all three efficiency measures. This number increased to 71.2% in the 2013 participation group. The higher proportion of participants receiving all three measures in 2013 reflects a greater focus on the direct install program component with 2013 participants. This likely reflects changes in the program delivery rather than a change in the make-up of the participant pool.

Table 6 also includes the distribution of comparison group's premises by combination of different energy efficiency measures. Among the comparison group for 2012 participants, 68.8% received all three efficiency measures. Similarly, the share of premises receiving all three measures in 2014, which form comparison group for 2013 participants, is 63.0%. The comparison groups are reasonably similar to the treatment groups with respect to measure distribution. Measure mix is primarily important as a home characteristic. As stated previously, these changes are more likely to reflect a shift in program emphasis than a change in home characteristics.

The tracking data also have information on the levels of duct sealing. Participants received three different levels of duct sealing measures. Levels were defined in section 4.1. Table 7 includes distributions by duct sealing levels of participation and comparison groups for both initial and final tracking data. The distribution of participants across different duct sealing levels between the initial and final tracking dataset is similar. Comparing the proportions of the levels across the years, there is a slight change for participants from 2012 participants to 2013 participants. Level 2 remains the most common level, but level 3 installations increased in 2013, primarily pulling from the level 1 proportion. The changes for the comparison group are more dramatic. The 2013 comparison group, effectively 2014 participants, shows a dramatic decrease in level 2 installations with increases in the other two levels taking up the slack. In particular, the level 3 installation were almost half of the installations in the 2013. These differences were a primary motivation for developing the model specification that directly compared level and in- or out-of-park homes to homes of similar characteristics. While there are fewer of the level 2 homes in the 2013 comparison group, they are both combined with the 2012 level 2 comparison group and provide a comparison for just the participant level 2 homes.

Table 7: Duct Sealing Levels in Initial and Final Tracking data

Measure Combination/ Installation Year	Initial		Final	
	N	% of total	N	% of total
2012 Participation Group				
Level 1	1,608	37.6%	627	38.1%
Level 2	1,873	43.8%	709	43.1%
Level 3	793	18.6%	309	18.8%
2013 Participation Group				
Level 1	1,534	29.5%	735	30.0%
Level 2	2,385	45.9%	1,105	45.1%
Level 3	1,279	24.6%	609	24.9%
2012 Comparison Group				
Level 1	1,534	29.5%	590	28.5%
Level 2	2,385	45.9%	962	46.5%
Level 3	1,279	24.6%	516	25.0%
2013 Comparison Group				
Level 1	903	36.8%	595	37.4%
Level 2	324	13.2%	223	14.0%
Level 3	1,225	50.0%	771	48.5%

Table 8 provides counts of duct-sealing premises by their in-park/out-park locations.[18] We also separate the distribution by participation and comparison groups. In-park duct sealing installation represents more than two-thirds of total premises for participation group of both 2012 and 2013. The comparison group of 2012 participants also have 72.6% of in-park premises in its final sample. Of premises that installed duct sealing in 2014, the comparison group for 2013 participants, the majority are located out-of-park. The in-park premises comprise only 31.3% of the final sample of 2013 participants' comparison group. This clearly shows that the program targeted duct sealing installation to out-of-park customers for 2014.

Table 8: Premise location (in-park/out-park) in Initial and Final Tracking data

Duct Sealing levels/Year	Initial		Final	
	N	% of total	N	% of total
2012 Participation Group				
In-Park	3,475	73.5%	1,036	62.7%
Out-Park	1,256	26.5%	617	37.3%
2013 Participation Group				
In-Park	3,999	71.6%	1,750	71.5%
Out-Park	1,584	28.4%	699	28.5%
2012 Comparison Group				
In-Park	3,999	71.6%	1,544	72.6%
Out-Park	1,584	28.4%	583	27.4%
2013 Comparison Group				
In-Park	750	29.0%	502	31.3%
Out-Park	1,832	71.0%	1,102	68.7%

4.3.3 Additional Participant Data

Additional participant data were provided by PSE later in the evaluation process.

[18] If in-park/out-park information was not provided in the tracking dataset, we assumed such premises to be in-park.

Table 99 provides a list of the fields that had reasonably complete data for the 2012 and 2013 program years. These data increased our understanding of the homes and occupants as well as certain aspects of ductwork. More fields capturing the condition of many aspects of the home such as insulation, vapour barrier, etc. were not apparently available for much of 2012 and 2013.

Table 9 Additional Participant Data Available for 2012 and 2013 Participants

Data Fields
Home Location
sqft
Year Built
Home Width
year round occupants
treatment history
Previously Treated
PSE Fuel Type
furnace type
Register
End Caps
Plenum Sealed
Crossover
Elbow
Job Type
WaterHeatType
SH GPM

We examined each of these data fields to determine if the results summarized by Level and location correlated with the reported impact results. In particular, we hoped to find some explanation for the relative low savings of Level 2 homes both in- and out-of-park. No apparent relationship was found between any of these single fields and the disparate impact results. While, it is possible that some combination of available characteristics could provide insight into the results, further analytical work on these data was out of the project scope. It is more likely that it could have been derived if the remaining fields with condition data had been available for all 2012 and 2013 participants had included complete data.

5 BILLING ANALYSIS RESULTS

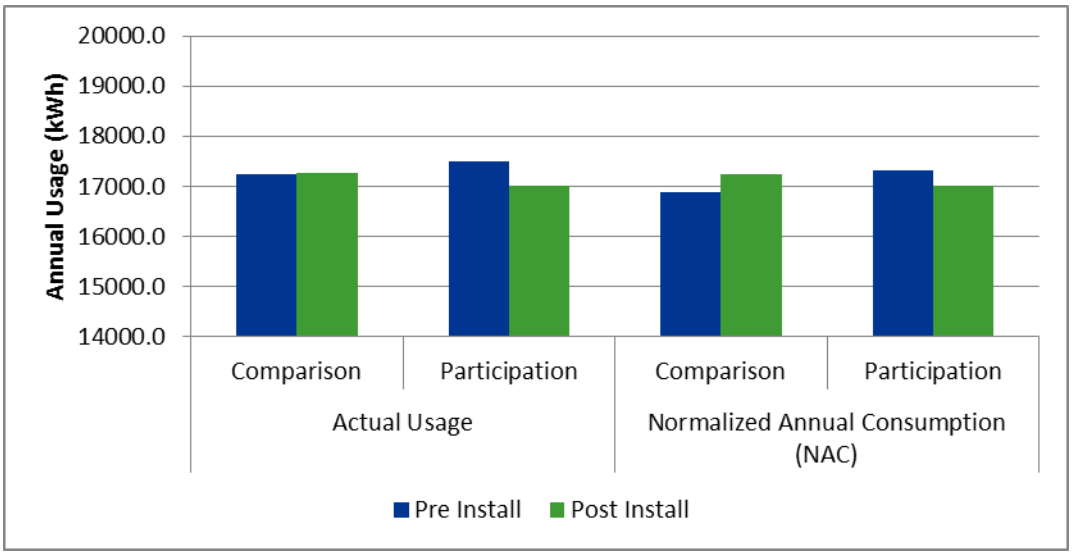
This section presents the results of the impact analysis of the MHDS program on electricity consumption. We first provide a comparison of average electric consumption – both actual and weather-normalized – for all population and sub-groups depending on duct sealing installation types. Then, we discuss program savings estimated from the difference-in-differences approach (see Equation 3 in Appendix).

5.1 Comparison of Usage

5.1.1 Actual Usage vs Normalized Annual Consumption

Figure 1 shows average annual actual and normalized consumption of MHDS participants and comparison groups during pre- and post-installation periods. This figure provides the components of the difference in differences calculation that is used to estimate savings. The pre- to post-installation difference of the participants captures consumption change between the pre- and post-periods. This change includes the savings effect of the program as well as any other non-program related changes in consumption that may have occurred between the periods. In both the actual and normalized cases, there was a clear reduction in consumption from the pre- to post-install periods.

Figure 1: Average Actual and Normalized Annual Electric Consumption



The comparison group did not receive any program measures during the pre- to post-install period. The pre-post consumption difference for the comparison group captures just the non-program related change. The comparison group's actual consumption did not change. The comparison group weather-normalized consumption showed a slight increase in consumption

The comparison group pre-post difference acts as a proxy for the non-program related change that is part of the participant difference. Taking the difference of the treatment and control pre-post differences provides an estimate for program related change free of non-program related change.

In this case, while the weather normalization changes the plots slightly, the effect on savings is small. Both participant and comparison group per-period consumption levels drop slightly indicating that the weather in the pre-install period was slightly colder than the typical weather over the last ten years. The actual weather savings are clearly captured in the participant pre-post difference. The weather-

normalized savings are the combination of the increased comparison group consumption and the smaller participant group decrease.

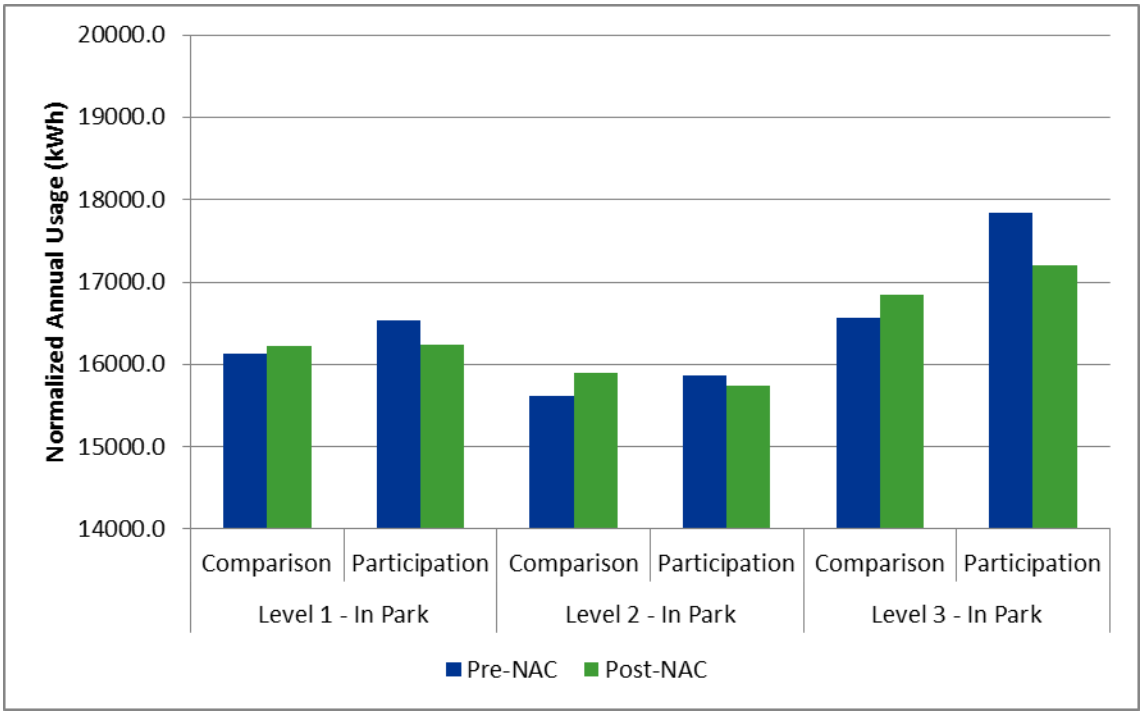
The ideal comparison group is identical to the participant group in the pre-installation period. This figure shows that, with respect to energy consumption, the comparison group consumption level is approximately two percent smaller than the treatment group consumption level. The difference in difference calculation controls for this difference and this is why this approach is used for these kinds of evaluation.

