PUGET SOUND ENERGY
The Energy To Do Great Things

2011 Duct Sealing & Repair

Impact & Process Evaluation

Contents:

This document contains both the final **2011 Duct Sealing & Repair Impact & Process Evaluation** and the Puget Sound Energy (PSE) **Evaluation Report Response** (ERR). 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.

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IMPACT AND PROCESS EVALUATION OF PUGET SOUND ENERGY'S DUCT SEALING & REPAIR PROGRAM

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Executive Summary

This report describes the impact and process evaluation activities completed for Puget Sound Energy's (PSE) Duct Sealing & Repair (Duct Ninja) Program for the 2009-2010 program cycles. The primary objective of this study was to determine the energy savings associated with duct system repairs conducted from a unique prescriptive duct sealing approach in the absence of diagnostic testing using a duct blaster or similar tool. A secondary objective involved assessing opportunities and areas of improvement in future program iterations.

A billing analysis of pre-/post-Duct Ninja home energy consumption estimated savings attributed to prescriptive duct system repairs. Navigant calibrated this model to adjust savings for variations in site characteristics, including home type, home vintage, heating system type, and cooling system type. The product of this analysis includes gross realization rates and average participant savings for PSE's Duct Ninja Program.

Results from the Impact Evaluation of PSE's Duct Ninja Program

Navigant obtained an estimate of energy savings attributed to the PSE Duct Ninja Program using an econometric regression model applied to *daily* billing data for a sample of PSE households enrolled in the program. An important aspect of the model involved using households that received Duct Ninja relatively late in the study period as control households in the months before they receive it. The model yielded two important findings:

1.) When accounting for the weighted mix of weatherization measures installed with Duct Ninja, Duct Ninja yields statistically significant savings of 28.90 therms per household per year. The 90% confidence interval around this savings estimate is [17.58, 40.22].

2.) When installed alone, estimated annual savings for Duct Ninja is 104.25 therms per household per year. The 90% confidence interval around this savings estimate is [81.14, 127.37].

3.) When attention is restricted to the mixes of weatherization measures that include duct insulation, estimated savings dropped considerably to 8.43 therms per household per year. The 90% confidence interval around this savings estimate is [-6.87, 23.73], indicating that the savings due to Duct Ninja were not statistically different than zero. In this case, the (incremental) impact of Duct Ninja was much less because of "thermal overlap" – a significant portion of the energy savings attributed to Duct Ninja when it is applied in isolation is captured by the duct insulation when they are combined.

4.) When Duct Ninja is installed with Duct Insulation, the combined savings from these two measures is 84.68 therms per household per year. The 90% confidence interval around this savings estimate is [65.39, 103.96]. It should be noted that even though the *point estimate* of savings for Duct Ninja and Duct Insulation is smaller than the *point estimate* of savings for Duct

Ninja alone, the two savings are not *statistically* different indicating an almost complete thermal overlap.

5.) Finally, savings from the combination of Duct Ninja and Duct Insulation given the mix of weatherization measures observed in the Program Tracking database amounted to 75.32 therms per household per year. The 90% confidence interval around this savings estimate is [61.50, 89.14].

Results from the Process Evaluation of PSE's Duct Ninja Program

In-depth interviews with 15 duct sealing contractors representing 80% of program activity in 2009-2010, coupled with surveys of Program staff, informed the process evaluation of PSE's Duct Ninja program. The interview instruments solicited feedback on contractor satisfaction, obstacles and barriers to effective duct sealing, and opportunities for improving the services offered and corresponding energy savings in future program cycles, namely:

1. The current program qualifying criteria are not aligned with the desired participant base.

2. The current procedures for qualifying program participants do not adequately verify the eligibility of participating homes.

3. The tracking database maintained by the program implementation contractor does not adequately define the baseline condition of participating duct systems.

The survey effort included a detailed assessment of the participant baseline as observed by the duct sealing contractors. The analysis of contractor feedback culminated in the recommendation of pre-/post-inspections to reduce uncertainty in the program baseline and corresponding savings while providing PSE with a cost effective quality control procedure.

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Introduction

Numerous studies indicate that the average duct leakage in existing homes can be 20% or more of the conditioned air volume.[1,2,3] These and other studies conducted in numerous states also indicate that the vast majority of existing homes with ducted forced air distribution systems may yield significant energy savings from a reduction in duct leakage. Duct leakage repair is one of the most cost effective energy efficiency solutions available for the tough to reach residential retrofit market and PSE has recognized a key barrier to wider spread implementation of duct sealing; cumbersome testing requirements and expensive test equipment.

PSE's Duct Ninja program addresses these issues by emphasizing training in duct sealing techniques to facilitate effective sealing prescriptively.[4,5] Properly evaluating this program will not only assist PSE in accurately accounting for savings and improving the program in future cycles, but will also serve as a resource for prescriptive duct sealing programs offered in other jurisdictions

The studies cited above indicate that most ducted systems, even in new construction, would benefit from leakage reduction. The question then becomes "is the incremental gain in air tightness that can be achieved by putting a test on the system worth the additional time spent performing the test and additional costs that the contractor must pass on to the homeowner to recoup the capital investment in the equipment?"[6]

Navigant initially sought to answer this question in March, 2010 through a comprehensive impact evaluation of PSE's Duct Ninja Program using a two-pronged approach that utilized on-site pre-post data logging of HVAC energy consumption in conjunction with a billing analysis to develop verified savings estimates for the Program:

1. Performing on-site metering of HVAC system energy consumption at least two weeks before and six weeks after duct system repairs. With a coefficient of variance of 0.7, a stratified sample size of 60 would be sufficient to attain 90/15 confidence and precision for the mean savings per homes.

[1] Arizona Public Service Duct Leakage Study, http://www.aps.com/_files/services/ResFAQ/ductleakage.pdf.
[2] South Face Energy Institute of Atlanta 1994 Duct Leakage Survey, Survey Showed Median Leakage of 19.5%.
[3] "Will Duct Repairs Reduce Cooling Load?" Parker, Cummings, Meier, 2008
[4] Bruce Manclark, Delta T. March 2, 2009. Presentation at the Regional Technical Forum. http://www.nwcouncil.org/rtf/meetings/2009/03/Duct%20Sealing%20-%20Puget%20Area%20Pilot%202009-03-02%209am.ppt
[5] Puget Sound Energy: Semi-annual Filing January-June, 2009. Washington Utilities and Transportation Commission. Docket Number UE-970698. http://www.wutc.wa.gov/rms2.nsf/177d98baa5918c7388256a550064a61e/8ac251fae3de461f88257612005594c5!OpenDocument
[6] "A Case for Prescriptive Duct Sealing," James Kingston, 2007

2. Perform a billing analysis of energy consumption before and after duct system repairs on a much larger sample of homes. Calibrate the energy savings from the billing analysis to the mean savings from the on-site metering analysis, and then use the billing analysis to adjust savings for variations in site characteristics, including home type, home vintage, heating system type, and cooling system type.

By December, 2010, the evaluation team and supporting duct sealing contractors could not procure a sufficient sample of qualified homes to participate in the on-site metering activities. Moreover, Navigant discovered that many of the duct sealing contractors adhered to different prescriptive duct sealing standards and methods for qualifying participating homes, introducing greater uncertainty in the baseline duct condition of participating homes.

In light of these uncertainties, Navigant redirected the impact evaluation activities to only a billing analysis of pre-/post-energy consumption of participating homes. Navigant also undertook a process evaluation of the PSE Duct Ninja Program. This involved in-depth interviews with 15 duct sealing contractors representing 80% of program activity in 2009-2010, coupled with surveys of Program staff, to gain a better understanding of program uncertainties and how to improve the program in future iterations.

The following sections describe in more detail the rationale and products of each impact and process evaluation activity.

Methodology for the Impact Evaluation of PSE's Duct Ninja Program

Pre-/Post-Metering

As noted earlier, our preliminary proposal for the impact evaluation of PSE's Duct Ninja Program was to estimate the population mean savings per square foot of conditioned space, μ, through an on-site metering analysis. A subsequent billing analysis was intended to develop more detailed regression-based models of how observable characteristics such as heating degree days (HDD), home vintage, structural characteristics, etc., condition expected savings. This two-pronged approach would provide robustness to the Program savings estimates because deriving an estimate of mean savings from independent data sources provides greater confidence in that estimate.

With this in mind, and using a preliminary estimate of 0.7 as the coefficient of variation, the evaluation team expected to pre-/post-meter a sample of 60 participant homes to achieve 90/15 confidence/precision in the estimate of μ.

Table 1: Number of Expected Site Visits Based on Precision and Coefficient of Variation Estimates

Coefficient of Variation	Number of Sites for 90/25	Number of Sites for 90/20	Number of Sites for 90/15	Number of Sites for 90/10
0.7	21	34	60	135

This sample size struck a balance between evaluation rigor and budget allocation. Both Navigant staff and three active duct sealing contractors representing more than 30% of program activity in the 2009-2010 program cycles took part in recruiting participants for this evaluation component between October and December of 2010.

By December, 2010, the evaluation team and supporting duct sealing contractors could not procure a sufficient sample of qualified homes to participate in the on-site metering activities. Navigant also discovered that many of the duct sealing contractors adhered to different prescriptive duct sealing standards and methods for qualifying participating homes, introducing greater uncertainty in the baseline duct condition of participating homes.

More specifically, the On-Site Measurement & Verification (M&V) process revealed uncertainty related to the baseline conditions of participating homes. This uncertainty was a product of three program design and implementation characteristics:

1. The current program qualifying criteria are not aligned with the desired participant base.
2. The current procedures for qualifying program participants do not adequately verify the eligibility of participating homes.
3. The tracking database maintained by the program implementation contractor does not adequately define the baseline condition of participating duct systems.

In light of these uncertainties, Navigant redirected the impact evaluation activities to only a billing analysis of pre-/post-energy consumption of participating homes. Navigant also undertook a process evaluation of the PSE Duct Ninja Program. This involved a thorough review of the program database and in-depth interviews with 15 duct sealing contractors representing 80% of program activity in 2009-2010, coupled with surveys of Program staff, to gain a better understanding of program uncertainties and how to improve the program in future iterations.

Billing Analysis: Data and Methodology

Navigant obtained an estimate of energy savings attributed to the PSE Duct Ninja Program using an econometric model applied to *daily* billing data for a sample of PSE households enrolled in the program. In the discussion below we first describe the data used in the analysis, including a discussion of summary statistics and their implication for the analysis, and then present the analysis approach.

Description of the Data

The data set available for the analysis was a panel data set in which the cross-sectional unit was a PSE residential household and the temporal unit was a day. The data spanned the period of January 1, 2008 through March 30, 2011. 7,605 households were included in the analysis. The criterion for inclusion was the recorded installation, after January 1, 2008, of at least one of seven weatherization measures: Duct Ninja, duct insulation, attic insulation, floor insulation, wall insulation, duct sealing (duct sealing that pre-dates Duct Ninja), and Duct Ninja with the installation of an energy efficient furnace. The focus of the analysis was on the energy savings derived from the first measure – Duct Ninja (*without* a furnace install). However, as discussed in the next section, to generate good estimates of Duct Ninja savings it was necessary to account for the effects of these other weatherization measures.

The original data set provided by PSE for the analysis included 10,430 households. The final data set of 7,605 households used in the analysis was derived by the following deletions:

- 2,744 households were eliminated because they had none of the weatherization measures indicated above. Including these observations in the analysis has no effect on the estimate of savings from Duct Ninja, and so, given the large size of the data set, we excluded them.
- 67 households were eliminated because they had only electric weatherization measures installed after January 1, 2008, and the focus of the analysis is on gas savings due to Duct Ninja.
- 4 households were eliminated because the data indicated the contradiction that they had both Duct Ninja with a furnace install and Duct Ninja without a furnace install.
- 10 households were eliminated due to various issues concerning missing data.

Summary statistics relevant to the analysis are provided in Tables 2 - 4 and Figure 1. Table 2 provides frequencies of pair-wise combinations of weatherization at the household level. Diagonal elements indicate the number of times a particular weatherization measure appears, and off-diagonal elements indicate the pair-wise combinations. Of the 7,605 households in the sample, 1,790 (23.54%) received Duct Ninja, 1,230 (16.17%) received both Duct Ninja and floor insulation, 1,203 (15.82%) received both Duct Ninja and duct insulation, and so forth.

Table 3 provides the number of pair-wise combinations of weatherization measures that appear in 1,790 households *with* Duct Ninja. Diagonal elements indicate the number of times a particular weatherization measure appears with Duct Ninja, and thus correspond to the off-diagonal elements of the first column of Table 2. The off-diagonal elements present the information on pair-wise combinations appearing with Duct Ninja. The most common pair-wise combination of measures occurring with Duct Ninja is duct insulation and floor insulation—945 sample households have Duct Ninja, duct insulation and floor insulation (53% of Duct Ninja households).

Because the unit of observation was a household-day, and the study period was January 1, 2008 through March 30, 2008, the total number of observations in the analysis is quite large – 8,818,723. Table 4 presents the number of observations with various pair-wise combinations of weatherization measures, with diagonal elements indicating the number of times a particular weatherization measure was observed in the data set. The most common weatherization measure in the data is attic insulation, which appears in 3,282,770 observations (37.23% of observations), while Duct Ninja is observed in 760,425 observations (8.62% of the total observations). The weatherization measure that appears most frequently with Duct Ninja is floor insulation (537,373 observations, 6.09% of all observations), followed closely by duct insulation (529,007 observations, 6.00% of all observations).