5.1.2 Normalized Annual Usage by Duct Sealing types

DNV GL looked at pre and post normalized annual consumption by combination of different duct sealing types and premise locations. The goal is to differentiate the impact of duct sealing characteristics on energy savings. The three duct sealing levels and in/out-park location of premises result into six different customer combinations.[19]

Figure 2 compares the average annual normalized consumption of in-park premises by duct sealing levels during pre- and post-periods for both participant and comparison groups. In-park premises installing Level 3 duct sealing have the highest weather-normalized energy usage as compared with other in-park level groups. Level 2 premises have lower consumption than level 1 premises.

Figure 2: Normalized Annual Consumption by Duct Sealing Levels for In-Park Premises



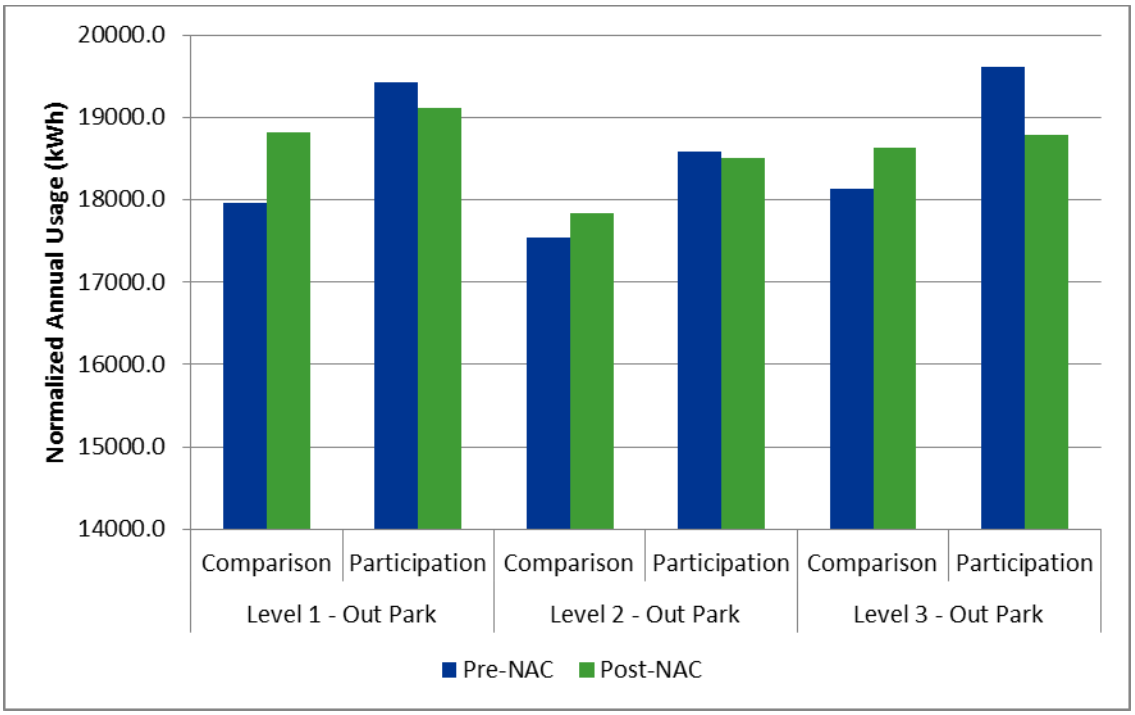
The three levels of duct sealing in Figure 2 show the same pattern as the overall weather normalized results in Figure 1. The general trend in consumption for non-participants was a slight increase in

[19] In/out-park information was not provided for all duct sealing installations. If this information was missing in the tracking dataset we set the premise to be in-park.

consumption. Participants in all three levels not only avoided this slight increase but reduced consumption as well.

Figure 3 shows the normalized annual consumption by duct sealing levels for out-of-park premises during the pre- and post-installation periods. The trends between pre/post average usage of both comparison and participation groups are similar to Figure 2. The comparison group's consumption increases from the pre-installation period to the post-installation period for all three out-of-park duct sealing levels. All three participant groups show reduction in post-installation usage as compared with their pre-installation electricity consumption.

Figure 3: Normalized Annual Consumption by Duct Sealing Levels for Out-of-Park Premises



In all three customer groups, the pre-period comparison group consumption is lower than the participant group consumption. The level 3, out-of-park difference is the largest difference of the six groups but remains under 10%. As discussed in section 3.1.1, by constructing the comparison group with future program participants, we put a priority on using premises that were all manufactured homes in need of a duct sealing program. This approach hypothesizes that the year over year change in consumption for these customers, who are similar across a number of key characteristics, is the best proxy for the participant non-program year over year change. We believe this to be the case despite the differences in pre-period consumption.

5.2 Consumption Analysis

The consumption analysis combines the estimates of pre-post change between participant and comparison groups of both years in a regression framework. The results are estimates of the average impact of MHDS program in energy savings for the six measure and location subgroups. Table 10 presents the average annual savings for each measure group along with the 90% confidence interval lower and upper limits. These savings estimates include all lighting and showerhead savings. The

process evaluation indicates a low likelihood of states indication of free ridership, so these results are both gross and net savings estimates.

Table 10: MHDS Program Savings per Household, by Measure Group

Customer Groups/ Impact (kWh/year)	Average Participant Savings (kWh)	Standard Error (kWh)	90% Lower Limit (kWh)	90% Upper Limit (kWh)	Part-icipants (N)	Comp-arison (N)
Duct Sealing Level 1- In-Park	388.6**	178.7	94.6	682.6	1,031	706
Duct Sealing Level 1- Out-Park	1,175.2***	261.5	745.0	1,605.4	331	479
Duct Sealing Level 2- In-Park	404.5**	167.7	128.7	680.3	1,217	782
Duct Sealing Level 2- Out-Park	358.1	234.7	-27.9	744.1	606	406
Duct Sealing Level 3- In-Park	930.1***	228.4	554.3	1,305.8	540	489
Duct Sealing Level 3- Out-Park	1,316.6***	226.9	943.3	1,689.8	385	801

*Note: The asterisk symbol (*) represent statistical significance level: * p<0.1, **p<0.05, ***p<0.01*

The group level savings are statistically significant for all groups except for Level 2 – out-of-park. There is a general increase in savings from Level 1 to Level 3 and from in-park to out-of-park. This is consistent with the increase level of both service and general premise size moving up in level and to out-of-park. For Levels 1 and 3, the out-of-park premises show increased savings – for Level 1 almost three times as much and for Level 3, 40% more.

With respect to the savings trends, Level 2 is an anomaly in both respects. The increase in savings from Level 1 to 2 is negligible for in-park and the savings from Level 2 out-of-park is lower than Level 2 in-park and dramatically lower than Level 1 out-of-park premises.

Table 11 combines the savings estimates with annual consumption to get percentage savings. The baseline consumption is average weather-normalized consumption of the participant group during pre-installation period.[20]

Table 11: MHDS Program Savings as Percentage of Consumption, by Measure Group

Customer Groups/ Percent Savings	Average Participant Savings (kWh)	Baseline Consumption (kWh)	% Savings
Duct Sealing Level 1- In-Park	388.6	16,533.2	2.4%
Duct Sealing Level 1- Out-Park	1,175.2	19,421.5	6.1%
Duct Sealing Level 2- In-Park	404.5	15,871.7	2.5%
Duct Sealing Level 2- Out-Park	358.1	18,580.4	1.9%
Duct Sealing Level 3- In-Park	930.1	17,842.7	5.2%
Duct Sealing Level 3- Out-Park	1,316.6	19,613.0	6.7%

[20] With an ideally matched comparison group, one would use the comparison group post-period consumption in the denominator. In this case, doing this would slightly inflate the percentage savings, so we used the participant group pre-period consumption.

With regards to savings magnitude, the Level 1 and Level 3 Premises were similar with Level 1 sites slightly smaller for In-park premises and slightly larger for out-of-park Premises. The substantial savings appear to come from Level 1 out-of-park Premises and both in- and out-of-park Level 3 premises. Level 1 and 2 In-park premise savings, both statistically significant are substantially more modest both with respect to magnitude and percentage of total consumption.

Table 12 applies the estimated savings to the tracking data populations from the 2012 and 2013 based on the numbers of participants within each subgroup. Total subgroup savings are provided along with the total savings from the tracking data and a realization rate.

These tracked savings include deemed savings for the duct sealing measures, lights and showerhead installed so they cover the same measure savings as the evaluated savings. On average, the deemed savings were 169 kWh for lighting (just over seven CFL bulbs per home) and 259 kWh for showerheads (a showerhead in approximately 85% of homes).

Table 12 MHDS Program Savings for 2012 and 2013 with Realization Rate

Customer Groups/ Percent Savings	Average Participants' Savings (kWh)	Total Participants: 2012 & 2013	Total Estimated Savings (kWh)	Total Tracked Savings (kWh)	Realization Rate
Duct Sealing Level 1- In-Park	388.6	2,433	945,550	2,202,349	42.9%
Duct Sealing Level 1- Out Park	1,175.2	674	792,084	719,609	110.1%
Duct Sealing Level 2- In-Park	404.5	2,961	1,197,713	3,346,482	35.8%
Duct Sealing Level 2- Out Park	358.1	1,305	467,359	1,781,328	26.2%
Duct Sealing Level 3- In-Park	930.1	1,233	1,146,756	1,730,396	66.3%
Duct Sealing Level 3- Out Park	1,316.6	861	1,133,580	1,389,716	81.6%
Total		9,467	5,683,042	11,169,880	50.9%

The overall realization rate is about 51% with subgroup realization rates ranging from 26% to 110%.

5.3 Evaluated Savings vs Tracked Savings

Table 13 compares the evaluated savings to the MHDS tracked saving for these subgroups during the 2012 and 2013 program years. The evaluated savings include duct sealing and the direct install savings. The deemed savings for the duct sealing measures were fixed while the number of lights and showerheads varied from home to home. The lighting and showerhead savings reported here are the subgroup average claimed savings in each category. The evaluated saving should be compared to the total claimed savings.

The evaluated savings for Levels 1 and 3 out-of-park homes are not statistically different than the total savings claims for that subgroup. The remainder of subgroup evaluated savings are all well below the claimed savings levels.

Table 13: Evaluated Savings Compared to Claimed Savings

Measure/Location	Evaluated Savings		Deemed Savings			
	Savings (kWh)	+/- (kWh)	Duct Sealing	Lights	shower-heads	Total
Duct Sealing Level 1- In-Park	403	315	600	127	211	937
Duct Sealing Level 1- Out Park	1,190	447	600	202	267	1,069
Duct Sealing Level 2- In-Park	419	300	800	150	233	1,183
Duct Sealing Level 2- Out Park	377	413	800	240	326	1,366
Duct Sealing Level 3- In-Park	947	399	1,000	154	271	1,426
Duct Sealing Level 3- Out Park	1,337	406	1,000	243	362	1,605

In 2014, the year after the focus of this impact evaluation (but the focus of the process evaluation) PSE changed the deemed savings levels. The 2014 deemed savings were increased based on a separate impact evaluation completed in 2013 by a third party evaluator for the program implementer. Across the board, those results were two to three times larger than estimated savings for this evaluation. Similar to the present results, those results also show a distinct pattern across the subgroups with all Level 3 homes and Level 1 out-of-park homes showing substantially higher savings. The 2014 deemed savings increased out-of-park savings compared to in-park and increased all magnitudes, with Level 3 out-of-park increased by 150%. The present evaluation savings estimates are inconsistent with the 2014 deemed savings values.