Table 2. Number of Sample Households Receiving Weatherization Measures During the Study Period (N=7,605).[a]

	Duct Ninja	Duct Ins.	Attic Ins.	Floor Ins.	Wall Ins.	Duct Sealing	Duct Ninja with Furnace
Duct Ninja	1,790						
Duct Ins.	1,203	2,739					
Attic Ins.	700	1,128	4,010				
Floor Ins.	1,230	2,150	1,363	3,588			
Wall Ins.	202	445	923	696	1,918		
Duct Sealing	0	370	208	271	113	413	
Duct Ninja with Furnace	0	6	6	9	2	0	232

[a]Diagonal elements indicate the number of households with the weatherization measure; off-diagonal elements indicate the number of households with pair-wise combinations of weatherization measures. *Source: Navigant analysis*

Table 3. Pair-Wise Combinations of Weatherization Measures in Households *with* Duct Ninja Installed (N=1,790)[a]

	Duct Ins.	Attic Ins.	Floor Ins.	Wall Ins.
Duct Ins.	1,203			
Attic Ins.	499	700		
Floor Ins.	945	458	1,230	
Wall Ins.	148	115	137	202

[a]Diagonal elements indicate the number of households with the weatherization measure; off-diagonal elements indicate the number of households with pair-wise combinations of weatherization measures. *Source: Navigant analysis*

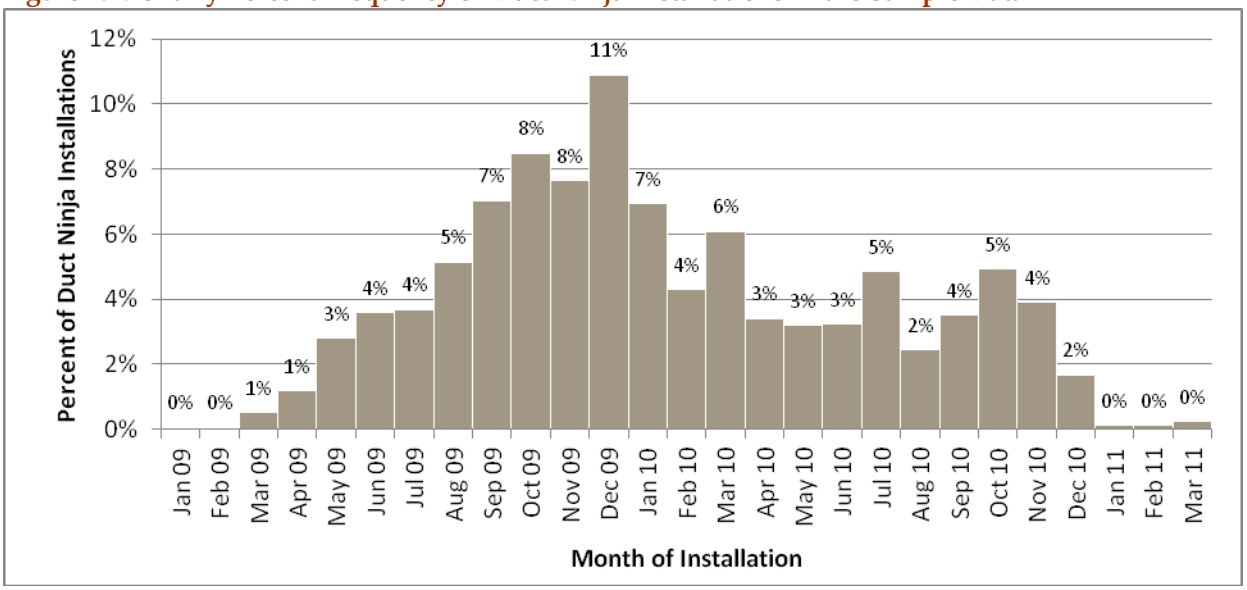
Table 4. Frequency that Weatherization Measures are Observed in the Analysis Data Set (An Observation was a Household-Day; N=8,818,723)[a]

	Duct Ninja	Duct Ins.	Attic Ins.	Floor Ins.	Wall Ins.	Duct Sealing	Duct Ninja with Furnace
Duct Ninja	760,425						
Duct Ins.	529,007	2,026,236					
Attic Ins.	300,563	837,534	3,282,770				
Floor Ins.	537,373	1,597,768	1,036,085	2,748,668			
Wall Ins.	93,946	359,768	768,438	568,380	1,629,514		
Duct Sealing	0	389,178	212,559	288,357	120,247	432,687	
Duct Ninja with Furnace	0	2,518	3,228	4,454	1,159	0	124,019

[a]Diagonal elements indicate the number of observations of the weatherization measure; off-diagonal elements indicate the number of observations of pair-wise combinations of weatherization measures. *Source: Navigant analysis*

Figure 1 provides the frequency distribution of months in which Duct Ninja was installed. Duct Ninja began being installed in January 2009 and the pace of installation stayed between 3-9% of all installations for most of the study period. As discussed below, that Duct Ninja was installed steadily over a long period of time was a critical aspect of the statistical analysis of savings.

Figure 1. Monthly Percent Frequency of Duct Ninja Installations in the Sample Data



Source: Navigant analysis

Analysis Approach

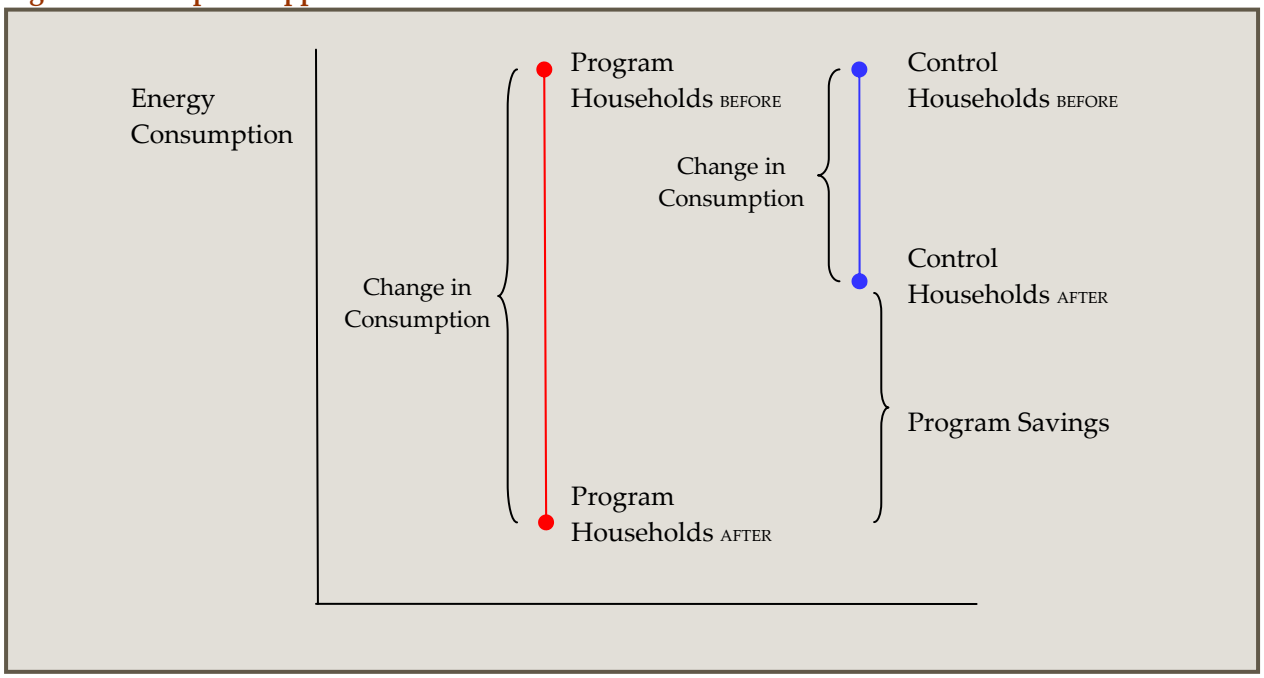
Estimates of savings from Duct Ninja are obtained via regression analysis. The basic conceptual model guiding the analysis is illustrated in Figure 2. Data on daily therm consumption revealed changes in a household's energy consumption before and after receiving weatherization. Even after correcting for differences in weather and other factors, it is important to note that the difference may not be due entirely to the weatherization activity; other unobserved, time-related factors may have also affected the change in energy consumption. To account for this possibility, a good analysis typically includes a set of control households drawn from the same population, but not receiving the weatherization "treatment." These additional households serve to identify the effect of these time-related factors and to thereby isolate the portion of the change that can be ascribed to the treatment.

In an experimental design, such a "good analysis" is created by randomly assigning households to the treatment and control groups, and the conceptual model illustrated in Figure 2 plays out exactly. The average difference in consumption before and after the treatment date is compared for control and treatment households, and the difference in these differences—the "difference-in-difference" (DID) statistic –is a measure of the program effect.

With non-experimental "observational" billing data, by contrast, the analyst does not have the luxury of an experimental design, and so defining a control group can be problematic. However, in this study we had a considerable advantage because Duct Ninja was implemented throughout a 21-month horizon (basically from March 2009 through December 2010; see Figure 1). And so, under the reasonable assumption that households that receive Duct Ninja late in the program period are not different than those that receive it early—or at least, not different in a way that is correlated with the effect of Duct

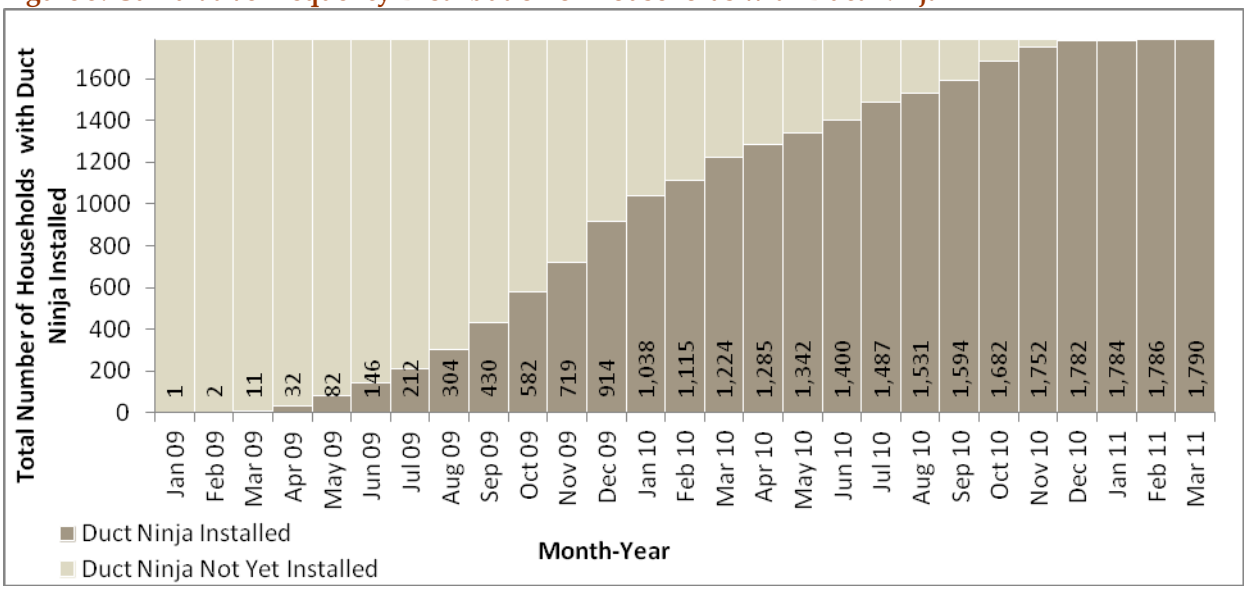
Ninja—the conceptual model is still effectively employed via regression analysis. The key insight is that households receiving Duct Ninja relatively late in the study period effectively serve as control households in the months before they receive it. Figure 3 presents the monthly allocation of Duct Ninja households between treatment households (households with Duct Ninja installed) and control households (households that eventually receive Duct Ninja, but do not have it installed in the month indicated). It shows that for the month of October 2009—the first month of the 2009 heating season—582 Duct Ninja households were effectively treatment households and 1208 were effectively control households. Similarly, in November 2009, 719 households were effectively treatment households and 971 were effectively control households; in December 2009, 914 households were effectively treatment households and 776 were effectively control households; and so on. As more households obtained Duct Ninja the size of the control group falls and the size of the treatment group rises. The conceptual point is that in a regression analysis households receiving treatment late in the study period effectively serve as control households for identifying the effect of the treatment, which in this case is the effect of energy savings of Duct Ninja. With the substantial temporal spread of installs revealed in Figure 1 and keeping in mind that observations were *daily*, the data provided an excellent foundation for identifying the effect of Duct Ninja on energy consumption.

Figure 2. Conceptual Approach to Estimation of the Conservation Effect



Source: Navigant analysis

Figure 3. Cumulative Frequency Distribution of Households with Duct Ninja



The fact that Duct Ninja was usually installed with other weatherization measures was a significant complicating factor in the analysis. This is evident in the data provided in Table 2 and Table 3 indicating that 1,203 (67%) of Duct Ninja installs also included the installation of duct insulation; 700 (39%) of Duct Ninja installs also included the installation of attic insulation. This component of the program implied two important considerations in the econometric modeling of the effect of Duct Ninja on energy consumption. First, the model must control for the effects of these other weatherization activities. Second, the model must account for the interaction between these other activities and Duct Ninja. For instance, the effect of Duct Ninja on energy consumption will change when it is installed alone versus when it is installed with duct insulation, or with floor insulation. We addressed these issues by including in the model variables for other weatherization measures, as well as interaction terms between Duct Ninja and these other measures.

A final issue in the development of the model involved handling the household-specific characteristics that influenced overall energy use. A typical approach when household panel data are available—that is, data containing multiple observations over time for each household, as in the present case—is to assign to each household its own constant, or *fixed effect*. This fixed effect encompasses all the household-specific, time-invariant variables that cause a household to use more or less energy on average than other households in the dataset. These variables include obvious ones that are often readily included in an analysis, such as square footage, as well as variables that are rarely available, such as whether the household has a woodstove, or tends to turn up the thermostat in winter. A significant statistical advantage of using household-level fixed effects in regression modeling is that they serve to remove possible correlation between variables in the model and unobserved household-level effects that would otherwise end up in the error term. Such correlation can bias regression results.

The Linear Fixed Effects Regression Model

The regression model used to estimate energy savings due to Duct Ninja took as components the following variables:

$Therms_{kt}$	=	Therms consumed by household k on day t;
HDD_t	=	Heating degree days on day t (base=65F);
DN_{kt}	=	Binary variable taking a value of 1 if Duct Ninja is present in household k on day t and 0 otherwise;
DS_{kt}	=	Binary variable taking a value of 1 if duct sealing is present in household k on day t, and 0 otherwise;
$Attic_{kt}$	=	Binary variable taking a value of 1 if attic insulation is present in household k on day t, and 0 otherwise;
$Floor_{kt}$	=	Binary variable taking a value of 1 if floor insulation is present in household k on day t, and 0 otherwise;
$Wall_{kt}$	=	Binary variable taking a value of 1 if wall insulation is present in household k on day t, and 0 otherwise;
DNF_{kt}	=	Binary variable taking a value of 1 if Duct Ninja and a new furnace are present in household k on day t, and 0 otherwise;
ε_{kt}	=	Unobserved factors affecting household therm consumption.

For households that eventually get Duct Ninja, the period over which the binary variable DN_{kt}=1 is essentially the **post**-installation period for the household.