5.4 Discussion

The savings results reported here are lower than the deemed savings for all but one level and in- or out-of-park subgroup. Moreover, the deemed savings have subsequently increased making the contrast even more dramatic. This section explores some of the possible explanations for the low savings results.

5.4.1 Savings Estimation Process

A substantial amount of good data was available for this evaluation and the constructed quasi-experimental approach is more robust than many billing analyses. The comparison group constructed from subsequent participants captures the key observable and unobservable characteristics of the target population. The comparison group is a good proxy for the participant group in most ways. Where there are apparent differences of less than 10% in the pre-period consumption levels, the difference in difference methodology controls for those effects. There are no obvious limitations to the savings estimation process that explain the lower than expected savings.

5.4.2 Possible explanations

Possible explanations for lower savings are discussed below.

- **Savings assumptions.** Deemed savings values assume electric heating as the primary fuel, and that it is used throughout the heating seasons. The process evaluation found more than a few participants who used their electric heat sparingly or had alternative primary heating system.

- **Broken heating or other equipment.** Two respondents reported that their heating equipment broke after the treatment (unrelated to participation). The nature of the problem would increase heating bills.
- **Limited duct leakage.** It could be possible that in some homes the extent of duct leakage is just not enough to generate the expected savings when sealed. Level 2 homes are supposed to be similar to level 3 homes (double-wide), but do not need a full replacement of the crossover portion of the duct that carries heat to the other side of the home. The substantial increase in savings from Level 2 to 3 indicates that major fixes like replacement of the crossover may drive substantial savings.

6 PROCESS EVALUATION

6.1 Program Description[21]

In 2014 PSE offered the MHDS program to customers living in manufactured homes with electricity as their primary heating source. (In earlier years the program was also offered to natural gas heating customers in manufactured homes.) Participants were provided up to 5 LED lights, 2 showerheads, furnace filters and duct sealing. Duct sealing is provided at three levels depending upon the duct sealing needs and accessibility.

The program provides duct sealing at three levels, depending upon need and accessibility. The 2014-2015 specifications for the three levels are:[22]

> **Level one:** Single-wide homes -ducts are sealed from the interior. Plenum is not treated because it is inaccessible, or the home passes the total duct leakage test (< 130 cfm at 25 Pa). For double-wide, ducts are sealed from interior. No exterior treatment of crossover due to inaccessibility, insulation of R-4 or more, or hard crossover.
>
> **Level two:** Single-wide – Ducts are sealed from the interior. Total duct leakage post-test < 130 cfm at 25 Pa and leakage reduction > 100 cfm at 25 Pa.
>
> Double-wide: Ducts are sealed from interior. Rigid crossover duct or V-box determined to be in good condition, but cannot be dropped. Rigid crossover or B-box sealed from exterior. Plenum not accessed.
>
> **Level three:** Single-wide – Ducts are sealed from the interior. Plenum sealed. Crossover ducts (if existing) are repaired or replaced.
>
> **Double-**wide - Ducts are sealed from interior. Plenum is sealed and/or crossover ducts are repaired or replaced.

PSE has contracted with UCONS since 2010 to deliver the program. UCONS is an independent implementation firm based in Washington that delivers similar programs in other utility service territories. UCONS handles all aspects of the program with internal staff – from marketing through installation and participant surveys. (See Figure 4 for the overall program delivery process.) They are also responsible for verification and quality control of project installations, which they sub-contract to Efficiency Services Group (ESG).

UCONS current contract and goals are for the 2014 – 2015 calendar years. In 2014 the program claimed meeting 79 percent of the two-year claimed kWh goal and 57 percent of the treated homes goals. This was accomplished spending 59 percent of the budget (See Table 14 below). This indicates that costs per treated home are consistent with the budget, while reported savings per home are higher than planned.

[21] This description is based on interviews with program staff and participants, materials review and the Statement of Work for the UCONS MHDS Renewal Program 2014-2015.

[22] Field Specification Manual attached to 2014-2015 PSE contract with UCONS.

Table 14 MHDS 2014-2015 Goals and Budget Relative to Claimed

Item	Goal/Budget	Reported (thru 12/31, 2014)	% of goal/budget
kWh(2014 values)	8,300,000	6,540,835	79%
Budget	$ 2,770,000	1,635,372	59%
Homes	6,000	3,411	57%
Out-of-park	60%	68 %	114%

* Reported kWh savings claimed includes 330 homes completed in December, 2013.

Expenditures do not include costs for these 330 homes.

In 2014 the program used higher claimed duct saving values than in prior years.[23] The greater apparent efficiency with which the program achieved savings appears to be primarily due to this increase in savings values, not in savings. Table 15 below shows 2014 program savings using three values for estimating savings. The first value is the 2014 claimed savings shown above. The second uses 2012-2013 claimed duct sealing savings, and the third uses the average per home savings estimated in this evaluation.

Table 15 2014 kWh Savings Using Claimed and Evaluated Values

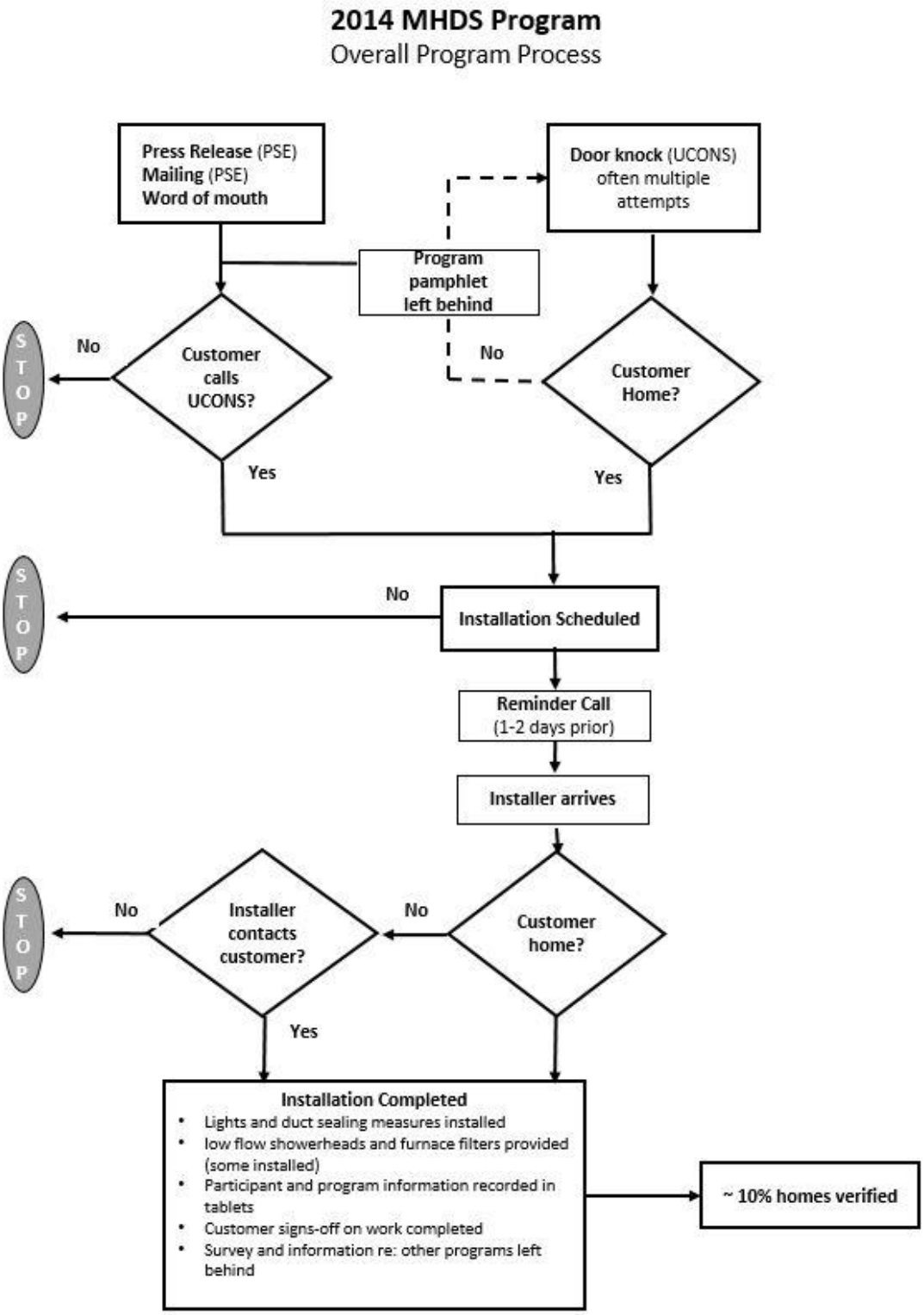
Savings Values Used	kWh Savings			
	Duct Sealing	Lights[1]	Shower-heads[2]	Total
2014 Claimed	5,195,600	346,564	998,671	6,540,835
2012-2013 Claimed	4,143,635	346,564	997,671	4,143,635
2012-2013 Evaluated				3,331,580

1 Both rows use 2014-2015 claimed savings for LEDs.

2 Claimed savings for showerheads did not change.

[23] From "f_Savings_MHDS_2014.xls" provided by MHDS Project Manager

Figure 4 Overall MHDS Program Process



6.1.1 Marketing

Marketing findings are based on PSE and UCONS staff interviews and a review of marketing material provided by PSE.

PSE and UCONS share marketing responsibilities, with UCONS leading all marketing efforts. PSE and UCONS share responsibility for marketing, and have different roles that are clearly delineated in the Scope of Work.[24] UCON is responsible for managing all marketing efforts, providing marketing materials, and for delivery of the marketing. Door knocking is a primary mode of getting program participation. By working with park managers and associations, UCONS obtains access to mobile home parks to promote the program through meetings and door knocking. Where no one answers the door, UCONS personnel leave pamphlets in a protected spot, if available. This one-page program description includes a toll free number to call UCONS and schedule an appointment.

PSE supports UCONS marketing efforts through periodic press releases, public service announcements, and program information on the PSE website. In 2014 PSE sent direct mailings (postcards) to customers to reduce program costs. (UCONS mailed them in previous years.) UCONS provides PSE with direction on where and when to send the mailers.

The 2014-2015 program refocuses efforts to out-of-park manufactured housing. The 2014-2015 program is focusing more on out-of-park housing, with a contract goal of at least 60 percent of treated homes being out-of-park. UCONS reports (in the scope of work attached to the contract) that the majority of remaining market potential is out-of-park. A staff person said that penetration was at about 75% for manufactured homes in parks. [25] Out-of-park homes are more expensive to treat because they are not located in close proximity to each other. This requires more driving to knock on doors and for installations. The earlier impact evaluation, however, found greater savings in out-of-park homes.

Program marketing was adapted in 2014 to address the challenges of a more dispersed target population. Marketers and installers are in every county monthly, and they tend to have shorter stays in specific areas. In 2014, program marketing postcards were sent every other month.

Program marketing materials overstate the savings that most participants will realize. Both the postcard and the one-page program description (flyer) cite 30% savings: the postcard says "up to 30% on your heating bill;" the pamphlet "up to 30% on your energy bill." A September 3, 2014 press release says "typically reducing heating costs by 20 percent or more." These savings claims are substantially higher than what most participants will realize, and lead to some disappointment among participants.

Inconsistent language is used across program materials. The printed program marketing materials refer to a "free home energy upgrade." Press releases focus on "Free Duct Sealing," and the participant survey refers to "Manufactured Home Duct Sealing," the "Manufactured Home

[24] Attachment 1: Statement of Work for the UCONS MHDS Renewal Program 2014-2015, January 1, 2014 (provided by PSE)
[25] The evaluation team requested data from PSE to verify these claims, but did not receive the dat.

Conservation Program" and the participant having their "home weatherized." Consistent terminology across marketing materials, press releases, other program materials, and how program staff refer to the program may help increase awareness of the program.

6.1.2 Program Delivery

Program delivery findings are based on PSE and UCONS staff interviews as well as participant interviews performed for this evaluation.

UCONS staffs are seen as PSE representatives. PSE provides UCONS staff with security badges and identification as PSE service providers. There are magnets on their vehicles, and they are required to wear PSE branded clothing such as t-shirts, hats and jackets. This maximizes the PSE brand and may help customers feel comfortable about the program. All participants interviewed seemed aware that the program was provided by PSE. Many spoke as if they assumed that the installers worked directly for PSE.

The use of tablets to collect and verify information is new and efficient. 2014 was the first program year in which UCONS used tablets for marketing, installation and verification of MHDS homes. Marketers used tablets for tracking their activities, filling out eligibility forms, and scheduling installation appointments. The (office) scheduler downloads the appointments at least once daily, and fills any gaps in the schedule. The office scheduler calls customers to remind them of the appointment 1-2 days prior to the scheduled day.

Installers are paid by the job, **which likely motivates them to assure that jobs are completed.** The amounts differ by whether the home is in or out of a park, and the level of duct sealing. They receive their schedules each night, which will have 5-6 jobs for the next day. They generally call ahead as their day progresses, letting participants know when they will arrive, which is appreciated by the participants. Installers determine the level of duct sealing based upon what they find at the home.

A substantial portion of appointments result in "no-shows." Multiple UCONS staff members report that roughly one to two appointments per day per installer are not completed because the customers are not home. Staff report that senior citizens are the most reliable. It is unclear why so many appointments are missed. (The evaluation did not address this issue.) Installers are persistent when a customer is not home – one installer reported calling the home repeatedly, leaving a voice mail message, and returning later in the day, as well as leaving a note. This installer will try to fit these customers with missed appointments in at the end of the day if they are at work. Sometimes, when there is a missed appointment, the scheduler can fill the installers' gaps.

There is no verification of owner's permission to participate in the program. The program "requires" an owner's permission to participate in the program. There is no written form or other verification process to assure that this requirement is met.

6.1.3 Communication

Communication findings are based on PSE and UCONS staff interviews and a review of the 2014 complaint logs.

Communication within UCONS Communication among UCONS staff is frequent and regular. Management (Director, Marketing Manager and Field Supervisor) meet weekly on Mondays. They discuss the prior week, new developments, changes, goals for the month and staffing. Every day the achievements are tallied and staff are informed of the progress relative to goals. The field supervisor is in contact with the installers daily and receives inspection reports electronically when they are completed.

Communication between PSE and UCONS. The PSE Project Manager and UCONS have regular contact regarding the program. UCONS bills PSE monthly. The monthly invoice provides achievements for the month and program to-date, as well as expenditures. There are periodic check-ins between the UCONS PM and PSE PM on as needed basis, as well as ad hoc communications as needed. UCONS uploads program data to PSE monthly. These data include information on all participants, including the date they participated, what was installed, and the level of duct sealing.

Customer complaints are handled and resolved quickly. Both PSE and UCONS receive customer complaints related to the program. PSE has a system for tracking the complaints coming from both sources and notifying the appropriate people to resolve the issues. The log shows customer complaints ranging from missed appointments, problems participants associate with the program (that may be unrelated), and assorted other issues. Many issues are resolved the day of the complaint, either by scheduling an installation appointment or clearing up a misunderstanding. Others take a bit longer because an action at the customers' home is required. Of 32 tracked complaints in 2014, only two remain open. These are open because the customer has not responded to repeated calls from UCONS.

Participants also call to compliment the program. The program also maintains a "compliment log." The 2014 log includes 25 compliments, most of them praising specific UCONS staff members for things such as professionalism, knowledge and courtesy. Others express appreciation for the program in general, saying they could not have been able to afford what was provided.

6.1.4 Inspections

The Field Supervisor reports that 10 percent of the treated homes are randomly selected for verification. Most inspections are conducted by Efficiency Services Group, a subcontractor to UCONS. In addition, the UCONS Field Supervisor completes some inspections, and PSE staff shadow other inspections.

Efficiency Services Group currently completes approximately 20 inspections per month, which are handled by one inspector. The inspector drives up from the Portland area 1-2 times per month. For each visit he picks one of three areas served by PSE. He attempts to visit the northern most region every 3rd or 4th trip. Within each area he looks for concentrations of treated homes to reduce driving and to maximize verifications for each visit. The sampling approach he described is a type of "convenience sampling" in that the participants are selected for their proximity to each other, and that they were home and willing to participate when the inspector came by. It is uncertain how representative of the population of participants they are. With the increased focus on out-of-park homes, the homes are more dispersed.

Participants are *not* given advance notice of the inspection – he knocks on doors to get participation, attempting to complete eight verifications per day. (He had tried calling in advance but did not find

this productive.) About 50% of the household let him in. The inspector will also tag along on some installations (without advance notice) to see the work in progress

On-site, the inspector accesses the site-specific data collected by the installer, which he has uploaded to his tablet. He inspects all the work recorded by the installer for that house. This includes checking all registers, plenums and cross overs, as well as counting light bulbs, showerheads and filters. If a duct leakage test was performed, he repeats the test. (He cannot see the earlier test results to avoid those influencing him.)

Inspections are pass/fail. The program has specifications regarding what is required to pass inspection. For example, the installer can miss no more than two boot-to-floor connections and no more than two boots into vertical connections without failing. (This flexibility is included because some vents may be inaccessible due to locked rooms or heavy furniture.) According to the inspector, most home meet the passing criterion, and the inspector focuses on work quality. He reports being especially attentive to homes that have installations conducted by newer installers. It is unclear whether the PSE receives the data collected by the inspector.

6.2 UCONS Participant Surveys

UCONS' installers are instructed to provide participants with a survey that addresses program satisfaction and related issues. Participants fill out the survey and mail it back to UCONS in the envelope provided. UCONS staff enters survey responses into a PSE survey database. Approximately 6 percent of 2014 participants returned surveys[26]

The current internal survey approach fits efficiently into the current implementation process and likely results in cost savings relative to alternatives. Program implementers say that they use the surveys internally to assess the program and make modifications. The survey is 2 ½ pages (see Appendix) and addresses topics of interest to program implementers and evaluators.

Despite the apparent efficiency of this approach, there are other considerations that offset this benefit. It is unusual for program implementers to have *sole* responsibility for implementing customer satisfaction surveys. Given implementers' lack of independence, regardless of how well the survey is handled, others may suspect the findings. Additionally, survey research requires using scientific methods throughout the process to obtain valid responses, and to reduce measurement and sampling error. In subsection 6.2.2 we discuss limitations to the current customer satisfaction approach.

6.2.1 UCONS Survey Findings

In this subsection we report on the 2014 UCONS participant survey findings. Except where noted, the findings are supported and elaborated on in the participant interviews completed for this evaluation.

Very high program satisfaction. The respondents indicate very high levels of satisfaction, with 94% of respondents indicated that they are "very satisfied" with the "weatherization and energy efficiency improvements" and are "very likely" to recommend the program to friends, neighbors, or family.

[26] Based on households treated through November 30 and surveys entered through December 17, 2014.

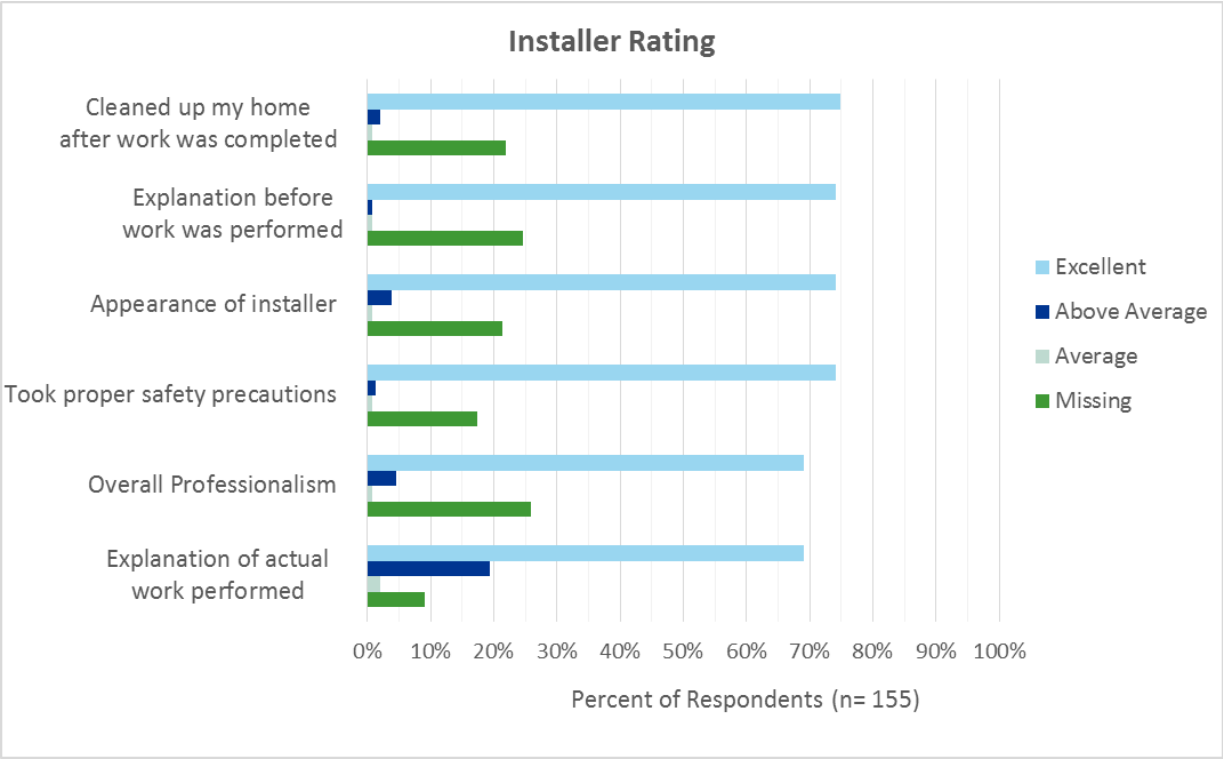
Most participants learned of the program from UCONS marketers. The UCONS survey indicated a great majority (95%) of survey respondents report learning about the program from a marketer showing up at their door. This is in contrast to the responses collected from out-of-park interview respondents for this evaluation. They indicated that they had heard about the program by referral or a mailing.

Scheduling an appointment was easy. Since most respondents learned of the program from marketers, the marketers scheduled their appointments. Very few had to reschedule and 95 percent of the respondents reported that scheduling was "very easy." Few had to reschedule.

Participant were asked to rate their satisfaction with multiple installer attributes. Approximately 70% of respondents provided installers with an "excellent" rating on each aspect. (See Figure 5).

Installers rated as excellent. Respondents also rate the installers highly on multiple aspects of the job (See Figure 5below).

Figure 5: Satisfaction with Installer



Participants were unaware of specific needs for energy efficiency improvements. The great majority of respondents, 90 percent, indicated that they were not "aware these improvements, repairs or upgrades could be made to" their home.

6.2.2 UCONS Survey Limitations

A review of the UCONS survey process and responses identified limitations that threaten the validity of the data. These are discussed under three sub-headings:

- Survey delivery and follow-up
- Data entry and item non-response
- Limited usability

Survey delivery and follow-up

Potential for installer selection bias. Installers are responsible for providing participants with the survey. If they encounter problems with the job or the customer, they may be less inclined to provide or highlight the survey. It is not possible to confirm that surveys are provided to all participants consistently.