The regression model estimated comprises these terms and a set of interactions involving them:

$$
\begin{aligned}
Therm_{kt} \;=\; & \\
& first-order\ terms: \\
& \quad \alpha_{0k} + \alpha_1 HDD_t + \alpha_2 DN_{kt} + \alpha_3 DI_{kt} + \alpha_4 DS_{kt} + \alpha_5 Attic_{kt} + \alpha_6 Floor_{kt} + \alpha_7 Wall_{kt} + \alpha_8 DNF_{kt} \\
& interactions: \\
& \quad + \beta_1 DN_{kt} \cdot DI_{kt} + \beta_2 DN_{kt} \cdot Attic_{kt} + \beta_3 DN_{kt} \cdot Floor_{kt} + \beta_4 DN_{kt} \cdot Wall_{kt} \\
& second-order\ DN\ interactions: \\
& \quad + \delta_1 DN_{kt} \cdot DI_{kt} \cdot Attic_{kt} + \delta_2 DN_{kt} \cdot DI_{kt} \cdot Floor_{kt} + \delta_3 DN_{kt} \cdot DI_{kt} \cdot Wall_{kt} \\
& \quad + \delta_4 DN_{kt} \cdot Attic_{kt} \cdot Floor_{kt} + \delta_5 DN_{kt} \cdot Attic_{kt} \cdot Wall_{kt} + \delta_6 DN_{kt} \cdot Floor_{kt} \cdot Wall_{kt} \\
& HDD\ interactions: \\
& \quad + \gamma_1 DN_{kt} \cdot HDD_t + \gamma_2 DI_{kt} \cdot HDD_t + \gamma_3 DS_{kt} \cdot HDD_t \\
& \quad + \gamma_4 Attic_{kt} \cdot HDD_t + \gamma_5 Floor_{kt} \cdot HDD_t + \gamma_6 Wall_{kt} \cdot HDD_t + \gamma_7 DNF_{kt} \cdot HDD_t \\
& third-order\ DN \cdot HDD\ interactions: \\
& \quad + \varphi_1 DN_{kt} \cdot DI_{kt} \cdot HDD_t + \varphi_2 DN_{kt} \cdot Attic_{kt} \cdot HDD_t + \varphi_3 DN_{kt} \cdot Floor_{kt} \cdot HDD_t \\
& \quad + \varphi_4 DN_{kt} \cdot Wall_{kt} \cdot HDD_t \\
& fourth-order\ DN \cdot HDD\ interactions: \\
& \quad + \psi_1 DN_{kt} \cdot DI_{kt} \cdot Attic_{kt} \cdot HDD_t + \psi_2 DN_{kt} \cdot DI_{kt} \cdot Floor_{kt} \cdot HDD_t \\
& \quad + \psi_3 DN_{kt} \cdot DI_{kt} \cdot Wall_{kt} \cdot HDD_t + \psi_4 DN_{kt} \cdot Attic_{kt} \cdot Floor_{kt} \cdot HDD_t \\
& \quad + \psi_5 DN_{kt} \cdot Attic_{kt} \cdot Wall_{kt} \cdot HDD_t + \psi_6 DN_{kt} \cdot Floor_{kt} \cdot Wall_{kt} \cdot HDD_t \\
& error: \\
& \quad + \varepsilon_{kt}
\end{aligned}
\tag{1}
$$

Several aspects of the model deserve comment and clarification:

- First, the subscript *k* on the constant term α_{0k} indicates that every household has its own constant –this is the household fixed effect.
- Second, the weatherization measure variables (DN, DI, etc.) indicate whether the measure is installed in household *k* on day *t* –i.e., whether day *t* is in the post-installation period for the measure for household *k*.
- Third, the model controls for non-Duct Ninja weatherization measures installed with Duct Ninja, and this control extends to the differential effect of these other measures on mild versus cold days (HDD interaction terms).
- Fourth, the model accounts for interactions between Duct Ninja and other weatherization measures (interactions, second-order interactions), and this accounting extends to the differential effect of such interactions on mild versus cold days (third-order Duct Ninja·HDD interactions, fourth-order Duct Ninja·HDD interactions).
- Fifth, in estimation we allow errors to cluster on households, meaning that the model allows for household-level serial correlation. The overall implication is that standard errors are larger than obtained with standard fixed effects models in which errors are not clustered, because allowing serial correlation essentially concedes that there may be less information in the data than imposed by the standard model.

The Issue of Selection Bias

The Duct Ninja program is an opt-in program, which raises the issue of whether calculated mean savings are biased upwards, in the sense that they are greater than would be obtained if households were randomly assigned to the program. The logic for selection bias is that households that can benefit most greatly from the program are most likely to enroll in it. With this in mind, all estimates of mean savings presented in this report should be understood to be unbiased estimates *conditional on customer program enrollment*. In other words, they are expected savings for households that opt into the program. Nonetheless, anecdotal evidence is that customers do not have a strong a priori understanding of their savings from Duct Ninja—as they might from, say, a rebate program for a high efficiency appliance—and so one might expect the selection bias to be fairly small.

Model Validity

The evaluation considered three types of tests of model validity. The first is whether mean daily savings were *greater* in the heating season than in the non-heating season. The second was whether mean savings were greater on colder days within the heating season. These tests merely recognized that customers ran their heating systems more on colder days, and so on such days the savings from Duct Ninja should be higher.

The third test assessed whether the mean "savings-added" from Duct Ninja was *lower* when applied with other weatherization measures, in particular duct insulation. This recognized that although overall energy savings should go up with additional weatherization measures, it is generally expected that this increase is less than additive, because to some degree weatherization measures substitute for one another –a relationship that we refer to as "thermal overlap". This substitutability relationship is most obvious with Duct Ninja and duct insulation, because adding Duct Ninja to ductwork wrapped in insulation would be expected to generate far less incremental savings than adding it to ductwork without insulation.

Measurement of Savings

The terms of the regression model (1) involving the Duct Ninja variable jointly indicate the mean effect of Duct Ninja on daily therm use, and thus jointly define the household-level mean daily savings from Duct Ninja. So, for instance, expected savings on day t for a household for which the only installed weatherization measure is Duct Ninja is,

$$Savings_{kt} = \alpha_2 + \gamma_1 HDD_t \quad . \tag{2}$$

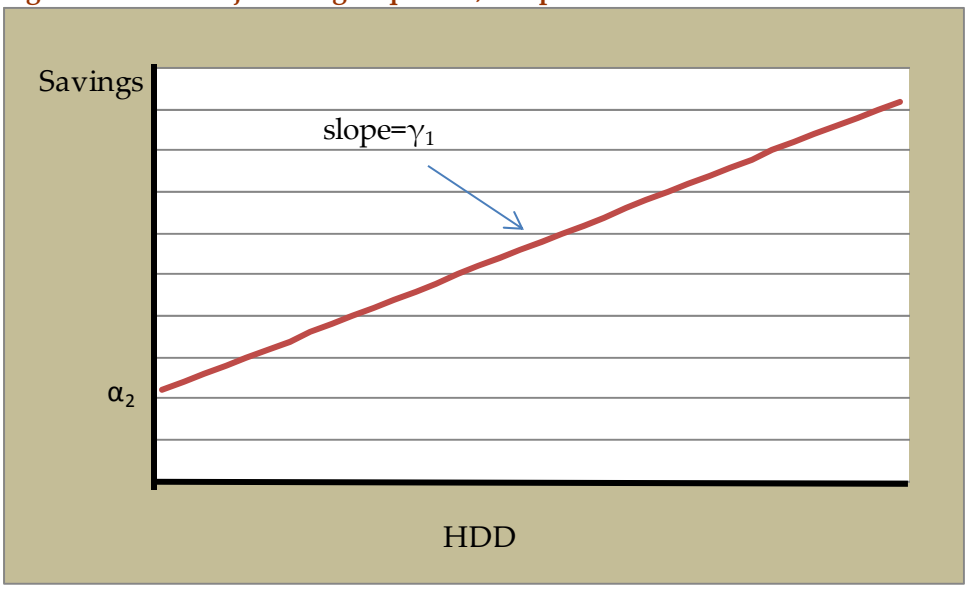
As shown in Figure 4, essentially average daily savings is estimated as a linear function of heating degree days, with intercept α_2 and slope γ_1.

As another example, for a household with both Duct Ninja and duct insulation installed, but no other measure, the expected savings on day t due to Duct Ninja is:

$$Savings_{kt} = (\alpha_2 + \beta_1) + (\gamma_1 + \varphi_1) \cdot HDD_t \; ; \tag{3}$$

Once again, savings is a linear function of HDD; installing Duct Ninja with duct insulation changes both the intercept and the slope of the savings function.

Figure 4. Duct Ninja Savings Equation, Simplest Case



Source: Navigant analysis

For a household with a given combination of measures, the estimate of *mean* daily household savings due to Duct Ninja over a specified time period (such as a particular heating season) requires using the mean value of HDD over the period in a savings equation that accounts for the combination of weatherization measures with which Duct Ninja is installed. Extending this logic, the calculation of mean daily household savings due to Duct Ninja *in a population* requires using the mean value of all variables in the model—not just the mean value of HDD, but the mean value of all the various interaction terms as well—in the following generalized savings equation (where "bars" indicate variable means):

$$
\begin{aligned}
\overline{Savings}_{kt} \quad &= \alpha_2 \overline{DN}_{kt} + \beta_1 \overline{(DN_{kt} \cdot DI_{kt})} + \beta_2 \overline{(DN_{kt} \cdot Attic_{kt})} \\
&+ \beta_3 \overline{(DN_{kt} \cdot Floor_{kt})} + \beta_4 \overline{(DN_{kt} \cdot Wall_{kt})} \\
&+ \delta_1 \overline{(DN_{kt} \cdot DI_{kt} \cdot Attic_{kt})} + \delta_2 \overline{(DN_{kt} \cdot DI_{kt} \cdot Floor_{kt})} \\
&+ \delta_3 \overline{(DN_{kt} \cdot DI_{kt} \cdot Wall_{kt})} + \delta_4 \overline{(DN_{kt} \cdot Attic_{kt} \cdot Floor_{kt})} \\
&+ \delta_5 \overline{(DN_{kt} \cdot Attic_{kt} \cdot Wall_{kt})} + \delta_6 \overline{(DN_{kt} \cdot Floor_{kt} \cdot Wall_{kt})} \\
&+ \gamma_1 \overline{(DN_{kt} \cdot HDD_t)} \\
&+ \varphi_1 \overline{(DN_{kt} \cdot DI_{kt} \cdot HDD_t)} + \varphi_2 \overline{(DN_{kt} \cdot Attic_{kt} \cdot HDD_t)} \\
&+ \varphi_3 \overline{(DN_{kt} \cdot Floor_{kt} \cdot HDD_t)} + \varphi_4 \overline{(DN_{kt} \cdot Wall_{kt} \cdot HDD_t)} \\
&+ \psi_1 \overline{(DN_{kt} \cdot DI_{kt} \cdot Attic_{kt} \cdot HDD_t)} + \psi_2 \overline{(DN_{kt} \cdot DI_{kt} \cdot Floor_{kt} \cdot HDD_t)} \\
&+ \psi_3 \overline{(DN_{kt} \cdot DI_{kt} \cdot Wall_{kt} \cdot HDD_t)} + \psi_4 \overline{(DN_{kt} \cdot Attic_{kt} \cdot Floor_{kt} \cdot HDD_t)} \\
&+ \psi_5 \overline{(DN_{kt} \cdot Attic_{kt} \cdot Wall_{kt} \cdot HDD_t)} + \psi_6 \overline{DN_{kt} \cdot Floor_{kt} \cdot Wall_{kt} \cdot HDD_t}
\end{aligned}
\qquad . \qquad (4)
$$

So, for instance, if the analyst is interested in mean daily savings for a population of Duct Ninja installs in which 62% of installs are Duct Ninja only, 27% are Duct Ninja and duct insulation only, and the remaining 11% are Duct Ninja with duct insulation and floor insulation, the relevant application of the generalized savings equation (4) is:

$$
\overline{Savings}_{kt} \quad = \alpha_2 + 0.27 \cdot \beta_1 + 0.11 \cdot \delta_2 + \gamma_1 \cdot \overline{HDD} + 0.27 \cdot \varphi_1 \cdot \overline{HDD} + 0.11 \cdot \psi_2 \cdot \overline{HDD} \qquad (5)
$$

Finally, the calculation of mean daily household savings due to Duct Ninja in a population for a *historical* heating season in which measures are installed *during* the heating season—as was the case in the study period January 2008 through March 2011—is an application of the generalized savings equation in which mean values of variables pertain to the mean values across all observations, where an observation is a household-day.

In all cases, the calculation of standard errors on daily household savings involves pre- and post-multiplying the coefficient covariance matrix by the terms of the relevant savings function, and taking the square root of this product.[7]

[7] See, for instance, Cameron and Trivedi, "Microeconometrics: Methods and Applications", Cambridge University Press (2006), pg.137.

Billing Analysis Results

As noted earlier, savings estimates attributed to Duct Ninja were derived from the model in Equation (1) and estimated separately for the heating season (October-April) and non-heating season. A discussion of the data used in the estimation is provided in the subsection *Description of the Data*, above. Parameter estimates and standard errors are also presented in Appendix A. In the analysis, Navigant clustered the errors ε_{kt} by household to account for the likely correlation in errors over time for a given household. Failing to correct for such household-level correlation does not bias the parameter estimates but does yield incorrect standard errors and therefore generates biased statistical inference (e.g. biased t-statistics).

In general for the heating season, the parameters corresponding to individual measures, HDD, and the interaction of individual measures with HDD are statistically different from zero. Interactions between Duct Ninja and other weatherization measures generally are not statistically significant, the exceptions being the interactions between Duct Ninja and duct insulation, and Duct Ninja and attic insulation. It deserves emphasis that in general the statistical significance of individual parameters are not the focus of this analysis because, as seen in equations (2)-(5), estimates of savings generally depend on linear combinations of parameters. Consequently, the standard errors on savings depend on the covariances among the relevant parameters.

Daily Savings Estimates for Various Combinations of Duct Ninja and other Weatherization Measures

Navigant examined the average daily savings resulting from Duct Ninja when installed alone and in combination with other weatherization measures. The results appear in Table 5, Figure 5, and Figure 6. These estimates assume average heating degree days for the season (the heating season October-April, and the non-heating season May-September) as indicated by weather data for the 30-year period 1981-2010. Highlights of the savings estimates include:

1. On average, Duct Ninja generates larger daily savings during the heating season than the non-heating season, and this holds for each combination of weatherization measure appearing in Table 5. This result is one of the indicators of model validity discussed in the subsection *Model Validity*.

2. In those few cases where estimated savings are negative, they are not statistically different from zero (10% significance level).

3. The (incremental) savings effect of Duct Ninja is generally less—sometimes much less—when combined with other weatherization measures. Essentially this is because of "thermal overlap" – some of the energy savings gained by Duct Ninja when it is applied in isolation is captured by the other measure(s) when it is combined with these measures. This is illustrated in Figure 7 for the case where Duct Ninja is installed with duct insulation. The incremental effect of Duct Ninja in the presence of duct insulation is the blue area. The results presented in Table 5, Figure 5, and Figure 6 indicate that thermal overlap is strongest when Duct Ninja is combined with duct

insulation, and weakest when it is combined with wall insulation—a quite intuitive outcome. Moreover, in general the overlap increases when Duct Ninja is combined with two other weatherization measures rather than one. So, for instance, savings from Duct Ninja when combined with duct insulation and floor insulation is less than when Duct Ninja is combined with either alone. Referring again to the subsection *Model Validity*, Navigant considers the presence of such thermal overlap in the estimated model to be another indication of model validity.