Potential for self-selection bias. There is no follow-up to remind or encourage participants to respond, and no way to determine how representative the respondents are to the participant population. Participants who are less fluent in English or dissatisfied with the program may be less likely to return the survey.

Low response rates. Response rates have been low and declining in the past three years. The low response rates may be due to a number of factors, including not receiving the survey, being unaware that the survey was left behind, or because there is no follow-up to encourage participation.

Table 16 UCONS Survey Response Rates

Year	Participants	Completed surveys	Response Rate
2014a	2,966	172	6%
2013	5,597	506	9%
2012	4,933	766	16%

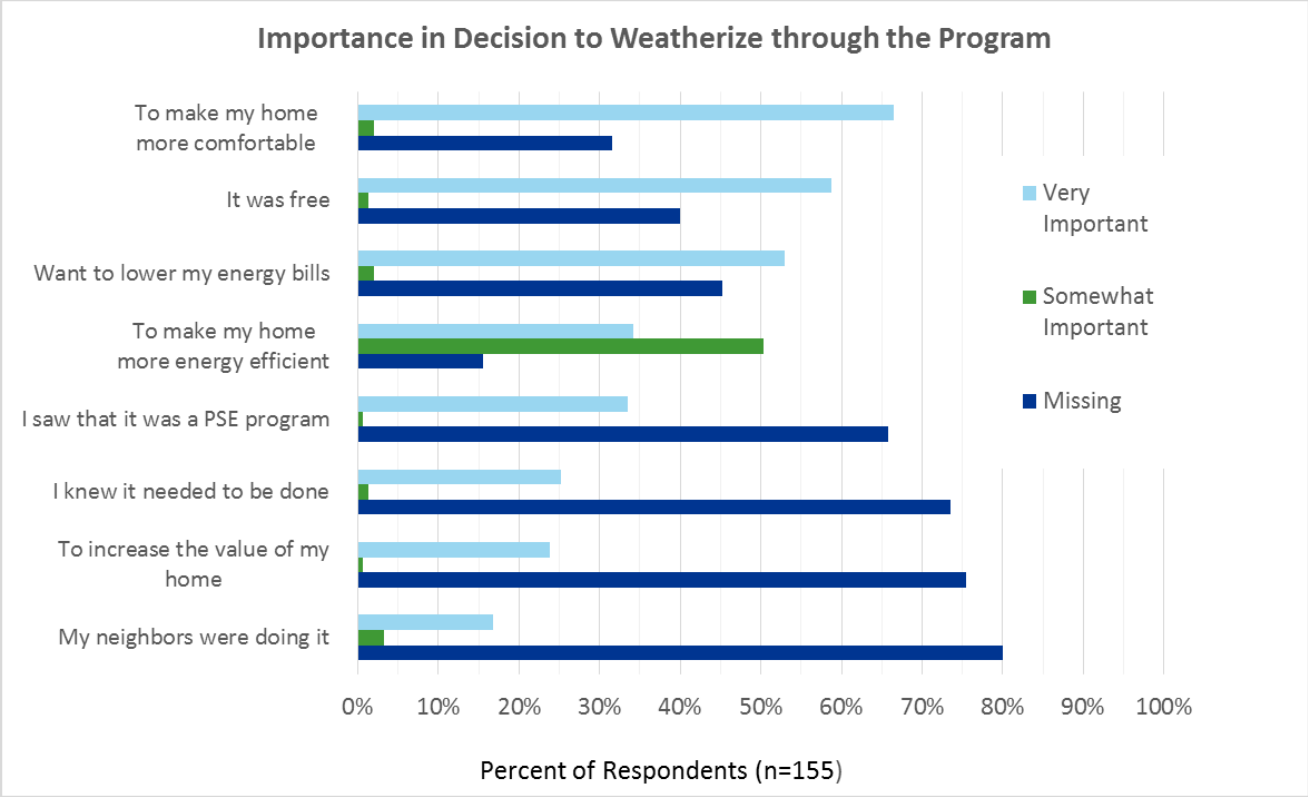
a 2014 based on households treated through November 30 and surveys entered through December 17, 2014. The final response rate may be slightly higher. Seventeen surveys entered in 2014 were in the 2012 survey file and are included in the response rate (but not the data analysis).

Data entry and item non-response

PSE provided the evaluation team with 2014 participant survey data that had been entered into the database between July 7 and December 17, 2014. The July start date is because surveys completed earlier in the program year were entered into an older database and later re-entered into the current system. Although UCONS staff reported entering open-ended responses verbatim, survey data files provided to the evaluation team included only responses to close ended questions. UCONS staff report that a minority of surveys included open-ended responses.

High item non-response. Item non-response refers to respondents skipping question that apply to them. In general, this is more likely to occur with personal questions (e.g. income), or later in a survey. Figure 6: below shows high item non-response for an early survey question. It appears that respondents chose to skip the question rather than indicate that something was "not important." Other questions (e.g.Figure 5) had item non-response that could indicate dissatisfaction. The 2014 survey data did not include a single response with a rating of three or below on five-point scales.

Figure 6: Example of High Item Non-response



- ## No Linkage between Survey and Participant Information

UCONS collects a great deal of information (in addition to PSE's information) when completing installations. These data include what is installed, who the installer was, the level of duct sealing, location and ownership status. The satisfaction survey responses, however, cannot be linked to the participating households. This limits the usefulness of the data in two important ways.

Inability to assess how well respondents represent participants. Given the opportunities for selection bias, as well as the low response rates, it is essential to assess how well the respondents represent the participant population.

Analysis of subgroups. Program implementers and evaluators could get substantially more value from the data by looking at differences across subgroups. For example, are some installers better than others at explaining what they do? (An opportunity for colleague-to-colleague training.) Are out-of-park participants more likely to read the local newspaper?

If the survey were linked to the household by an ID, the survey respondents' characteristics could be compared to the participant population. This would allow for:

- Assessing the representativeness of the respondents
- Weighting survey responses, if necessary, to better reflect the population,
- Conduct analysis of subgroups, and

- Eliminate the questions about what services the respondent received. (It is unclear how these are currently used.)

6.3 Evaluation Participant Interviews

The process evaluation included 16 telephone interviews with 2014 program participants. These interviews were conducted for three reasons:

- To better understand the participant experience,
- To identify issues that may not have been addressed in the UCONS-delivered survey, and
- To assess the viability of conducting telephone surveys with the target population. (Multiple program staff reported that the target population is very difficult to contact via telephone and thus do not use telephone approaches for surveys or marketing.)

6.3.1 Respondents

A total of 16 in-depth-interviews were completed with 2014 MHDS program participants in March 2015. The participants were randomly sampled from participants who received duct sealing between January 1 and September 30, 2014 and for whom PSE provided telephone numbers. Participants were stratified by whether or not they were identified as in or out of a manufactured home park.

The evaluation found that participants that were reached were willing to answer questions about the "free energy upgrade program."

Table 1717 provides the response rates for the telephone interviews. The interviewer started each call by introducing herself and saying she was "calling on behalf of Puget Sound Energy to follow-up on the free energy upgrades your household received in [month] of last year." One initially suspicious respondent agreed to participate because the interviewer had sufficient information regarding his participation, and she agreed to skip the more personal household questions.

The high response rate from the IDIs suggests that telephone surveys) may be viable for this population. Telephone calls were made during day and evening hours. Program participants, in general, are more likely to respond to surveys about the program for several reasons.

- They recognize and trust the survey sponsor (PSE),
- The topic is salient, and
- They received something and feel some obligation to give back, and

The first two reasons suggest that telephone calls may also be effective for program marketing.

Table 17 UCONS Interview Response Rates

	Strata	
	Out-of-park	In-Park
Households called	20	18
Bad #a	5	
Moved	2	1
Valid Sample	13	17
Language problem		2
No recall of program	1	
Not reached	3	8
Completed	9	7
Response rate	69%	41%

a "Bad numbers" included not in service, number new to person answering the telephone, or not resident of address treated.

b Language problem identifies respondents who did not speak English fluently enough to answer the questions. One indicated he wanted to respond but needed a Spanish interviewer.

c "Not reached" are participants who were called at least once but no contact was made. Only one was called more than two times.

The interviewer confirmed with respondents the address treated, and whether or not the home was in or out-of-park. The interviewer also independently checked the first 20 addresses in each stratum using google maps and google earth, to assess the incidence of errors. Of the 40 sampled participants, two identified in the program data as out-of-park were located within parks. (One of these completed the survey, and is discussed as an in-park respondent)

Table 18 Verification of In or Out-of-park Status

	Strata	
	Out-of-park	In-Park
Program data designation	20	20
Resident confirmed	8	7
Google confirmed	10	13
Resident different[a] (Google confirmed)	2	0

a One participant had moved, the other completed the interview.

Respondents ranged from an out of park senior living alone to families of six (6) within a park. Most respondent households had 2 or more adults living in the home, and no children under 18.

Although all participants are lower income, there appeared to be a range in relative wealth. In general, the seniors appeared to be more comfortable, as did longer term residents. Some participants have incomes high enough to be ineligible for social service programs, but low enough to have little or no disposable income. (One respondent said he is just over the line for receiving energy assistance.) Others may not be aware of social service programs or ineligible for other reasons. Many respondents keep temperatures low to manage energy expenses. The extreme case is a home (with young children) kept between 50 and 55 degrees because the furnace is cycling erratically and they cannot afford to fix it.

Interviews are a qualitative research approach that does not rely on statistical sampling to represent the population. Instead, sampling can be purposive – intended to meet specific objectives such as homogeneity or maximum variation. In this instance, we sought variation in and out-of-park, and in levels of duct sealing. The interview findings are not meant to be representative of the population, and should not be interpreted that way. Instead, they explore in more detail program process and issues from the participant perspective and identify potential differences, where appropriate.

6.3.2 Energy Efficiency Actions and Awareness

Respondents were asked about their participation in energy efficiency programs, what energy efficiency actions they had taken on their own, and how aware they were of the need for energy efficiency improvements in their home.

Few respondents had participated in other energy efficiency programs. One participant reported getting a rebate on an energy efficient clothes washer. Another respondent had received a replacement refrigerator, but was unclear about whether they got this through the organization providing energy assistance or through PSE.

Most participants were not aware of the need for duct sealing prior to program participation. Participants had a general sense that their home needed energy efficiency improvements. Many reported that their PSE bills were high, with some associating this with poor windows (either leaky or single pane) or leaky doors. For example, one respondent said that he "could see through it {the door} and feel the drafts." A couple mentioned poor insulation. None reported being aware of the need for duct sealing.

Five of the 16 respondents had made energy efficiency improvements to their home's shell. Three replaced their windows, one added insulation when he replaced the siding, and another added insulation over two bedrooms when reroofing. Four of the five were long term residents in their homes – with tenures ranging from 16-32 years. The fifth family had just bought the home and replaced the windows.

6.3.3 Program Delivery

Participants were asked to discuss various aspects of the program delivery, from how and what they learned about it, through post installation inspections. Many respondents had difficulty remembering the details – different respondents paid attention to or remembered different aspects of the experience.

Most in-park participants learned about the program from direct or indirect contact with UCONS marketing staff. These respondents either talked to a person who knocked on their door, or responded to the pamphlet left behind. Another attended a meeting held in the park. One learned from a flyer in the mail, and the eighth in-park respondent learned about it on Facebook. One respondent said marketers visited her home four times before she said yes.

Out-of-park participants learned about the program from a wider variety of sources. Three were visited by a UCONS marketer. Another three were referred to the program – one each from a social service agency, a neighbor, and a family member. Two others reported hearing about it "through the mail."

Participants varied in what they recalled "being told" about the program. Many recalled being told it was free and that they would save money on their energy bills. A few recalled specific savings'

values. One recalled being told him "would save up to 30%, but it varies by households. I was skeptical" One reported being told he would save up to 50, another said "½ the bill."

Others recalled being told "what would be looked at," with some providing specifics such as

> "They would check to see if it was efficient and give me light bulbs."
>
> "I would get LEDs; they would put air damns in my duct work, and investigate to see if I needed floor insulation."

At least three respondents use non-electric fuels as their primary heating source. After the first five interviews, all respondents were asked if they had heating sources other than the electric furnace. Most did. One respondent reported using wood as his primary fuel. He turned the electric furnace on only when out of town during the winter. Two other respondents reported using propane to provide the majority of their fuel, with one saying that electricity was too expensive.

Multiple other respondents use supplemental fuel sources. A third respondent reported using propane for some of his heating, but added he uses it every day. Another has a wood burning stove that is used often, but she was unclear if this was the primary heating source. Other respondents used kerosene (1) and other electric (non-ducted) heat sources (2). All of these supplemental heat sources (including the electric ones) would reduce the savings associated with duct sealing.

Several participants knew little about what would occur before the installer came. One woman, when asked what she had been told, said "Not much. I didn't know what to expect. No expectations, no disappointment."

Participants had little to say about the scheduling process because it was efficient. Respondents scheduled the installation with the marketer (if they had direct contact with them) or called UCONS (if they heard about the program some other way). In both situations all respondents reported scheduling the installation for a time that worked for them, and that was within the following 2 weeks.

One participant had his installation moved to the next day and was informed about 2 hours before the original appointment. This participant was upset, as he had taken the day off of work. His wife, who does not speak English, was home for the installation, but he lost out on the benefit of talking to the installer.

All but two participants were very positive about the installer. Some volunteered positive statements such:

> "He was polite, efficient and knew what he was doing."
>
> "Very nice young man."
>
> "Knowledgeable"

Respondents who had a specific question or an interest in the installation felt that the installer did a good job of addressing their issues.

One participant did not receive program services. One respondent reported that the installer left his home within ~10 minutes of arrival, with no explanation.[27] The database recorded this home as getting a Level 3 duct sealing and direct install measures. The respondent said that the installer did not complete any work underneath the home. A couple of other respondents identified as Level 3 did not recall the installer going under their home or telling them about sealing the crossover.

Respondents varied in their understanding of what was done to their ducts. Some had a clear understanding of what was done. These respondents said the installer showed what he had done and why. Most had a vague understanding and did not recall spending time with the installer getting an explanation. Others admitted to not paying much attention.

Respondents recall installations taking 15 minutes to less than one hour. Installers varied in how long they reported spending on homes, with estimates ranging from 1-1.5 hours to 2-4 hours. Participant recall may be flawed.

Respondents had limited recall of written materials left behind by the installer. Most respondents did not recall the installer leaving written materials behind or had a vague recollection, but did not remember the content. Those that remembered mentioned a sheet about the refrigerator replacement program. Even when asked if they received a survey to fill out, only one respondent recalled it.

6.3.4 Measure Retention and Satisfaction

Participants were very happy with the LED lights. Participants really like the LED lighting. Many were pleased with how bright they are, with how quickly they start, or both. "I can read by it," said one respondent. Another said they he planned to buy more of them, now that the prices are going down.

Three participants were less satisfied with the lights, and may have received CFLs. Three participants were less satisfied with the lights they received, saying they took too long to start and were not bright enough. When asked to describe the lighting all three identified what sound like CFLs. It's unclear if they were confusing these lamps with lamps received from another program.

Almost every lamp installed in respondent homes is still in use. All but one respondent reported still having all the lights, whether LED or CFL, in use in their home. The exception was a respondent who had electrical problems that damaged some of the bulbs.

Participants who received showerheads were also satisfied. Many (but not all) participants received low flow showerheads. In some cases the installer put them in, in others the resident put them in, and in yet others they were never installed. Most people's comments were similar to what one person said "It works fine."

Retention was very high for all showerheads installed. Once a showerhead was installed (either by UCONS or the resident) it remained in use. No one reported removing the showerhead. Many, but not all showerheads left at the home were installed.

[27] During an interview one installer mentioned leaving a house because of very unhealthy conditions.

Many participants received furnace filters. Most respondents were either handed furnace filters or had one put into their furnace. Participants did not have much to say about them, although one respondent had been unaware that the furnace had a filter before the installer visited. Another respondent said the ones left did not fit his furnace.

About ¼ of the participants have changed the furnace filter since the installation. Few respondents had changed the furnace filter. Those that had had done it one or two times. One respondent had purchased a "high efficiency" filter so that he did not have to remember to change it as often. For one or two others, the question served as a reminder

Very few participants notice a difference in their home since the duct sealing was completed. Most participants say that there is no noticeable difference in the comfort of their home since the work was completed and some seemed disappointed by this. One said "There is not much difference and the house is still too cold."

Several participants noticed a difference in air flow after the installation. Three participants noticed increased air flow from the ducts, which increased the homes' comfort. For one home the difference was dramatic: 2 bedrooms that had not been getting heat are now heated. The other two homes reported increased flow from one or two vents, which make the home more comfortable.

Some respondents report limited bill savings. One participant reported noticeable bill savings. Other participants said "I think . ." there was savings on the bill, but in the context of "there must be savings given the work that they did." Few could identify an amount and none said it was substantial. One respondent reported that his budget billing amount increased by $10 (but this is likely due to energy use prior to the program).

When asked for suggestions to improve the program, respondents identify additional measures needed. Most respondents do not have suggestions for program improvement, saying they have not thought about it. Those that respond suggest including weatherization measures (caulking and weather-stripping), or providing new windows.

6.4 Staff Interview Findings

Staff interviews focused on how the program is operated, and the roles and responsibilities of the various staff. Several general findings emerged.

Staff are well suited and prepared for their responsibilities. Almost all UCONS and Energy Services Group staff had a background in the work they were doing, or in something that related closely to their current job.

Program staff report high job satisfaction. All program staff appear satisfied with their jobs and are enthusiastic about the program. They feel that they are making a difference in people's lives.

Program staff see the missed opportunities in the homes. A few respondents noted that there are missed opportunities. When AARA money was available the program provided additional direct install measures (such as pipe insulation). They also see more need but are limited in what they can do.

Some program staff appear protective of the target population. Program staff described the target population as suspicious and difficult to reach.

6.5 Free-ridership and "Take back"

PSE was interested in assessing the level of free ridership in the program. They were also interested in identifying potential "take back" behaviors. Either of these would affect the savings achieved. Free ridership should be accounted for in system planning while take back could indicate that further education is needed to maximize energy and bill savings.

Free ridership in the program is likely close to zero. Most respondents were unaware of the specific need for duct sealing, which would preclude them from seeking out the service. There is very little retrofit duct sealing occurring in Washington, except that which is associated with rebate programs. (PSE, for example, provides 50% of the cost, up to $500 for duct sealing and insulation.) The manufactured home sector is unlikely to learn about duct sealing from this program, as it is not the target sector.

Had MHDS participants been aware of the need for duct sealing, it is unlikely that they could have paid someone to address the problem. MHDS participants tend to be low income, with little or no disposable income. For example, two of the respondents reported that their furnaces were not working properly. One lived in a somewhat remote location and a contractor he contacted wanted to charge $140 just to look at the system, a price he could not afford. Another respondent had a broken window, which had been patched up with plastic that eventually ripped. She was unable to find a way to get the window fixed. Multiple respondents talked about keeping their homes at low temperatures to keep heating bills down.

Program "take back" is minor. Respondents were asked if they had "changed their thermostat settings since participating in the program." One respondent thought he might have raised the temperature by 1 degree during the day. Another said that they "use the heat more," but he thinks their bills are lower this year. (This respondent had a cross-over repaired and noticed an immediate change in the home.) None of the other respondents indicated any changes to their energy use habits – more than a few keep their homes at lower than comfortable levels to save money.

7 CONCLUSION

7.1 Summary

7.1.1 Summary of Billing Analysis

The study evaluated the impact of MHDS program on annual electricity consumption. The final sample of analysis consisted of 4,102 premises in a participation group that installed duct sealing measures in 2012 and 2013. The analysis applied a difference-in-differences method to weather-normalized annual consumption to estimate program savings.

Table 19 summarizes net savings estimates for the 2021 and 2013 MHDS program. In particular, Levels 1 and 2 for out-of-park homes did well. Overall, however, the realization rate was just 51% compared to deemed savings estimates from those program years.

Table 19 MHDS Program Savings for 2012 and 2013 with Realization Rate[28]

Customer Groups/ Percent Savings	Average Participants' Savings (kWh)	Total Participants: 2012 & 2013	Total Estimated Savings (kWh)	Total Tracked Savings (kWh)	Realization Rate
Duct Sealing Level 1- In-Park	388.6	2,433	945,550	2,202,349	42.9%
Duct Sealing Level 1- Out Park	1,175.2	674	792,084	719,609	110.1%
Duct Sealing Level 2- In-Park	404.5	2,961	1,197,713	3,346,482	35.8%
Duct Sealing Level 2- Out Park	358.1	1,305	467,359	1,781,328	26.2%
Duct Sealing Level 3- In-Park	930.1	1,233	1,146,756	1,730,396	66.3%
Duct Sealing Level 3- Out Park	1,316.6	861	1,133,580	1,389,716	81.6%
Total		9,467	5,683,042	11,169,880	50.9%

There are no conclusive explanations for the low savings estimates relative to the tracked (expected) savings. The billing data used for the analysis, a combination of monthly and daily reads, were complete and used consistently across treatment and comparison groups. The savings estimation process that was used is well-established and widely used this kind of program. Possible explanations include a combination of unreasonable savings expectations given the nature of ducts being sealed and other factors (participant behaviors, broken heating systems, etc.) that overwhelm the modest positive effects from the duct sealing.

7.1.2 Summary of Process Evaluation

PSE's MHDS program has been in operation since 2008, and delivered by UCONS since 2010. PSE's Project Manager "adopted" the program in mid-2014, with responsibility for a total of five programs. The MHDS program operates like a "well-oiled machine". Responsibilities for each of the entities involved (PSE, UCONS and Efficiency Services Group) are clear. Staff are clear about their responsibilities, as well as qualified and motivated to fulfill them. They also feel that their work is

[28] These totals do not include the homes where not duct sealing measures were done. The homes had a total of 311,793 additional kWh in the tracking data at a per home average of 369.0 per home across lights and showerheads.

meaningful. The introduction of tablets to program delivery streamlines processes and data transfer. UCONS provides PSE monthly invoices and data that are timely and accurate.

The program is on track to meet 2014-2015 savings goals and under budget. This is due to the experience of the staff, improvements to program processes over time, and the focus on meeting goals. UCONS program staff track program progress relative to goals daily, and discus this at weekly management meetings.

UCONs maintains tight control of the program budget. Installers pick up their supplies at various locations where UCONS has accounts. UCONS owns installer trucks and purchases all the supplies. Program marketers are paid based on their recruitment success. Program installers are paid by the job completed, which varies based on the level of duct sealing provided. Paying employees by achievement contains costs to budgeted amounts, regardless of the time that is required to complete them. Installers are motivated to get projects done, and done quickly so they can move onto the next home.

Participants are treated well and find staff knowledgeable and helpful. They appreciate the program services, and some notice substantial improvements in the comfort of their home. Almost all appreciate PSE making the effort to provide them with needed improvements and efficient lights. Complaints are tracked and addressed quickly.