When Duct Ninja is installed alone, average savings per day in an average heating season are 0.41 therms. When it is installed jointly with just one additional weatherization measure (duct, attic, floor, or wall insulation), incremental savings due to Duct Ninja range from 0.09 to 0.39 therms per household per day. The lower end of this range occurs when Duct Ninja is jointly installed with duct insulation, indicating that duct insulation is highly effective at reducing energy consumption. The most common pair of weatherization measures combined with Duct Ninja is duct insulation and floor insulation (53% of all Duct Ninja households have this combination). When Duct Ninja is combined with duct insulation alone the incremental effect of Duct Ninja is (as already indicated) 0.09 therms per day. When Duct Ninja is combined with floor insulation alone the incremental effect of Duct Ninja is 0.32 therms per day. When Duct Ninja is combined with duct insulation and floor insulation together the incremental effect is 0.04 therms per day.

A notable statistical insight provided by Figure 5 and Figure 6 is that where the confidence bound on the incremental effect of Duct Ninja in the figures crosses the horizontal axis at zero, *it is not possible to reject the hypothesis that the thermal overlap is complete*. More specifically, one cannot reject the hypothesis that the incremental effect of Duct Ninja is zero.[8] With reference to the illustration in Figure 7, this means it is not possible to statistically reject the conclusion that the two circles overlap completely. Figure 5 shows that in the heating season this is regularly the case when duct insulation is installed with Duct Ninja, and Figure 6 shows that this is almost always true during the non-heating season. Although our best estimate of the average incremental effect of Duct Ninja with duct insulation is the estimate provided in Table 5—0.09 therms per day—we cannot reject, with 90% confidence, that the effect is actually 0.

A somewhat different perspective on the relationship between Duct Ninja and other installation measures is provided by the combined savings of Duct Ninja with these other measures; the full area of the two circles in Figure 7Figure 7. Figure 8 and Figure 9 present these values. The most notable result, indicated by the substantial overlap of confidence bounds for Duct Ninja alone and Duct Ninja with duct insulation, is that the savings from Duct Ninja with duct insulation is not statistically different from the savings with Duct Ninja alone. In light of the results above indicating that complete thermal overlap between Duct Ninja and duct insulation can't be rejected, this result is not surprising.

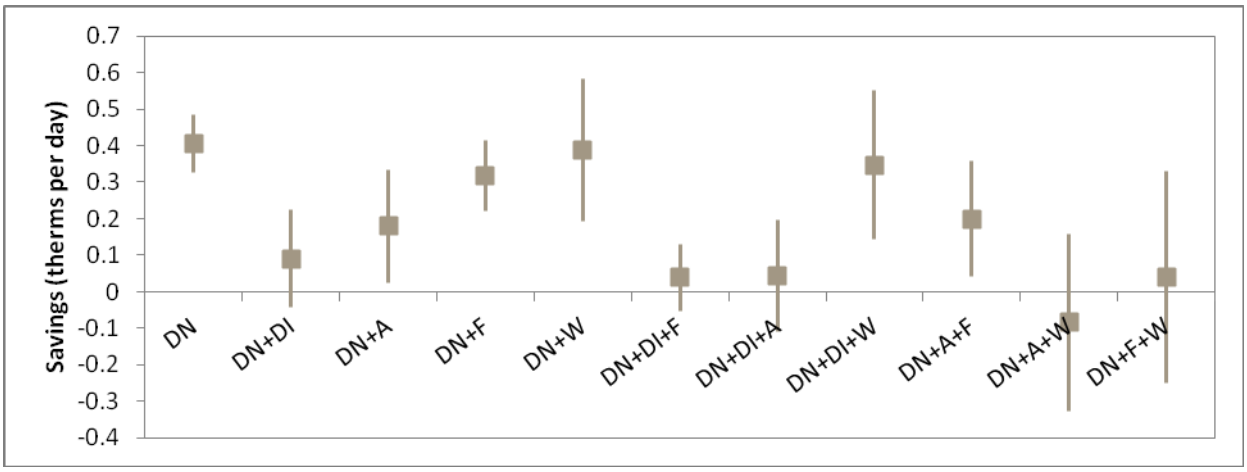
[8] It deserves emphasis that our best estimate of the incremental effects of Duct Ninja when combined with other measures are the estimates obtained from the regression analysis—the estimates in Table 5, which correspond to the "squares" in Figures 5 and 6). If the true incremental effect is close to zero, a larger sample size would generate statistically significant results.

Table 5: Incremental Duct Ninja Savings, per household, per day (therms)

Household Set	Savings, Heating Season	Standard Error	Savings, Non-Heating Season	Standard Error
Duct Ninja Only	0.4058	0.0484	0.1191	0.0245
Duct Ninja + Duct Ins.	0.0904	0.0812	-0.0205	0.0321
Duct Ninja + Attic Ins.	0.1793	0.0939	0.0392	0.0401
Duct Ninja + Floor Ins.	0.3168	0.0589	0.1272	0.0258
Duct Ninja + Wall Ins.	0.3871	0.1187	0.0225	0.0427
Duct Ninja + Duct Ins. + Floor Ins.	0.0390	0.0560	-0.0114	0.0213
Duct Ninja + Duct Ins. + Attic Ins.	0.0441	0.0920	-0.0340	0.0381
Duct Ninja + Duct Ins. + Wall Ins.	0.3462	0.1237	0.0048	0.0439
Duct Ninja + Attic Ins. + Floor Ins.	0.1991	0.0953	0.0393	0.0399
Duct Ninja + Attic Ins. + Wall Ins.	-0.0841	0.1465	-0.0690	0.0519
Duct Ninja + Floor Ins. + Wall Ins.	0.0399	0.1760	0.0017	0.0572

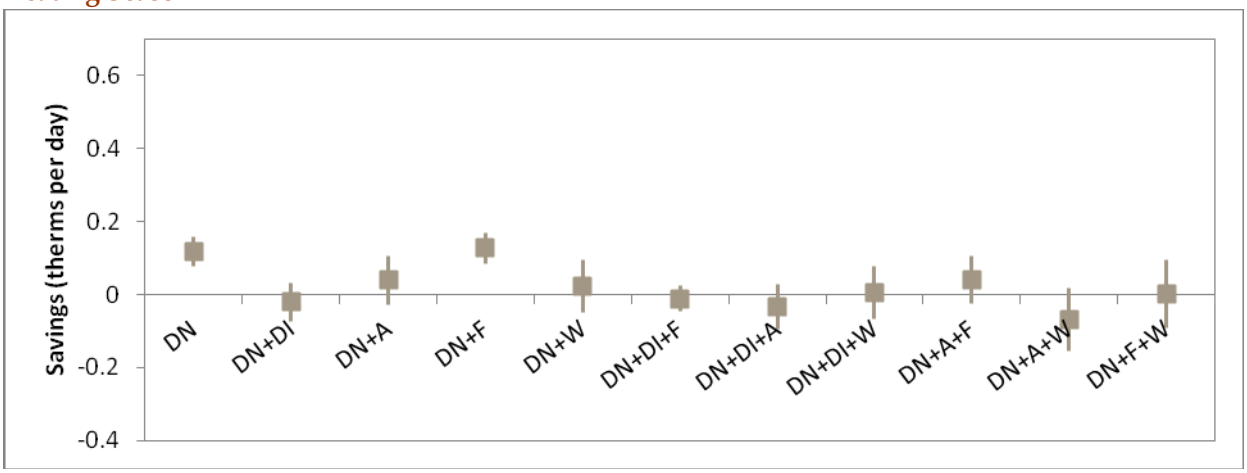
Source: Navigant analysis

Figure 5. 90% Confidence Intervals on Incremental Duct Ninja Savings (therms per day), Heating Season[a]



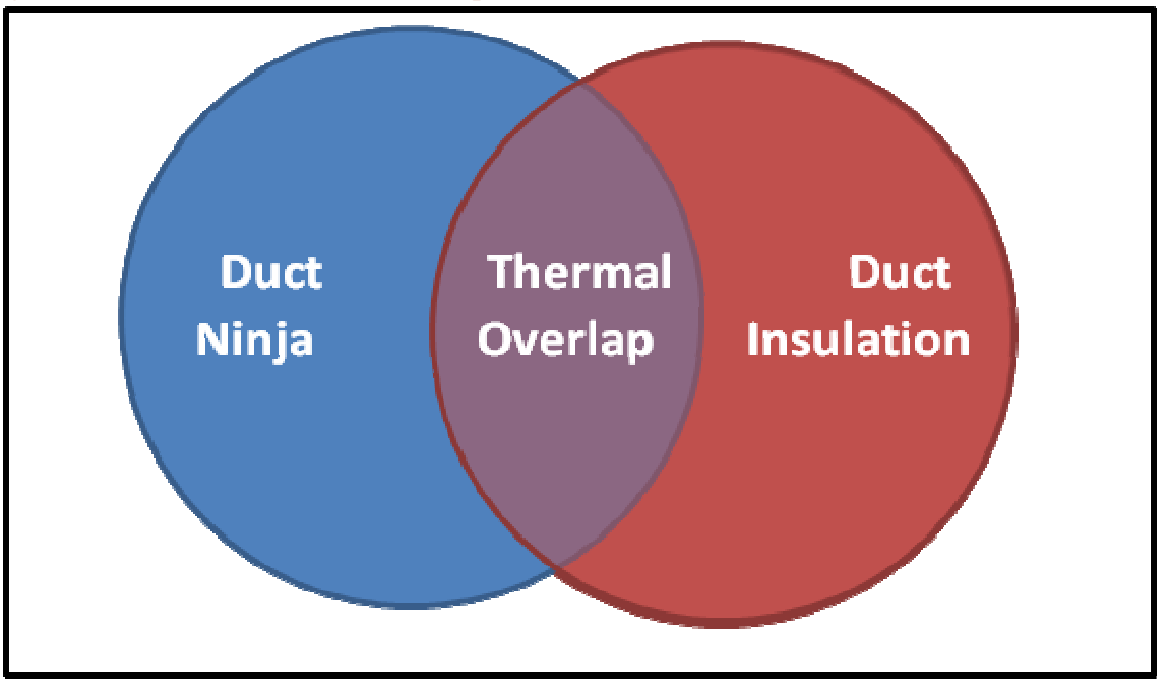
[a]DN=Duct Ninja; DI=duct insulation; A=attic insulation; F=floor insulation; W=wall insulation. *Source: Navigant analysis*

Figure 6. 90% Confidence Intervals on Incremental Duct Ninja Savings (therms per day), Non-Heating Season[a]



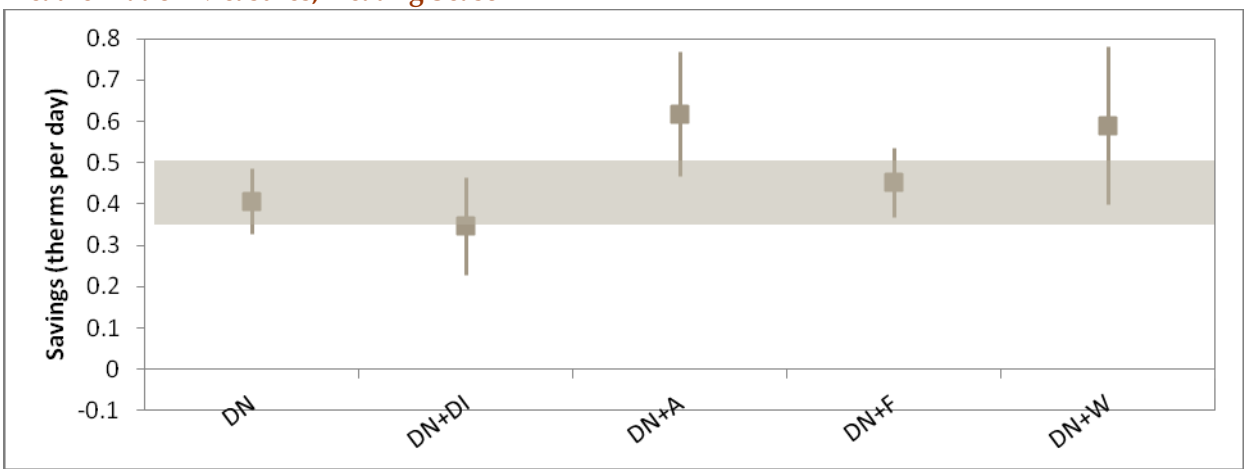
[a]DN=Duct Ninja; DI=duct insulation; A=attic insulation; F=floor insulation; W=wall insulation. *Source: Navigant analysis*

Figure 7. Illustration of Thermal Overlap



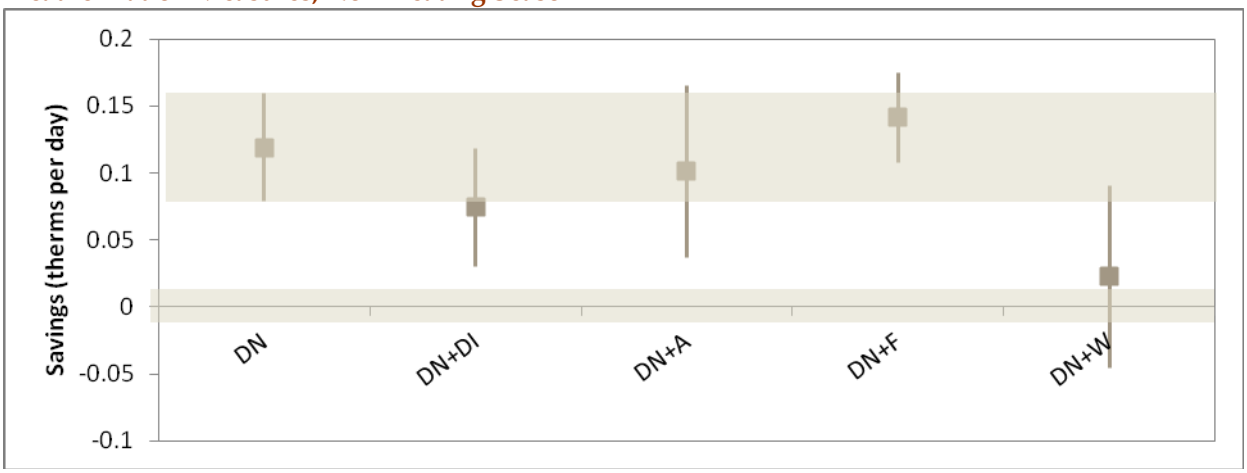
Source: Navigant analysis

Figure 8. 90% Confidence Intervals on Total Savings (therms per day) Due to Combinations of Weatherization Measures, Heating Season[a]



[a]Shading indicates the 90% confidence interval for Duct Ninja alone. *Source: Navigant analysis*

Figure 9. 90% Confidence Intervals on Total Savings (therms per day) Due to Combinations of Weatherization Measures, Non-Heating Season[a]



Seasonal and Annual Average Savings Estimates due to Duct Ninja

The discussion above concerns the energy savings attributable to Duct Ninja with other weatherization measures given that heating degree days are set at their daily average for the 30-year period 1981-2010. In this section we now turn to the "typical" incremental savings due to Duct Ninja, where we use the observed combinations of weatherization measures in the sample in the generalized savings equation (4) to estimate incremental mean seasonal and annual savings.

There are three mixes of Duct Ninja and other weatherization measures of particular interest because of the frequency with which they occur in the program population, and consequently they are the focus of the seasonal and annual average savings estimates presented below:

1. **Mix 1—Overall Duct Ninja Mix**: This is the mix of weatherization measures among the 1,790 Duct Ninja households. Table 6 gives the proportion of weatherization combinations for the 1,790 households with Duct Ninja.[9] So, for instance, 39% of all Duct Ninja households have attic insulation, 26% have attic and floor insulation, and so on.
2. **Mix 2—Duct Ninja/Duct Insulation mix**: this is the mix of weatherization measures among the 1,203 Duct Ninja households that also have duct insulation (67% of all Duct Ninja households). Table 7 gives the proportion of weatherization combinations for these households.
3. **Mix 3: Duct Ninja/Duct Insulation/Floor mix**: this is the dominant 3-way combination of measures; 945 Duct Ninja households (53% of all Duct Ninja households) had this combination of weatherization measures. Table 8 gives the proportion of such households that also had attic and wall insulation.

Table 6: Percentage of Duct Ninja Households with Other Measures Installed (N=1,790)

	Attic Ins.	Floor Ins.	Wall Ins.	Duct Ins.
Attic Ins.	39%			
Floor Ins.	26%	69%		
Wall Ins.	6%	8%	11%	
Duct Ins.	28%	53%	8%	67%

Source: Navigant analysis

Table 7: Percentage of Duct Ninja/Duct Insulation Households with Other Measures Installed (N=1,203)

	attic	floor	wall
attic	41%		
floor	31%	79%	
wall	7%	9%	12%

Source: Navigant analysis

Table 8: Percentage of Duct Ninja/Duct Insulation/Floor Insulation Households with Other Measures Installed (N=945)

	attic	wall
attic	39%	
wall	7%	12%

Source: Navigant analysis

[9] Note that this table is simply a proportional representation of Table 3; dividing the number of households in Table 3 by the 1,790 Duct Ninja households generates the proportions in Table 6.

The estimated incremental seasonal and annual savings attributable to Duct Ninja for each of these mixes for a typical year are presented in Table 9.[10] Overall Duct Ninja generates savings of 28.90 therms per year, and this savings is statistically significant. Not surprisingly given the results presented above, when attention is restricted to the mixes of weatherization measures that include duct insulation, estimated savings drop considerably and are not statistically different than zero.

Table 9: Average Incremental Savings Due to Duct Ninja in Therms/Household, by Season and Annually, for prominent Duct Ninja Weatherization Mixes (see text for definitions of weatherization mixes; standard errors in parentheses)[a]

Weatherization Mix	Heating Season Savings	Non-Heating Season Savings	Annual Savings
Mix 1: Duct Ninja	26.95*** *(6.59)*	1.95 *(1.89)*	28.90*** *(6.86)*
Mix 2: Duct Ninja + Duct Ins.	11.48 *(8.91)*	-3.05 *(2.55)*	8.43 *(9.27)*
Mix 3: Duct Ninja + Duct Ins. + Floor Ins.	9.82 *(9.70)*	-3.67 *(2.78)*	6.15 *(10.09)*

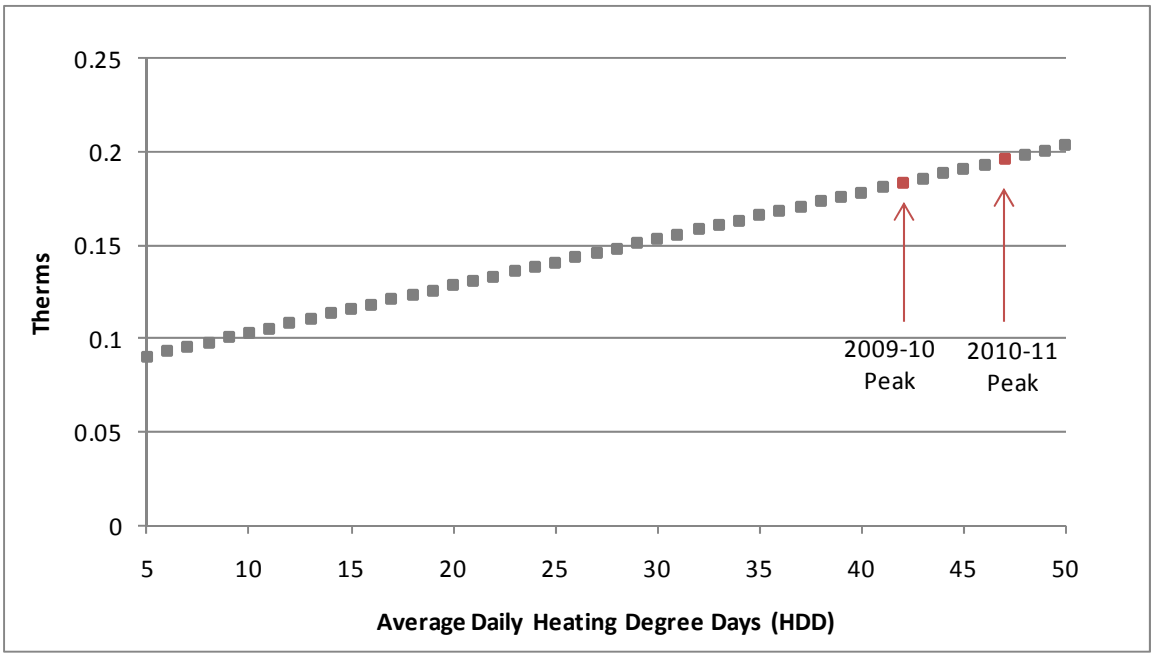
[a]Statistical significance at the .01 level indicated by *** . *Source: Navigant analysis*

Peak Savings

Savings estimates vary with Heating Degree Days (HDD). In general, an increase in HDD results in larger estimated savings with peak savings occurring on the coldest day of the year. Figure 8 illustrates the relationship between HDD and daily savings for the overall Duct Ninja weatherization mix (Mix 1), and identifies the peak daily savings for this mix in the 2009-10 and 2010-11 heating seasons. Table 10 provides the average annual peak daily savings for each of the three common Duct Ninja mixes for the average coldest day of the year over the period 1981-2010. Peak Duct Ninja savings estimates are statistically different from zero for the overall Duct Ninja mix and for the Duct Ninja/Duct Insulation mix, but not for the Duct Ninja/Duct Insulation/Floor Insulation mix. Peak Duct Ninja savings are approximately 49% higher than average savings for a typical heating season.

[10] The typical year assumes total heating season HDD equal to 4,146, and total non-heating season HDD equal to 603.3.

Figure 10. Average Daily Duct Ninja Savings per Household, by Heating Degree Days (Heating Season)



Source: Navigant analysis

Table 10: Average Peak Savings per Household (Therms per Day)

Household Set	Peak Day Savings	Standard Error
Duct Ninja	0.1897	0.0664
Duct Ninja + Duct Ins.	0.1718	0.0896
Duct Ninja + Duct Ins. + Floor Ins.	0.1217	0.1014

Note: Standard errors are clusterd on the household

Heating Degree Days = 44.6

Source: Navigant analysis

Methodology for the Process Evaluation of PSE's Duct Ninja Program

As noted earlier, the initial on-site Measurement & Verification (M&V) process revealed uncertainty related to the baseline conditions of participating homes. This uncertainty was a product of three program design and implementation characteristics:

4. The current program qualifying criteria are not aligned with the desired participant base.

5. The current procedures for qualifying program participants do not adequately verify the eligibility of participating homes.

6. The tracking database maintained by the program implementation contractor does not adequately define the baseline condition of participating duct systems.

The following subsections provide more detail on each of these issues, supported by an in-depth review of PSE's Program tracking database. The findings from this effort were used to inform and validate in-depth interviews with 15 duct sealing contractors representing 80% of Duct Ninja activity in the 2009-2010 Program Cycles.

The Current Program Qualifying Criteria are not Aligned with the Desired Participant Base

A thorough review of existing program materials and bid applications revealed that the current program qualifying criteria does not preclude homes with pre-existing duct insulation and sealing from receiving Duct Ninja services. As a result, the program may accept rebate applications for homes that yield lower than expected savings.

The current program eligibility requirements procured from existing program documentation are provided below: [11]

> *Home was built after 1990 or home was built before 1990, but is a fully insulated building defined as: attic insulation is 12" or greater, floor insulation is 6" or greater, and wall insulation is 3" or greater. Insulation must be intact and functioning.*
>
> *For homes that do not meet the above requirements, the customer should be directed to the PSE Quality Assured Duct Sealing Program. This program offers free duct sealing with the installation of 1 qualifying insulation measure (wall, attic, duct, or floor).*
>
> *Additional requirements:*
>
> - *Must be a residential PSE customer who uses electricity or natural gas from PSE as the primary heating source*

[11] QA Duct Sealing overview for Bobbi 2010-06-21 v2.docx

- *At least 30% of the ducts must be in the following unconditioned spaces:*
- *Crawl spaces*
- *Garages*
- *Attics*

The Uniform Bid Form[12] (UBF) provides additional criteria for participating homes, including:

> *Eligible pre-existing condition defined as ducts not in disrepair […] Duct sealing includes minor repair not to exceed 3 linear feet of duct replacement.*

Finally, Table 11 details the qualifying criteria for individual weatherization measures, any one of which may serve as a prerequisite for duct sealing services:

Table 11: PSE Weatherization Program Qualification and Incentive Matrix[13]

Measure	Incentive	Pre-Existing Condition	Post-Installation Condition
Attic Insulation	50% of cost up to $200 total incentive	0 to 4 inches of any type of insulation	As close to R-38 as possible
Floor Insulation	50% of cost up to $200 total incentive	Empty cavity – must not contain any insulation	R-30 or fill the joist cavity, whichever comes first
Wall Insulation	50% of cost up to $200 total incentive	Empty cavity – must not contain any insulation	R-13 blow in or Batt
Duct Insulation	50% of cost up to $200 total incentive	1 inch or less of any type of insulation	R-11 Batt Insulation
Duct Sealing	**FREE by trained authorized contractor when a customer purchases any qualifying insulation measure.**	**Ducts not in disrepair, over 30% of ducts accessible from the exterior**	**All accessible ducts sealed and repaired with a limit of 3 lineal feet or less of duct replacement**

And while the qualifying criteria are consistent across the program materials, they exhibit *qualitative* properties open to interpretation by participating duct sealing contractors. Similarly, the qualifying criteria do not adequately address the physical characteristics of duct systems which may influence the ability to perform the prescriptive duct sealing services. Collectively, this lack of specificity contributed towards the baseline uncertainty of participating homes.

[12] Appendix A
[13] QA Duct Sealing eligibility and contractors 2010-07-21.xlsx

As an example, during the course of the study, a past Weatherization Program participant was recruited to support the on-site Measurement & Verification component of the evaluation. Though the customer qualified for duct sealing through the program criteria, field staff confirmed that the duct system *appeared* to be well insulated and sealed. Unbeknownst to the evaluation team, the same customer also received three bids for insulation & duct sealing services as a new Weatherization Program participant through the installation of a new weatherization measure. And of the three bids, two duct sealing contractors recommended duct sealing, while one did not.

This experience, coupled with contractor feedback procured through the interview process, indicated the potential for variability in prescriptive duct sealing practices currently adopted by the program contractors, while bringing to light two very important questions:

1. What is the average program practice for qualifying a participating home?

2. What is the average condition of duct systems prescriptively sealed through the program?

Though the particular duct system qualified for sealing by existing program standards, it was not consistent with program expectations of the participant base; preliminary discussions with the implementation contractor indicated that participating duct systems were in poor condition and prescriptive duct sealing almost always accompanied duct insulation.

However, a review of the program database[14] revealed that of 1969 unique participants receiving prescriptive duct sealing between January 1st, 2009 and June 24th, 2010 through the Gas Weatherization Program, only 1,333 also received duct insulation (68%). And of the 2010 Gas Weatherization Program participants recruited over a two month period, only 13 customers qualified for prescriptive duct sealing and agreed to participate in the study. This recruitment rate was not sufficient to secure the 60 pre-/post-metered duct sealing participants[15] that would support the convergent validity in logger and consumption analysis.

In an effort to meet the sampling expectations for the on-site metering analysis, the evaluation team also attempted to recruit past Gas Weatherization Program participants that had not received prescriptive duct sealing services. However, of 161 prior participants expressing interest in the study, 152 either failed to qualify under the current program participation criteria or had pre-existing duct insulation deemed too cumbersome by the participating contractors to remove. Table 12 through Table 14provide additional fidelity on the causes of Gas Weatherization Program participant recruitment failure:

[14] PSE Wx Jobs since 2006_Matches.xls

[15] Assuming a preliminary estimate of .7 as the coefficient of variation, the sample size of pre-/post-metered duct sealing participants required to achieve 90/15 in the estimate of μ was 60.

Table 12. Past Gas Weatherization Program Recruitment Statistics

Status	Quantity
Attempted Contact	516
Refused to Participate	84
Failed Screening	152
-Failed Phone Survey	*133*
- Failed On-Site	*19*
Passed	9
-Site Visit Completed	*7*
-Rescheduled - Not Yet Completed	*2*
Total	**761**

Of 152 past program participants that did not qualify for the study, 133 (88%) failed the phone survey, while 19 (12%) passed the phone survey but failed the on-site inspection. Table 13 details the causes of failed phone surveys:

Table 13. Past Gas Weatherization Program Recruitment Statistics – Failed Phone Survey

Status	Quantity
Customer Moved	3
Dual Stage Furnace	6
Duct Sealing Already Completed	7
Ducts Inaccessible	3
Ducts Not In Crawlspace/Attic	56
-Ducts in Basement	*11*
- Ducts in Conditioned Space	*45*
Heating System To Be Replaced	2
Insulated Ducts	35
No Gas Furnace	11
Unclear	4
Vacant Home	36
Total	**133**

It should be noted that duct system location and pre-existing insulation accounted for a majority of failed phone surveys – 42% and 26%, respectively.

Table 14. Past Gas Weatherization Program Recruitment Statistics – Failed On-Site

Status	Quantity
Ducts Inaccessible	1
Ducts Not In Crawlspace/Attic	3
-Ducts in Basement	*1*
- Ducts in Conditioned Space	*2*
Insulated Ducts	9
No Gas Furnace	1
Unclear	5
Total	**19**

Similarly, 3 (16%) of the 19 past program participants that passed the preliminary phone survey failed the on-site inspection because of duct location, while an additional 9 (47%) failed due to pre-existing duct insulation.