In 2014 the program shifted the focus from in-park to out-of-park homes, identifying that most of the remaining potential is in out-of-park homes. Out-of-park homes are more dispersed, and thus more challenging to engage and require more travel time to service. Both of these factors affect program costs. UCONS has made some adaptations to program marketing to address these challenges.

UCONS has done an excellent job of hiring, training and motivating program staff. The program is run efficiently. PSE can and does rely on UCONS to deliver the program and meet their goals. PSE's trust in UCONS has extended to two functions generally outside the role of program implementers: project verification and customer satisfaction. Currently UCONS manages the contract with Efficiency Service Group for verification of project installations. They are also responsible for the delivery and data entry of customer satisfaction surveys. Although there is no evidence of a problem, UCONS lack of independence makes the findings less reliable. In regards to the customer satisfaction surveys, low response rates and high item non-response cause additional concern.

7.2 Recommendations

7.2.1 Impact Evaluation

Impact evaluation recommendations are generally limited compared to process evaluation recommendations. The impact evaluation is more focused on what happened, while the process evaluation asks and answers the question why.

The low impact results point toward a need to prioritize manufactured homes that will really benefit from the duct sealing process. The apparent move toward out-of-park homes with the correlated drop in Level 2 duct sealing focusses the program where the savings are highest.

It may be time to re-assess the duct tests and confirm that they both identify houses truly in need of duct sealing, and that getting those tests results to the required threshold offers a realistic expectation

of the savings from an engineer perspective. It is not clear that tests are necessarily performed on the doublewide homes but perhaps they would help to identify the truly problematic houses.

The complete program participant tracking data should be available for all homes starting with the 2014 program year. This may make it possible in the future to correlate specific characteristics with program-related savings. This may allow future evaluations to give more specific recommendations regarding which aspects of the program support higher savings estimates.

The program should have a fully transparent and clear set of decision rules that decide the Level of service for each home. The process by which homes are placed in Level 2, for instance, was not clear enough to understand why those homes might produce lower savings. Rules should be based on verifiable measurements and consistently applied across all levels to minimize implementer discretion. Once again, this may allow future evaluations to give more specific recommendations regarding which aspects of the program support higher savings estimates.

7.2.2 Process Evaluation

This section includes recommendations for consideration by PSE. They are provided in order of priority.

PSE should consider using an independent firm to conduct participant satisfaction surveys.

Current participant satisfaction efforts result in low response rates and high item non-response. The resulting data cannot be linked to other participant data to assess how representative the respondents are, and to substantially improve the data value to program and evaluation staff. The independent firm should consider the following:

- Update the survey instrument.
- Use IDs to link surveys to participants
- Conduct quarterly surveys to improve recall
- As a survey incentive, hold quarterly drawings for respondents for items such as cash gift cards, LED lights, or other energy saving items.
- Conduct telephone or mixed-mode surveys
- Have available Spanish language interviewers and survey instruments.
- Set quotas, or compare respondents to participants, to assure representativeness.

PSE should consider taking responsibility for the verification contract with Efficiency Services Group.

Many program implementers have internal quality control measures as part of the program delivery and improvement process. However, regulators and other stakeholders expect independent verification. Conservation Services Group has a contract with UCONS – in other words, they are verifying the work of their client, with whom they have an on-going relationship. They are not "independent."

Increase program transparency by obtaining more complete program data.

The evaluation team found it difficult to obtain information and data from UCONS and PSE. PSE staff (evaluation, program and IT) have substantial demands on their time that make it challenging to fulfill data requests, and they may not have all program data that is collected.

PSE should continue to receive* additional *data collected by UCONS and Efficiency Services Group. In combination with more clear criteria for placing homes in Levels, these data will support future evaluations in identifying what characteristics support cost-effective savings for the Manufactured Home Duct Sealing Program.

Have UCONS collect additional data that will support program planning and evaluation. The evaluation team identified additional data that could easily be collected during installation, and that would be of benefit to evaluators and program planners. This includes:

- Secondary heating sources
- Approximate age of home
- Length lived there

Have Efficiency Services Group verify additional information. The inspector verifies the measures installed, but does not explicitly verify the level of duct sealing. Verification of the level of duct sealing, and in or out-of-park should be added to the form.

Explore additional marketing opportunities to reach out-of-park and underserved MH homes.

The MHDS program has relied heavily on door to door marketing. This approach was successful in reaching homes within parks (unverified in-park program penetration estimates are as high as 75% for in-park homes). As the program attempts to reach those who were not responsive to earlier marketing, new approaches may be needed to engage unserved in-park and unaware out of park customers. Some suggestions to consider are (in no particular order):

- Hire at least one bi-lingual Spanish speaker
- Coordinate with CAP, Energy Assistance providers, and other social service agencies to increase referrals
- Offer incentives to participants for referrals that result in a completed job.
- Establish Facebook sites in English and in Spanish. Encourage participants to mention the program on their Facebook page.
- Consider telephone marketing to out-of-park customers. This would require some calling in the evening.

8 LIST OF APPENDICES

8.1 Impact Methodology

8.1.1 Stage 1: Site-level Modelling

The full model specification of the site level modelling is as follows:

$$\boldsymbol{E_{im}} = \boldsymbol{\mu_i} + \boldsymbol{\beta_H H_{im}(\tau_H)} + \boldsymbol{\beta_C C_{im}(\tau_C)} + \boldsymbol{\varepsilon_{im}} \quad \text{---- Equation (1)}$$

where:

E_{im}	Average electric consumption per day for participant *i* during billing period *m*
μ_i	Base load usage (intercept) for participant *i*,
$\boldsymbol{H_{im}(\tau_H)}$	Heating degree-days (HDD) at the heating base temperature τ_H
$\boldsymbol{C_{im}(\tau_C)}$	Cooling degree-days (CDD) at the cooling base temperature τ_C,
β_H	Heating coefficient, determined by the regression,
β_C	Cooling coefficient, determined by the regression,
$\boldsymbol{\tau_H}$	Heating base temperatures, determined by choice of the optimal regression,
$\boldsymbol{\tau_C}$	Cooling base temperatures, determined by choice of the optimal regression, and
$\boldsymbol{\varepsilon_{im}}$	Regression residual.

Rather than forcing the same degree-day base temperature on all of sites used in this study, we estimated consumption across a range of heating and cooling degree day bases. CDD bases covered 64˚F to 84˚F while HDD bases covered 50˚F to 70˚F. Electric consumption analysis includes three different models: 'heating and cooling,' 'cooling only,' 'heating only,' and 'baseload only' models. For each model estimated, we chose the best cooling and heating degree base for each site based on the individual R-squared and used an F-test to determine which model specification was superior We then examined the distributions of cooling and heating base temperatures from the 'best' model to determine if the optimal degree day base temperature was on the border. If so, we re-estimated the models using the median base temperatures.

We then calculated normalized annual consumption using the parameter estimates from the best model selected for each site. Normalized annual consumption (NAC) is calculated with the help of parameters estimated from site-level regression modelling (see Equation 2). Weather normalized annual consumption is particularly important for application of billing results to development of deemed unit savings estimates that can be used for program planning and administration.

Normalized Annual Consumption is calculated as follows:

$$\boldsymbol{NAC_i} = \boldsymbol{(365.25 \times \hat{\mu}_i) + \hat{\beta}_H H_0 + \hat{\beta}_C C_0} \quad \text{---- Equation (2)}$$

Where:

NAC_i	Normalized annual consumption for customer i,
H_0	Average ten-year heating degree days calculated at the optimal heating base temperature $\hat{\tau}_H$ for participant i,
C_0	Average ten-year cooling degree days calculated at the optimal cooling base temperature $\hat{\tau}_C$ for participant, and
$\hat{\mu}_i, \hat{\beta}_H, \hat{\beta}_C$	Baseload and heating parameter estimates from the site-level models.

8.1.2 Stage 2: Difference-in-Differences

The second stage follows a difference-in difference method that compares the change in the average normalized consumption of the participant group during pre- and post-program period with the change in usage during the same period for the comparison group. We estimate savings separately by duct sealing combination in order to account for the difference in the impact of these measures in the energy savings. The second-stage regression model has six different duct sealing measures arising from unique combination of two premise location (in-park/out-park) and three duct sealing levels information.

The difference-in-differences approach is a simple, robust approach to measuring program-related savings. The approach compares normalized annual consumption between the pre- and post-installation periods for both the participants and the comparison groups. The participant group pre-post difference captures all changes between the two periods including those related to the MHDS program. The comparison group captures all changes with the exception of those related to the MHDS program. Removing the non-program differences, as represented by the comparison group difference, from the treatment difference produces an estimate of the MHDS program's isolated effect on consumption.

The difference-in-differences method has the following structure:

$$\Delta \boldsymbol{NAC_i} = \boldsymbol{\alpha} + \sum_k \boldsymbol{\gamma_k X_{ki}} + \sum_k \boldsymbol{\beta_k T * X_{ki}} + \boldsymbol{\varepsilon_i} \quad \text{---- Equation (3)}$$

where

ΔNAC_i	=	Pre-post difference in normalized annual consumption for household *i*;
α	=	Intercept
X_k	=	Duct sealing type indicator (value of 1 if participant receiving k^{th} type duct sealing combination, 0 otherwise)
T	=	Treatment indicator (value of 1 if Participant and 0 otherwise)
β_k	=	Treatment effect, impact of MHDS program in energy savings, of duct

		sealing combination type *k*
ε	=	error term

The coefficient, β_k, associated with difference-in-difference is the primary interest of our evaluation. The coefficient also gives the standard errors and statistical significance of the saving estimates. Standard errors can be used to calculate confidence intervals of saving estimates and test statistical hypothesis.

8.2 About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.

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Evaluation Report Response

Evaluation Report Response

Program: Manufactured Home Duct Sealing

Program Manager: Luke Giustra

Study Report Name: Impact Evaluation for Program Years 2012-13, Process Evaluation for Program Year 2014

Report Date: November, 2015

Evaluation Analyst: Jim Perich-Anderson

Date ERR Provided to Program Manager: 11/09/2015

Date of ERR: 12/4/2015

Evaluation Overview, Methodology and Key Findings:

Overview:
The independent impact and process evaluation conducted by DNV GL, of PSE's Manufactured Home Duct Sealing Program focused on two elements:

1. Estimate savings for duct sealing and distributed material measures installed in 2012 and 2013
2. Assess recent program implementation, participants and related issues

The goal of the independent impact evaluation was to identify savings realization rates for the three levels of duct sealing treatments and determine how distributed measures provided during the duct sealing service impact energy consumption in the home. The impact evaluation included standard IPMVP evaluation practices using a two-stage billing analysis approach. The first stage utilizes site-level modeling to develop weather-normalized consumption of the participant group. The second stage uses the difference-in-differences approach to provide an unbiased measure of program savings. The difference-in-differences approach also incorporated DOE's Universal Methods Project to construct the comparison group, due to the fact that the Manufactured Home Duct Sealing program is an opt-in program and therefore impacts the ability to "randomly select customers in the control and treatment groups."