Though it may be argued that the lackluster recruitment rates were attributed to past program effectiveness, there was sufficient variability between discussions with program duct sealing contractors, the existing program database, and the evaluation field observations, to justify a more thorough investigation into the average participant baseline conditions. The 15 in-depth interviews with qualified Duct Ninja contractors participating in the Duct Ninja Program facilitated this effort and were also designed to address the second source of uncertainty related to the baseline conditions of participating homes; namely, the current procedures for qualifying program participants do not adequately verify the eligibility of participating homes.

The Current Procedures for Qualifying Program Participants Do Not Adequately Verify the Eligibility of Participating Homes

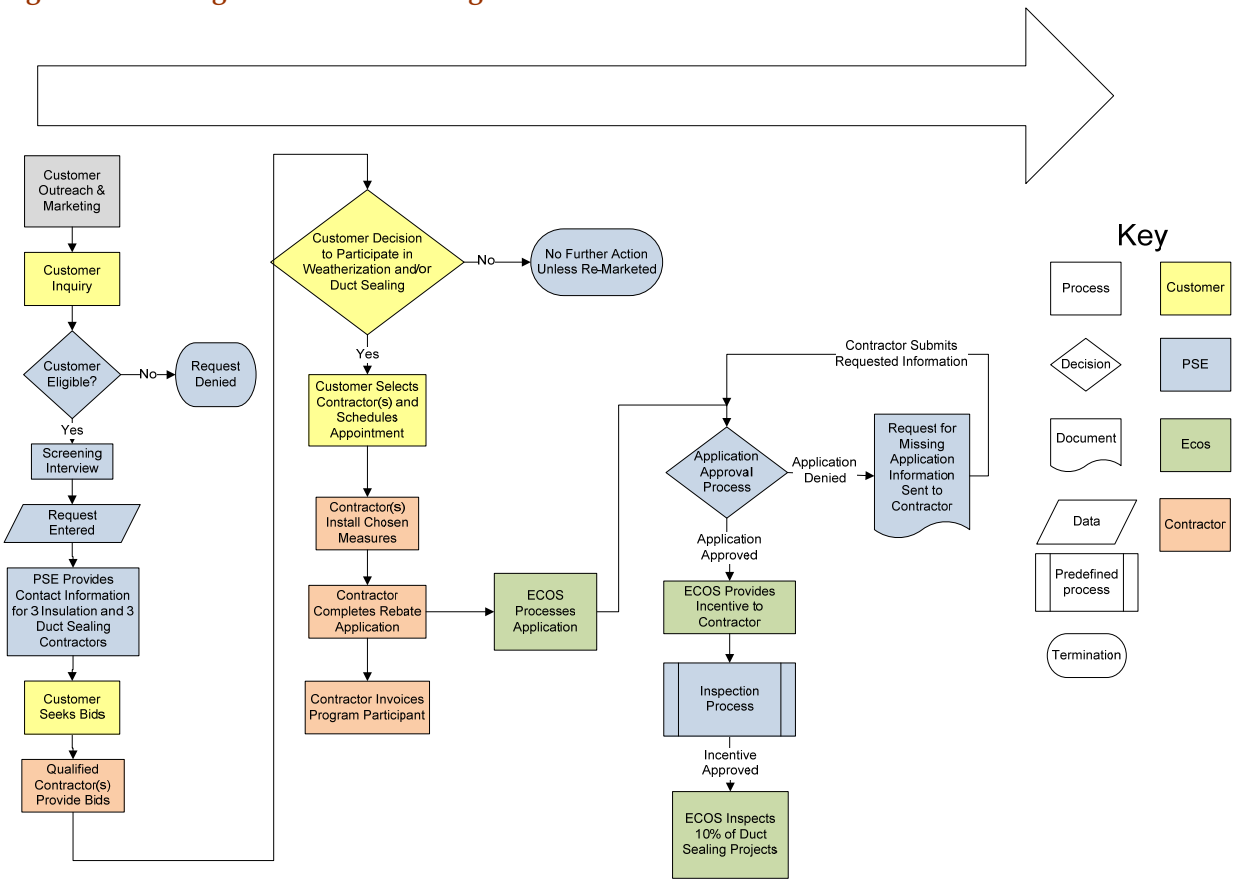
As noted earlier, the evaluation revealed a case where a participant received conflicting bids from contractors regarding the need for duct sealing services. This indicates that the contractors were either unaware of the program qualifying criteria or were not applying existing criteria correctly. In addition to refining the qualifying criteria for the program, it is equally important to develop more effective customer screening procedures.

Effective screening is an integral component of the Duct Ninja Program because the absence of pre-/post-measurement requirements has created significant uncertainty about baseline conditions and program savings potential. Program *ex ante* savings estimates are dependent on the judgment of participating contractors to baseline conditions, and their adherence to, and application of, Duct Ninja sealing standards.

To gain a better understanding of how the current service and scheduling intricacies interact with qualifying protocols, Navigant reviewed and documented the existing process flow. Figure 11 represents

the expanded Weatherization Program process flow highlighting the different tasks and responsibilities assigned to each program actor:

Figure 11. Existing Weatherization Program Process Flow



From a process and program redesign perspective, Navigant solicited contractor feedback on the recommended program pre-screening procedures intended to reduce uncertainty and verify duct sealing eligibility of participant homes. More specifically, the in-depth interviews with Duct Ninja contractors investigated the following topics, as well as those previously mentioned:

1. The project timeline in terms of how jobs are sold, how is the work scheduled, and completed. This will inform the design of the pre-/post- and post- only inspection activities:

    a. Are the proposed descriptions for the following systems accurate?

    b. Method of defining ducts system in disrepair;

    c. Method of describing preexisting insulation;

    d. Method of describing duct systems;

e. Method of describing potential duct leakage areas.

2. What quality control metrics for contractors should be implemented?

3. What program operations systems (flow paperwork flow, communications tools etc.) would contractors like to see implemented?

The Tracking Database Maintained by the Program Implementation Contractor Does Not Adequately Define the Baseline Condition of Participating Systems

As part of the evaluation effort, Navigant reviewed the existing program database and identified a number of structural and data quality issues that contributed towards the uncertainty of baseline conditions in participating homes:

1. The database is stored in one Microsoft Excel® spreadsheet that is not readily available / accessible by program staff.

2. The current structure requires the duplication of customer information if more than one weatherization measure is installed. This increases the potential for data entry error and inflates the volume of records stored.

3. The current data collection parameters are not applicable across all weatherization measures. As a result, there are a number of fields that are not relevant to a participant line item which increases the probability of data entry errors.

4. Many of the data collection parameters do not provide the information necessary to accurately assess the duct sealing eligibility and quality of a participating home. More specifically, the existing database only confirmed the following information related to the duct sealing qualification process:

    a. Whether a prerequisite weatherization measure was installed.

    b. Whether duct sealing eligibility was confirmed through weatherization services. It should be noted, however, that this field was consistently left empty which did not provide any information on the eligibility of the average duct system.

Table 15 details the information collected through the existing program database:

Table 15. Existing Program Database Structure and Parameters

Status	Description
Program Name	Gas or Electric Weatherization
Contractor Name	Name of Weatherization / Duct Sealing Contractor
Address	Address of Participant Home
City	City of Participant Home
State	State of Participant Home
Zip Code	Zip Code of Participant Home
Measure Type Name	Weatherization Measure Description
Installation Date	Date of Weatherization Service
Cost	Invoice Cost of Weatherization Services
Incentive	Invoice Cost of Weatherization Services
CheckRunDate	Date Incentive Check was Processed
Ln_Ft_	Linear Feet of Duct Insulation Installed
Sq_Ft_	Square Footage of Weatherization Measure Installed
Phone	Phone Number of Participant Home
Qty	Quantity of Weatherization Measure Installed
Begin R	Beginning R-Value of Weatherization Measure Installed
End R	Ending R-Value of Weatherization Measure Installed
Duct Sealing Inspected	Pass/Fail/No

Based on this review, Navigant recommends revising the existing Microsoft Excel® based flat file with a normalized database schema that more accurately characterizes the participant baseline and is consistent with the improved qualifying criteria and eligibility verification procedures recommended through the in-depth interviews with PSE Duct Ninja contractors. This effort would not only improve transparency, but decrease the uncertainty of estimated savings attributed to duct sealing and repair activities. Establishing the database structural improvements will define the flow of data and assist in developing consistent file structure, field name, and variable format attributes – all of which are important to the smooth and efficient operation of logistical database operations and processes. The revised database will also be more conducive to the real-time quality control of participant information being stored.

Navigant perceives the quality control of all analytical products from a "preemptive" and "reactive" perspective. This method serves to identify problems or issues relating to data quality, data quantity, or analysis methodologies early in the project work schedule so any mid-course corrections may be made while minimizing any budget and schedule impacts.

More specifically, by establishing data entry requirements and input thresholds, the improved database may preemptively circumvent potential consistency and recall issues that jeopardize the accuracy of future analysis activities. These features preemptively minimize potential quality control issues that would not otherwise be addressed as early in the program cycle.

From a reactive perspective, algorithms may be built into the revised database infrastructure to automatically identify outliers and data entry/analysis errors that may bias the accuracy of evaluation findings. The results of this exercise, including the frequency and nature of errors identified, may be presented electronically to project managers on a regular basis such that commonly recurring issues may be resolved.

Other quality control advantages afforded by an improved database are that the trained users do not need to be connected to an internal network to access and modify project level information. This is convenient for geographically diverse project team that requires frequent and convenient access to the databases and is also conducive to real-time reporting.

As part of the in-depth interview process, Navigant also investigated other parameters that should be collected in the revised database that would minimize the uncertainty associated with the participant baseline in future program cycles.

Interview Findings from the Process Evaluation of PSE's Duct Ninja Program

In depth interviews with Duct Ninja contractors were conducted to validate and solicit feedback on the uncertainty associated with the aforementioned program design and implementation characteristics:

1. The current program qualifying criteria are not aligned with the desired participant base.
2. The current procedures for qualifying program participants do not adequately verify the eligibility of participating homes.
3. The tracking database maintained by the program implementation contractor does not adequately define the baseline condition of participating duct systems.

More importantly, the interviews were structured to provide the Duct Ninja contractors with the opportunity to identify procedural areas of improvement in future program cycles that would reduce this uncertainty while improving/increasing realized savings. Table 16 provides information related to Program activity for each of the 15 contractors interviewed through the process Evaluation of PSE's Duct Ninja Program:

Table 16. Process Evaluation and Program Redesign Interview Sample

Program Contractor ID	PY 2009 – 2010 Program Activity
1	27.8%
2	6.5%
3	5.9%
4	5.6%
5	5.3%
6	5.1%
7	4.9%
8	4.3%
9	4.2%
10	3.5%
11	3.2%
12	3.0%
13	0.7%
14	0.2%
15	0.1%
Total	**80.3%**

In addition to the PSE Program Database, Navigant also reviewed a comprehensive report[16] on PSE's predecessor to the Duct Ninja Program. The report provided feedback on the previous Duct Sealing

[16] Bruce Manclark, Delta-T, Inc., Bob Davis, Ecotope, Report on Delta Q Field Testing, January 2009.

Program which was structured around pre and post duct leakage testing through a duct blaster or other similar tools. The report also identified barriers that *must be overcome* before becoming a main stream activity within PSE's residential weatherization program, including:[17]

1. Training of crews, inspectors, and utility personnel;
2. A significant investment of time to determine if these measures are appropriate (will they save energy?) on any given house;
3. High levels of Quality Control required to be effective;
4. High levels of reluctance on the part of contractors to include services with a perceived level of complication and risk;
5. Testing procedures that give incorrect and inconsistent feedback to the crews;
6. The difficulty of re-training contractors and program personnel in test procedures and importance of prioritizing repair/sealing based on duct type/accessibility;
7. The cost of testing (including training and equipment);
8. Dry holes (those are the homes that money was spent on contacting, traveling to, and testing but in which sealing was not done);
9. Time spent fixing duct leakage with only minor leakage reduction (or time spent sealing a return system rather than focusing on the supply side).

Navigant remained cognizant of these barriers associated with the previous Duct Sealing Program throughout the interview process in order to determine if they were adequately addressed through the current Duct Ninja Program. Consequently, the interviewed contractors identified several issues that aligned with these specific market barriers associated with the previous Duct Sealing Program, while revealing new barriers and program opportunities that included:

1. Contractor Dissatisfaction with the current Duct Ninja Program
    a. Excessive Lead Time for Reimbursement
    b. Difficulty Processing Paperwork
    c. Limited Prospects for Profitability
2. Uncertainty Regarding Achieved Savings
    a. Duct Ninja Contractor Performance and Sealing Protocols
        i. Lack of Contractor Training Opportunities.
        ii. Variability in the Quality of Duct Ninja Services Offered by Contractors
    b. Inadequate Description of Baseline Systems
3. Inadequate Information to Characterize the Participant Baseline

[17] Ibid.

4. Threat to Flex Duct System Life from Rodents

The following subsections provide more insight each of these issues conveyed by the duct sealing contractors and supported by the review of the existing Program Tracking Database. Moreover, these subsections also communicate contractor recommendations to address each of these issues through further research or Program process flow revisions.

Contractor Dissatisfaction with the Operation of the Program

Excessive Lead Time for Reimbursement

There was a consensus among the interviewed contractors that the interval between invoicing payment to the implementation contractor and receiving reimbursement was particularly excessive; to the point of being disruptive to their revenue stream. Of the contractors interviewed, the average lead time between submission and reimbursement was two to three months; although two contractors noted that in the worst case scenario, the lead time spanned half a year. To provide context, the contractors cited an average reimbursement lead time of one month for the Snohomish Public Utility District's (SnoPUD) Duct Sealing Program.

It is important to note that Navigant did not solicit feedback on payment lead time during the interview; instead, the contractors consistently raised the topic as an area of improvement for the Duct Ninja Program. Given this circumstance, the issue warrants further investigation and Navigant recommends the following actions:

1. PSE and ECOS should identify metrics to define the payment cycle such as the average payment time for each contractor or an aging invoice report by contractor (e.g. 30, 60, and 90+ aging);
2. If the payment cycle is deemed acceptable by PSE this should be communicated to contractors so that all parties understand what is expected;
3. If the payment cycle is deemed unacceptable by PSE then the invoicing and payment process should be reviewed for correction;
4. ECOS should identify if some contractors are having chronic aging receivables issues due to poor performance by the contractor in complying with program invoicing guidelines. These contractors should be engaged to correct deficiencies.

Difficulty Processing Paperwork

Four of the contractors, representing 12% of Program activity in 2009-2010, indicated that the administrative protocols and paperwork associated with the Duct Ninja Program were inefficient and cumbersome. These same contractors also compared the PSE Duct Ninja Program with similar duct sealing programs offered by SnoPUD, Seattle City Light, and Tacoma Power and indicated that the PSE Program was more logistically challenging (e.g., the amount of paperwork required to be completed).

Navigant concluded that this issue may not be specific to the Weatherization & Duct Ninja Program because there are a number of different avenues for a customer to receive Duct Ninja services

(previously through the HomePrint Energy Audit, etc.). Similarly, the dissatisfaction with Program protocols and paperwork may overlap with the lead time for reimbursement previously addressed. These issues are important to clarify, however, because they may adversely affect the program. More specifically, it may be discouraging contractors from actually participating in the program.

Three of the interviewed contractors, representing 14% of 2009-2010 Program activity, reported that they have used the PSE Duct Ninja Program to advertise and validate their services, while completing and charging customers for their services outside of the Program. In these cases, the contractors felt the time required to complete the paperwork and receive payment was not worth the incentive. We discuss this issue more thoroughly in the subsequent section titled: *Inability of Existing Program to Capture Spillover Savings.*

While specific recommendations are beyond the scope of our activity, we recommend investigating this issue in parallel to the lead time for reimbursement.

Limited Prospects for Profitability

All interviewed contractors indicated that although the program incentive is fixed, overhead costs often exhibit a great deal of variability based on the length of duct run, the type of duct system encountered, and the pre-existing quality of the duct system. As an example, Table 17 illustrates the most common duct systems reported by contractors in the Duct Ninja Program.[18]

Table 17. Common Systems Sealed Through the Duct Ninja Program

Duct System Types	% of Duct Ninja Projects	Approx Vintage Range
All Sheet Metal (Sheet Metal Spider)	61%	1960 - 1970
Central Sheet Metal Trunk with Flex from the Trunk to the Boot	45%	1970 - 1990
Flex from Plenum to Boot (Flex Spider or Octopus)	23%	1990 - Onward

While most of the contractors acknowledged that some homes would be more profitable than others, many spoke favorably about a tiered incentive. Notable suggestions include:

1. "The program incentive should be tied to the size of the home sealed. Though there is not a direct correlation between square footage and length of duct run, it is reasonably close."
2. "Incentive levels should account for repair services. Most systems are put together very poorly and we spend a lot of time repairing ducts that fall apart once the insulation is removed."
3. "PSE should offer a larger incentive based on the fact that a majority of duct systems we encounter are in *bad* shape"

Table 18 provides additional feedback on contractor feedback for different tiered incentive strategies:

[18] The "% of Projects" do not sum to 100% because certain contractors only provided information on select duct system types.

Table 18. Recommendations for Structuring a Tiered Incentive Mechanism

Tiered Incentive Strategy	Response Frequency
Square Footage	59%
Duct Length	28%
Duct System	13%

A majority of contractors preferred to structure incentives by square footage because:

1. There is a *relatively* stable correlation between square footage and duct length.
2. Square footage is easily assessable both on-site and online.

A tiered incentive by duct length fell out of favor with the contractors because it is difficult to measure given the limited amount of time on-site. Similarly, a majority of contractors stated that the duct system in a participating home did not provide enough information on the extent of repairs.

Feedback regarding repair services outside the scope of the Duct Ninja Program (Comments 2 & 3) was of particular importance to the interviewed contractors. Nine of the interviewed contractors, representing 63% of Program activity in the 2009-2010 cycles, indicated that they tried to negotiate major repair services outside the scope of the program (i.e., exceeding 3 lineal feet of repair) as an additional cost to the customer. All nine of the responding contractors felt this reflected poorly on their company because they were faced with presenting a final invoice that exceeded the customers' original expectations of the Program. In fact, six of the contractors, representing 54% of program activity in 2009-2010, claimed to absorb repair costs at a loss for the sake of securing the accompanying weatherization work. Notable feedback included:

1. "The problem with program is that we are often forced to eat repair costs. It is very difficult to change an invoice estimate once it is given and it is often impossible to gauge the state of the duct system before you remove the insulation on the day of the job."
2. "We've basically become an HVAC repair company. I once had to reassemble and bring in sheet metal pieces for duct system that was in poor shape. We did this for free even though a traditional repair company would have charged anywhere between $800 - $1,100 dollars."
3. "I almost always throw in a box of flex duct (i.e. 25 lineal feet) if the ducts are in bad shape. If replacements exceed a box, I notify the customer that the repairs exceed the program qualification metrics and hope the customer will call back to renegotiate a repair price."

On average, contractors reported that approximately ten percent of Duct Ninja projects fell into this category. Based on the responses received, Navigant recommends the following actions:

1. PSE should model a program design with a payment structure that provides a base compensation that is calibrated to compensate adequately for small projects while offering incremental increases in incentives based on the project size (i.e., sq. ft. of crawl space). A

majority of contractors expressed that this will strike a balance between accurately assessing the scope of sealing efforts and fairly compensating contractors for their time and materials;

2. Projects that receive additional incentives may require increased EM&V rigor;
3. Clarify qualification metrics for customers so that they fully understand the scope of Duct Ninja services and the systems that qualify. There were cases in which a homeowner thought they qualified when they did not because:
    a. The duct system required over three lineal feet of repair;
    b. The duct system was located in conditioned space (e.g., basement, attic, etc.).

    Calibrating customer expectations will improve both customer and contractor satisfaction with the Program.

Uncertainty Regarding Achieved Savings

All of the aforementioned issues collectively contribute towards the uncertainty of achieved savings by the PSE Duct Ninja Program. This final section addresses the remaining factors contributing towards this uncertainty while recommending Program revisions that seek to address each of these issues.

Duct Ninja Contractor Performance and Sealing Protocols

Our interview efforts confirmed that there is significant variation in the breadth and quality of Duct Ninja services offered by the Program's participating contractors. The following subsections further clarify these concerns with supporting examples from the 15 contractor interviews.

Inadequate Contractor Training

All 15 of the contractors interviewed indicated that the Duct Ninja training consisted of two to four on-site visits that helped them gain hands-on experience with the prescriptive duct sealing protocols. The feedback on the quality of this training was unanimously positive.

However, the interview also prompted the contractors to discuss the frequency and opportunity of additional training seminars to account for staff turnover.[19] In this case, all but one of the contractors indicated that they had not received additional training since they first entered the Program and that new staff who were marketing and selling Duct Ninja services received training internally. Similarly, all but two of the contractors interviewed indicated that they were unaware of opportunities for additional training seminars (e.g., *a refresher course*). It should be noted that the interview did not address whether the contractors *requested* training and were declined; only the *availability* of regularly scheduled training opportunities were addressed.

[19] Q5. What are the training procedures for the Duct Ninja Program? [PROBE INTO ON-SITE VISITS]
Q5A. Does your sales team receive the same training as your duct sealing contractors? [IF NO, PROBE]
Q5B. Are new staff trained internally, or are there additional training seminars offered through the Program?

Due to the fact that a Program contractors have staff offering Duct Ninja services that have not received formal Program training, adherence to the Program qualifying criteria and prescriptive sealing procedures will inevitably vary greatly among the contractors. Interviews with 15 contractors are supportive of this finding; eight contractors, representing 34% of program activity in 2009-2010, stated that they seal unconditioned basements even though Program guidelines prohibit sealing basements altogether.[20] The following subsection addresses additional variability in the duct sealing practices employed by each contractor.

In order to assure the quality of the customer qualification and acquisition process, Navigant recommends the following actions:

1. PSE should provide Duct Ninja training on a semi-annual schedule that allows contractors to have newly hired staff trained. The method of delivery (in person, web based, etc.) should be consistent with the regularly scheduled Program meetings.
2. Both the contractor representative that initially qualified a participating home, along with the contractor representative that performed the sealing services should sign the Uniform Bid Form[21] (UBF). This will improve transparency and accountability for quality control purposes.
3. The UBF should only be signed by a person who has received formal Duct Ninja training from a qualified PSE designated Program trainer.

Variability in the Quality of Duct Ninja Services Offered by Contractors

As noted above, the lack of formal training seminars to educate new staff and refresh older contractors on the Duct Ninja Program contributes significantly towards the variability of Duct Ninja practices and procedures employed by each contractor. To illustrate this point, Table 19 provides the distribution of pre-existing duct insulation in participant homes weighted by contractor Program activity in 2009-2010:

Table 19. Pre-Existing Duct Insulation Findings

Level of Pre-Existing Duct Insulation	% of Participants
No Duct Insulation	17%
Some Duct Insulation (R-2 – R-4)	73%
Full Duct Insulation (R-8 – R-11)	10%

While these results are in line with the types of homes expected to participate in the program, Duct Ninja contractors do not follow a standard protocol when sealing homes with pre-existing duct insulation. Table 20 illustrates the distribution of sealing practices by pre-existing duct insulation levels weighted by contractor activity in the 2009-2010 Program cycles:[22]

[20] It should be noted that many contractors felt the program qualifying criteria was a *moving target*
[21] PSE BID FORM-6-18-10-V9.xls
[22] The response distribution was weighted by the number of completed duct ninja applications for each contractor interviewed.

Table 20. Pre-Existing Duct Insulation Sealing Practices

Level of Pre-Existing Duct Insulation	Insulate & Seal[23]	Remove, Seal, & Reapply	Do Not Seal
No Duct Insulation	80%	0%	0%
Some Duct Insulation (R-2 – R-4)	37%	33%	0%
Full Duct Insulation (R-8 – R-11)	50%	10%	15%

Though sealing practices differ among contractors, all contractors interviewed unanimously expressed a desire for duct insulation to be mandatory prerequisite for Duct Ninja. This recommendation would require contractors to remove all pre-existing duct insulation (regardless of quality) prior to Duct Ninja, and apply new duct insulation through the Weatherization Program once the duct sealing services were completed. The most common reasons supporting this claim include:

1. "Cutting around pre-existing insulation is not practical and impedes our ability to seal leaks quickly and prescriptively."
2. "Surgically cutting into pre-existing insulation is time consuming. It is not worth the incentive to peel back the insulation and then try to reapply it."
3. "More often than not, the insulation is in bad shape anyways. The customer would be better off and achieve more savings if they received duct insulation and sealing as a paired measure."

The variability in duct sealing practices extended beyond pre-existing duct insulation protocols. Table 21 provides additional perspective on Duct Ninja sealing practices weighted by Program activity in 2009 - 2010:

Table 21. Prescriptive Duct Sealing Protocols

Subjective Duct Sealing Scenarios	Yes (%)	No (%)
Are Supply and Return Ducts Treated Equally?	27%	73%
Do You Seal Square Sheet Metal Ducts?	100%	0%
Do You Seal Panned Duct Systems	57%	43%
Do You Only Seal Flex-Duct Systems at the Connection Points?	100%	0%

Almost all of the contractors interviewed were involved with other Duct Sealing programs offered by other utilities; SnoPUD offers a 100% pre-/post-inspection duct sealing program while Tacoma Power adheres to the PTCS Duct Sealing protocols. It is clear that the absence of additional training opportunities, coupled with the different duct sealing standards used by other utilities contributes towards the variability of Duct Ninja practices observed during the interview process. As an example, four of the contractors interviewed showed a preference towards sealing supply ducts as outlined under

[23] This involves removing any pre-existing insulation, sealing the duct system, and installing new installation through PSE's Weatherization Program.

the PTCS protocol – not the Duct Ninja procedures. Based on these findings, Navigant recommends the following actions:

1. PSE should couple Duct Insulation and Duct Ninja services in future Program Cycles. This will streamline the prescriptive sealing process and reduce confusion among contractors on how to address different pre-existing insulation levels. Moreover, by removing existing (and deteriorating) insulation from existing duct systems, the Duct Ninja contractors will be able to quickly identify and repair disconnects[24] in the duct work which represent a large opportunity for savings.
2. During the regularly scheduled training seminars, PSE qualified trainers should carefully review the qualification metrics and prescriptive duct sealing priorities. This will minimize confusion with duct sealing program protocols offered in other jurisdictions.

Inability of Existing Program to Capture Spillover Savings

As noted earlier, three of the interviewed contractors, representing 14% of 2009-2010 Program activity, reported that that they are using the PSE Duct Ninja Program to advertise and validate their services while completing the work outside of the Program. This represents Program spillover[25] that is currently not captured by the Program. And although this may be corrected by improving the efficiency of program paperwork and the lead time to reimbursement, Navigant recommends revising the Program to track these activities.

Our proposed program revisions in the section titled: *Inadequate Description of Baseline Systems* accounts for this recommendation.

Threat to Flex Duct System Life from Rodents

Navigant's interviews with two Duct Ninja contractors that also provided pest control services revealed a threat to flex duct system life, and consequently, a threat to the persistence of Program savings. Feedback from these contractors, coupled with supporting claims from other weatherization contractors, revealed that rodents tend to chew through flex duct runs contributing towards leakiness in homes of all vintages. In this case, it may be necessary to implemented additional prescriptive duct sealing standards on flex systems, or at least notify contractors of the issue and prescribe corrective procedures.

Table 22 provides contractor feedback on the percentage of flex duct systems that experience leakage due to rodent damage: [26]

[24] As noted in Table 24, 89% of the Duct Ninja projects completed by the interviewed contractors involved sealing disconnects.
[25] A majority of interviewed contractors did not provide a percentage around the spillover estimate and instead noted its presence.
[26] SnoPUD currently incents homeowners to repair and replace insulation even if the damage was caused by rodents (50% or greater are damaged).

Table 22. Potential for Damage in Flex Duct Systems from Rodents

Rodent Damage	Response Frequency
Breach of Inner Lining (Air Leakage)	15%
Insulation Damage/Tears	21%

It should be noted however, that the *response frequency* exhibited significant variability because many qualified Duct Ninja contractors specialized in different practices (e.g., weatherization, pest control, etc.), while others encountered different distributions of duct systems through the Duct Ninja Program. Overall, estimates on the percentage of flex systems that are losing air because of rodent damage ranged from 2% to 30%. The feedback included:

1. One Duct Ninja contractor indicated that their primary business was pest control. Of 4,000 houses (jobs) per year, approximately 100-200 houses had problems from rodents. Of these, roughly 50 had been damaged to the extent that air loss was possible, indicating that possibly 2.5% to 5% of homes have rodent damage that has resulted in air loss in the duct system. This number may be misleading because the pest control company services homes of all vintages of homes, and the contractor could not clarify the distribution of duct systems affected by rodent damage. If up to 5% of all duct systems have damage resulting in air loss, and most damage is to flex systems, then the percentage of flex systems with damage may be considerably higher than 5%.
2. One Duct Ninja contractor indicated that 10% of full flex systems encountered suffered from rodent damage and that 2% of full flex systems will have measureable air loss from a breach of the inner lining.
3. Another Duct Ninja Contractor indicated 30% of flex systems encountered suffered from rodent damage including:
    a. Rodents using the ducting as a pathway; the shifting weight would cause ducts to disconnect.
    b. A breach of the inner lining

Though this phenomenon was outside the scope of the initial survey objectives, Navigant recognizes that rodent's represent a threat to the persistence of Program savings. Going forward, Navigant recommends that the UBF be updated to collect information on damage caused by rodents so that the issue may be further investigated while quantifying impacts.