The objectives of the independent process evaluation include the following elements, as outlined in the final report:

1. Identify and document program implementation process
2. Assess participation satisfaction with the MHDS program and measures
3. Assess (qualitatively) the extent of free-ridership in the program
4. Identify any take-back behaviors that may reduce savings

Key Findings/Analysis:
Impact Summary: It is noted that the final billing analysis conducted by DNV GL consisted of 4,102 premises in the participation group and 3,731 premises in the comparison group. The evaluation aimed at identifying stand-alone savings across all levels of duct sealing treatments provided to customers. However, the evaluated savings and realization rates derived from DNV GL's analysis, as illustrated in Table 20 below, represents the total savings for the homes inclusive of duct sealing, showerheads and lighting upgrades. Providing isolated showerhead and lighting upgrade savings proved problematic because the DNV GL "could not get separate savings estimates that were statistically significant different than zero." Furthermore, various levels of duct sealing, specifically Level 2, showed significantly lower realization rates. Additional data was provided to

DNV GL to identify the leading reasons for the low savings of the Level 2 homes. DNV GL indicated that a comprehensive set of supporting data was not available and therefore, "No apparent relationship was found between any of these single fields and the disparate impact results." Overall, the evaluated savings indicate a 51% realization rate of savings across the program, with some specific levels of duct sealing, predominately Level 1 and Level 3 out-of-park, meeting accepted savings estimate claims.

Table 20 MHDS Program Savings for 2012 and 2013 with Realization Rate

Customer Groups/ Percent Savings	Average Participants' Savings (kWh)	Total Participants: 2012 & 2013	Total Estimated Savings (kWh)	Total Tracked Savings (kWh)	Realization Rate
Duct Sealing Level 1- In-Park	388.6	2,433	945,550	2,202,349	42.9%
Duct Sealing Level 1- Out-Park	1,175.2	674	792,084	719,609	110.1%
Duct Sealing Level 2- In-Park	404.5	2,961	1,197,713	3,346,482	35.8%
Duct Sealing Level 2- Out-Park	358.1	1,305	467,359	1,781,328	26.2%
Duct Sealing Level 3- In-Park	930.1	1,233	1,146,756	1,730,396	66.3%
Duct Sealing Level 3- Out-Park	1,316.6	861	1,133,580	1,389,716	81.6%
Total		9,467	5,683,042	11,169,880	50.9%

Possible factors identified by DNV GL driving the lower-than-expected level of savings include:

1. **Savings assumptions.** Deemed savings values assume electric heating as the primary fuel, and that it is used throughout the heating seasons. The process evaluation found more than a few participants who used their electric heat sparingly or had alternative primary heating system.
2. **Broken heating or other equipment.** Two respondents reported that their heating equipment broke after the treatment (unrelated to participation). The nature of the problem would increase heating bills.
3. **Limited duct leakage**. It could be possible that in some homes the extent of duct leakage is just not enough to generate the expected savings when sealed. Level 2 homes are supposed to be similar to level 3 homes (double-wide), but do not need a full replacement of the crossover portion of the duct that carries heat to the other side of the home. The substantial increase in savings from Level 2 to 3 indicates that major fixes like replacement of the crossover may drive substantial savings.

To address these factors, DNV GL presents a set of recommendations for future iterations of the program. The recommendations are summarized below:

1. Better prioritization should be used to identify the need for duct sealing in manufactured homes that will really benefit from the process. The program should continue to focus on out-of-park homes with the correlated drop in Level 2 duct sealing to focus the program where the savings are highest.
2. Diagnostics should be employed on homes to indicate homes that are "truly in need of duct sealing." Duct tests may be able to inform the installer of the types of structures and duct systems that are "truly problematic houses."
3. Program rules should be "fully transparent and [a]clear set of decision rules that decide the level of service for each home."

Process Summary: The process evaluation illustrates the value of the duct sealing program from the customer perspective. DNV GL found that overall the program operates fairly smoothly with communications amongst all stakeholders being regular and effective. Based on a customer survey, general satisfaction in the program participants is very high, often exceeding 85 percent. However, the customer satisfaction surveys are administered by the implementation partner of the program and represent a very small (6 percent) sample. Due to the small, and self-selected, sample response DNG-VL indicates that, "the data collection precludes assessing how well respondents represent the participant population."

DNV GL found that high measure retention exists with customers receiving distributed materials and free ridership is practically negligible. DNV GL states, "Almost all interviewed participants were unaware of the need for duct sealing in their home before

participating in the program." Takeback behavior was also identified as very low for the program. In summary, the process evaluation presented a set of recommendations for the future iterations of the program:

1. Prioritize work in out-of-park homes
2. Develop clear set of rules around the treatment level of duct sealing to occur in the home
3. Consider using an independent firm to conduct both the verification of installed measures and customer satisfaction surveys
4. Explore additional marketing opportunities to reach out-of-park customers and potentially underserved ethnic populations

To improve the ability to identify program savings going forward, the process evaluation also recommended that the program require the following information be captured at the project level:

Data Fields
Home Location
Square Feet
Year Built
Home Width
Year Round Occupants
Treatment History
Previously Treated
PSE Fuel Type
Furnace Type
Register
End Caps
Plenum Sealed
Crossover
Elbow
Job Type
Water Heat Type
Showerhead Gallons per Minute

The evaluation team identified additional data that could easily be collected during installation, and that would be of benefit to evaluators and program planners. This includes:

- Secondary heating sources
- Approximate age of home
- Length of occupancy

The above data points will be incorporated into the incentive applications or QA/QC protocols as deemed necessary to support future verification and evaluation goals.

PSE Program Response to Evaluation Findings:

Action Plan:

PSE program staff will apply results from 1) the quantitative-based impact evaluation, and 2) the survey-and interview-based process evaluation, to improve PSE's offerings to manufactured home customers. As discussed below, PSE commits to various improvements that are responsive to these findings.

Based on the findings of the impact and process evaluation, PSE will continue to refine its systems and processes to provide a consistent set of measures to the manufactured home customer segment. Beginning January 1, 2016, the program will adopt the RTF prescriptive duct sealing measures and delivery mechanisms introduced in August, 2015. An outline of the delivery mechanism is outlined below:

1. Ducts must not have been previously sealed with mastic.
2. Appropriate materials and duct sealing methods shall be used.

   A. UL-181 listed mastic is an appropriate material to seal non-flexible duct connections. Cloth-backed duct tape shall not be used to seal, secure, or fasten ducts. Loose tape shall be removed prior to sealing. Secured tape that remains must be completely covered with mastic. Where there are large gaps in sheet metal or duct connections, repairs shall be made using sheet metal, sheet metal screws, and/or mastic with mesh-reinforcing tape (for holes or gaps less than 1 inch).

   B. For flexible crossover ducts, both the inner and outer lining shall be tightly fastened using a compression strap tightened with a tool designed for that purpose.
3. End caps shall be made of either sheet metal or a UL-181 approved rigid product, and sealed.
4. Ducts shall be sealed from the interior at every supply register (boot-to-duct connections, floor-to-boot gaps, and any other duct connections within an arm's reach).
5. Plenum connections shall be sealed (plenum-to-furnace connection and plenum-to-trunk duct connection).
6. Crossover duct connections shall be sealed (crossover duct takeoff-to-trunk and crossover duct-to-collar connections).
7. Inferior sections of crossover duct, such as rusted, crushed, disconnected, torn, or sections otherwise ineffective, shall be repaired or replaced. New crossover ducts shall be insulated to a minimum of R8.
8. Crossover duct shall be mechanically fastened and supported to avoid disconnection and airflow restrictions.

The below table illustrates the measures and associated savings estimates by heating system type that supports the above delivery mechanism:

Procost Full Measure Name	Measure Life (years)	Annual Savings @ Site (kwh/yr)
Manufactured Home Prescriptive Duct Sealing - Electric FAF - Heating Zone 1	18.0	973
Manufactured Home Prescriptive Duct Sealing - Heat Pump - Heating Zone 1	18.0	615

Beginning January 1, 2016, PSE will transition from a service provider delivery for the Manufactured Homes Duct Sealing program to providing customer incentives offered through PSE CAN contractors. All duct sealing measures and incentives will be administered through PSE-qualified CAN contractors and associated with PSE's single-family existing weatherization portfolio. In addition to this, PSE will also revise qualifications associated to its home energy assessment program, HomePrint, to include manufactured and mobile homes not previously served through the MHDS program. These revisions will ensure that PSE is supporting the manufactured homes customer segment with comprehensive set of offerings that are consistent to all single-family customers.

PSE has been providing weatherization services for the mobile home market through low income (LIW) and other weatherization services since 1998. In 2004 PSE introduced duct sealing as a specific component of the program. Since 1998 over 30,000 homes have received duct sealing through PSE's MHDS and LIW programs out of a total of 55,000 mobile homes in our service area, and believe that the remaining potential can be served as part of comprehensive home energy assessment and rebate program.

During the first quarter of 2016, PSE will develop all necessary field and technical specifications as well as administer training to qualified CAN contractors. The specifications and trainings will be a component of the single-family weatherization and HomePrint programs. Contactor agreements applicable to each program will be updated to reflect the applicable changes to the services offered and participation requirements. This specification and process will apply to all homes and align with best practices in the region to achieve the accepted level of estimated RTF UES savings.

Program marketing activities will focus on the participant population with the greatest remaining need. The focus of the program will target predominantly out-of-park customers and ethnic populations not previously served through the program. The remaining in-park homes will also be offered services through PSE incentives. Incentives will be developed to achieve consistency with neighboring utilities within the Puget Sound region.

PSE will also revise the delivery of the QA/QC and customer satisfaction survey functions of the program beginning January 1, 2016. Both elements of the program will be managed by either an independent firm selected to support the program, or PSE staff, as deemed the most efficient and appropriate use of resources. A sample of all homes will receive diagnostics to further evaluate the effectiveness of the installed measures. A refined set of data collection requirements will be established to ensure consistency in the delivery and reporting to PSE to support future evaluation efforts.

Since 2014, the Manufactured Home Duct Sealing program has exclusively provided LED lighting options for participants. At this time, PSE utilizes a set of RTF-modified savings for all LED lamps distributed through its programs. These savings estimates have been developed in coordination with RTF staff and account for updated baseline assumptions derived from RBSA data and more specifically applicable to PSE's service territory. PSE will continue to utilize these metrics for LED lighting savings across its portfolio. There will be no change to savings assumptions used to support leave-behind or direct install showerhead measures for homes with PSE electric water heat.

Program Implementer Response to Evaluation Findings:

The Program Implementer was provided the opportunity to review this program evaluation report. The implementer identified the following as key facts to highlight:

1) In various places in this report the ex ante savings values used are not for duct sealing alone. Rather, they combine ex ante duct sealing saving values with ex ante values for Direct Install lighting and Direct Install showerhead values. Table 13 of the report presents the evaluated vs. deemed (ex ante) values for each of the program measures.

Table 13: Evaluated Savings Compared to Claimed Savings

Measure/Location	Evaluated Savings		Deemed Savings			
	Savings (kWh)	+/- (kWh)	Duct Sealing	Lights	shower-heads	Total
Duct Sealing Level 1- In-Park	403	315	600	127	211	937
Duct Sealing Level 1- Out Park	1,190	447	600	202	267	1,069
Duct Sealing Level 2- In-Park	419	300	800	150	233	1,183
Duct Sealing Level 2- Out Park	377	413	800	240	326	1,366
Duct Sealing Level 3- In-Park	947	399	1,000	154	271	1,426
Duct Sealing Level 3- Out Park	1,337	406	1,000	243	362	1,605

2) PSE designed the participant satisfaction survey administered by UCONS, and is responsible for overseeing its administration and reviewing its results. The survey focuses on customer satisfaction with the quality of service, and is not intended to capture information on customer characteristics, attitudes regarding energy efficiency or measure retention. Results from the customer surveys, when combined with results from evaluation participant interviews (Section 6.3) and staff interview findings (Section 6.4), provide important and actionable information for improving processes and offerings for manufactured home customers. PSE commits to various program revisions that are responsive to the survey and interview findings. As noted on page 5 of the Evaluation Report Response, 'These revisions will ensure that PSE is supporting the manufactured homes customer segment with comprehensive set of offerings that are consistent to all single-family customers.'