Inadequate Description of Baseline Systems

The Delta Q Report defines various duct systems and the likely source and severity of leakage. However, this level of information about the system and implied baseline performance risk is not currently captured on the UBF or PSE Duct Sealing Quality Control & Payment Request Form (PRF). Table 23 provides a summary from the duct system comparison provided in the Delta Q report that shows the likely sources and severity of leaks, and also includes an estimated vintage based on the Delta Q report and contractor interviews.

Table 23. Revised Duct System Comparison Table[27]

Type	Vintage	Plenum Pressure	Likely Sources of Leaks	Existing Leakage	Difficulty in Sealing (1-10 where 10 is the hardest)
Vintage Seattle	< 1980	Low	Furnace to Plenum and disconnects caused by floor insulation crews	Low	2
Sheet metal Spider	1980-1990	Med to high	Furnace to Plenum and disconnects caused by floor insulation crews	Low	2
Flex Spider	> 1990	High	Plenum take- offs, furnace-to- plenum connection, bad flex	Med	3
Homes with Cavities for Returns	NA	NA	Massive return leaks	High on Return Side	10
Smorgasbord	NA	Low to high	Connections between different materials	High	10

Furthermore, Table 24 illustrates the distribution and variability of prescriptive duct sealing activities weighted by contractor Program activity in 2009-2010:

Table 24. Distribution of Prescriptive Duct Sealing Activities[28]

Other Duct Ninja Actions	% of Projects
Re-attaching Boot and Registers	84%
Sealing Take Offs	92%
Sealing Base Can Seams	65%
Repairing Disconnects	89%
Tightening Connection Points	89%
Replacing Ductwork[29]	51%

Recommendations for Future Program Cycles

Throughout the course of the in-depth interviews, Navigant emphasized the importance of improving the Duct Ninja qualification procedures while reducing the uncertainty in program performance when speaking with qualified contractors. In this way, Navigant investigated opportunities to improve future

[27] Bruce Manclark, Delta-T, Inc., Bob Davis, Ecotope, Delta Q Field Testing Summary Report, November 2008, Page 19.
[28] Duct_Ninja_Duct Sealing and Repair Guide.pdf
[29] This includes the use of Crimping, Flex Duct Knife, Notcher, and Tensioning Tools

program cycles while discussing the practicality of these program revisions with Duct Ninja contractors based on their field experience.

In an effort to ensure that the eligibility of program participants are appropriately verified, Navigant requested the contractors to provide feedback on pre-/post-inspection data collection parameters that would be most effective/efficient for assessing duct leakage across different system types. Table 25 provides information on the proposed inspection criteria and feedback received.

Table 25. Recommended Data Collection Parameters (During Sales Call) to Support Pre-/Post-Inspection Efforts

Inspection Criteria	Response Frequency
Note Discoloration (i.e., Dark Rings) at Joints	73%
Note Visible Disconnects	100%
Note System Type (e.g., Flex, Metal)	91%
Note Vintage of Home	91%
Inspect Under Existing Insulation to Determine Eligibility	27%

Overall, an overwhelming majority of the interviewed contractors were amenable to noting visible disconnects, recording the duct system type, along with the vintage of the home. Most of the contractors were also willing to identify any discoloration at duct joints as this is useful in identifying leakage, though many commented that this could take a significant amount of time depending on how many joints were inspected. Less than 30% of contractor responses were in favor of inspecting under the existing insulation to confirm eligibility, citing inadequate training of the sales staff to accurately assess this information. Moreover, many contractors stated this was labor intensive and not worth the extra time given that the Duct Ninja job may not be awarded to them.

Navigant also solicited feedback on the potential for pre-inspection on a sample of participant homes, and how this procedural change would affect the Duct Ninja contractor's business prospects. Table 26 provides information on the recommended lead time for pre-inspection efforts after a Duct Ninja contractor has been awarded work from a participating home:

Table 26. Recommended Interval for Pre-Inspection Efforts by PSE (After Sales Call)

Inspection Duration	Response Frequency
1 Business Day	0%
2-3 Business Days	28%
4-5 Business Days	43%
6-7 Business Days	12%
More than 7 Business Days	17%

Most of the contractors recognized that 2 to 3 business days did not provide enough time to schedule and perform pre-inspection activities. On the opposite end of the spectrum, however, most contractors also felt that if the interval for pre-inspection extended beyond 5 days, there would be a significant impact on sales potential due to long lead times. As such, a majority of the contractors indicated that 4 to

5 business days was an adequate compromise that would allow sufficient time for pre-inspection efforts to be scheduled, while minimizing the adverse impact on sales prospects who would like the weatherization and sealing work completed as soon as possible.

The following section recommends Program revisions, informed through the interview feedback above, that are intended to address the uncertainty in performance within the current Duct Ninja Program.

Process Evaluation Recommendations

The collective feedback obtained through Duct Ninja contractor interviews served to guide the following Process Evaluation recommendations. These recommendations involve revisions to the existing program process flow, qualifying procedures, and breadth of information collected to support both *ex ante* and *ex post* evaluation efforts.

At present there is a clear disconnect between the guidance available from the Delta Q report, and the data being collected through the Program forms. Navigant recommends a pre-/post-inspection methodology that incorporates the Delta Q Report Findings to reduce uncertainty regarding the Program baseline and corresponding savings. This will provide PSE with a cost effective quality control procedure that targets systems that demonstrate a higher potential for leakage and corresponding program savings:

1. The customer solicits bids for weatherization services and potential Duct Ninja services through qualifying contractors provided by PSE's Energy Advisor. Each contractor must complete the UBF and provide a copy to the customer when proposing a bid. The customer may or may not decide to proceed with the contractor at the time of the qualifying inspection.

2. When the customer selects the successful contractor, the contractor will then schedule the installation services. Interview findings reveal that it generally takes three to seven business days from the point of sale to the completion of weatherization and Duct Ninja services. This time varies between depending on the season by season and contractor. Winter is a more active time for most contractors and installation take longer than in the summer.
3. After the contractor receives authorization from the customer to proceed, the contractor immediately submits a signed UBF to PSE via email or fax. The UBF will be revised to collect the following keys types of information that PSE will use to assess whether or not to proceed with an inspection;
    a. The vintage of the home
    b. The approximate size of the home and the number of room served by the duct system
    c. The vintage of the duct system
    d. The type of duct system as defined in Table 23
    e. A description of any unique duct system characteristics
4. Once the UBF has been revived, PSE will decide whether to pre-inspect a home before the scheduled appointment based on two criteria;
    a. The history of the performance of the contractor such as;
        i. Was the UBF signed by person trained by PSE Duct Ninja trainer
        ii. What has been the history of previous inspections of that contractor's work

iii. How much does the contractor participate in the program

iv. Does the contractor sub-out Duct Ninja work or use internal staff

b. What is the likelihood that the home has significant duct losses based on the system profiles defined in the Delta Q report.

The pre-inspection should operate as follows;

a. The pre-inspection will confirm program eligibility and will capture baseline duct system characteristics, including:

a. Duct system type

b. Vintage of home

c. Visible Disconnections

d. Discoloration at duct joints

e. Cursory inspection under pre-existing insulation (if any) to confirm eligibility

f. Any rodent damage to the pre-existing duct system to inform future program decisions (e.g., breach of inner lining, insulation tears, etc.)

c. Within 24 hours of receiving the UBF from the contractor PSE schedule a pre-inspection with the home owner

d. The contractor will be notified to wait 5 business days before installation in order to allow PSE to complete the pre-inspection

e. The pre-inspection will consist of one of the following protocols;

i. Visual inspection, including full length of duct runs

ii. Delta Q Test

iii. Duct Pressurization Testing

f. Ineligible systems will be rejected and the customer will be notified that the system does not qualify for the PSE program but may proceed with the contractor at their discretion. The contractor will be notified immediately that the installation may proceed but will not received incentives from the program.

5. The contractors will submit the Duct Ninja Quality Control report and PSE may then proceed with a post-inspection.

Figure 12 provides a revised general process flow diagram showing where the activities indicated above occur in the overall program process flow, while Figure 13 and Figure 14 provide details on the process flow for both the pre- and post- installation inspection activities.

Figure 12. Revised Program Process Flow (New Activities Highlighted in Blue)

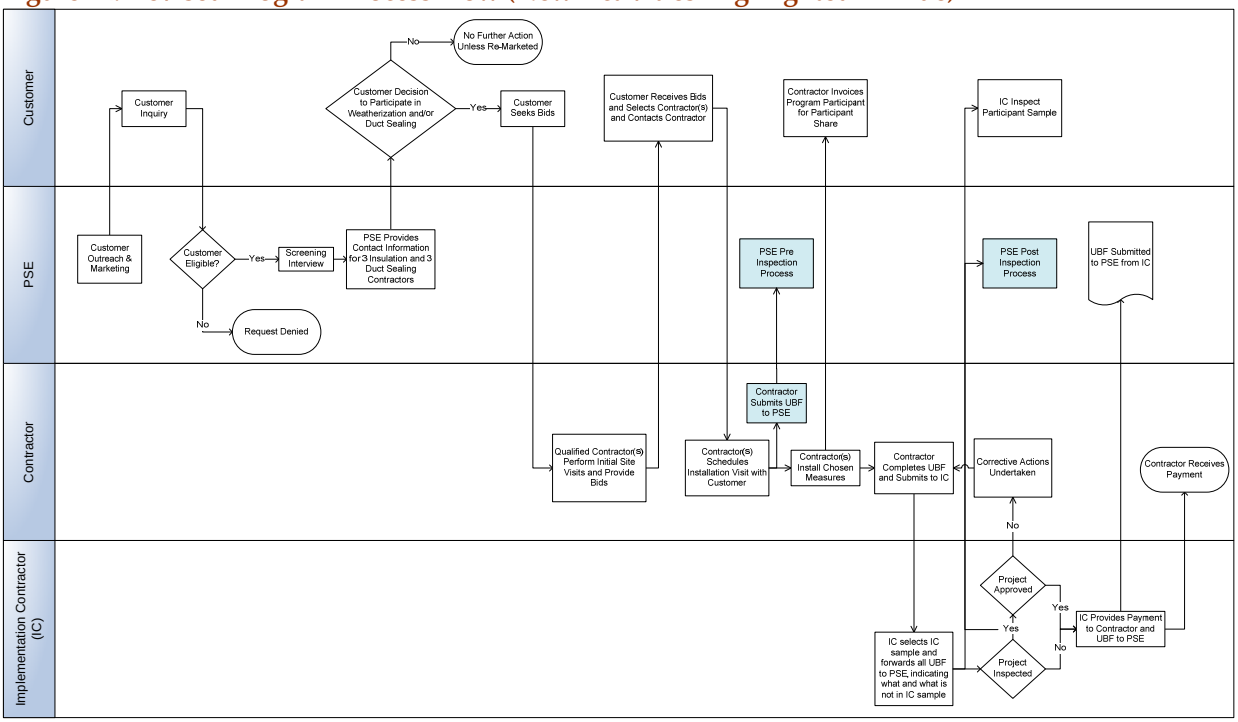


Figure 13. Revised Pre-Inspection Process Flow

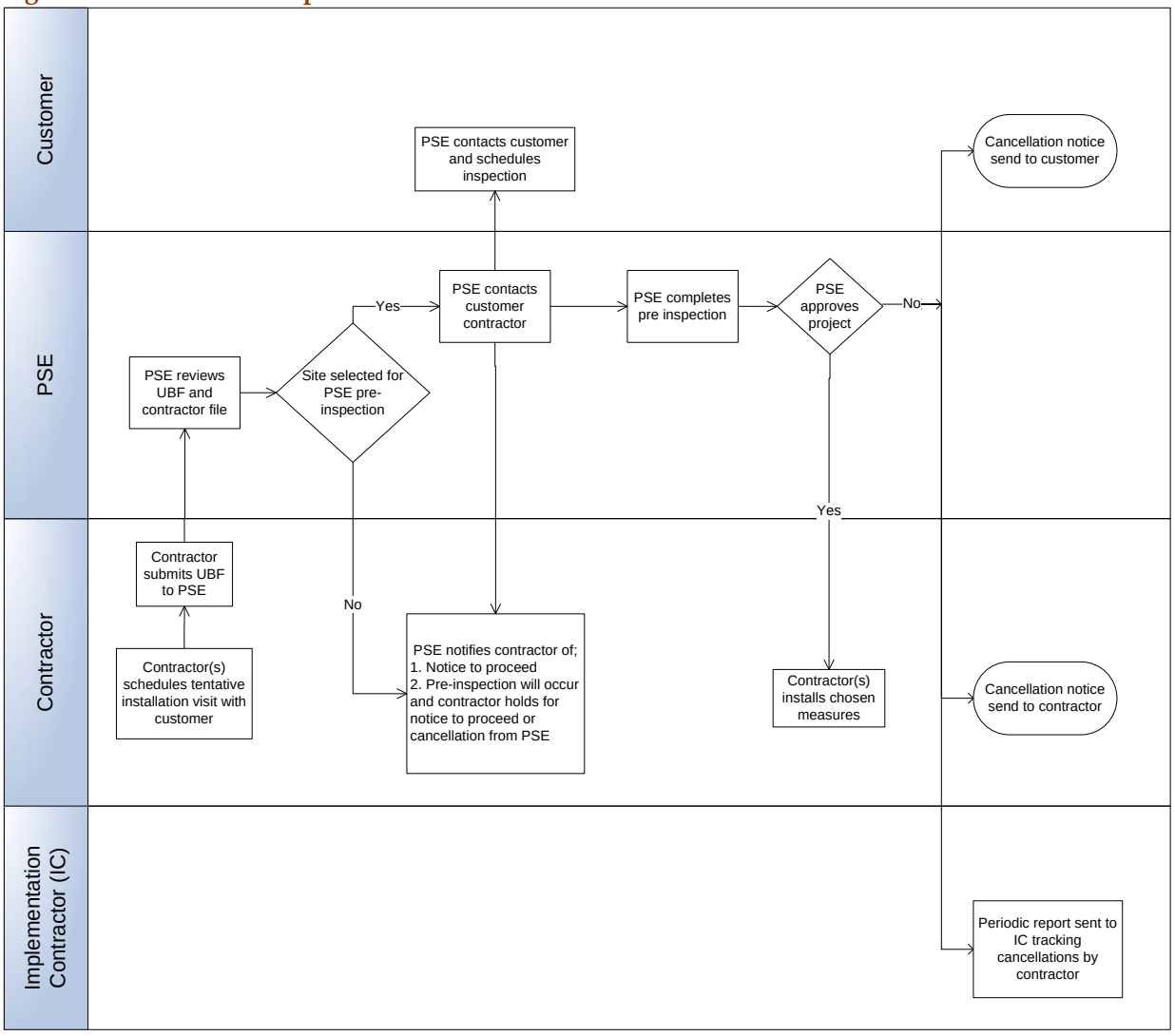
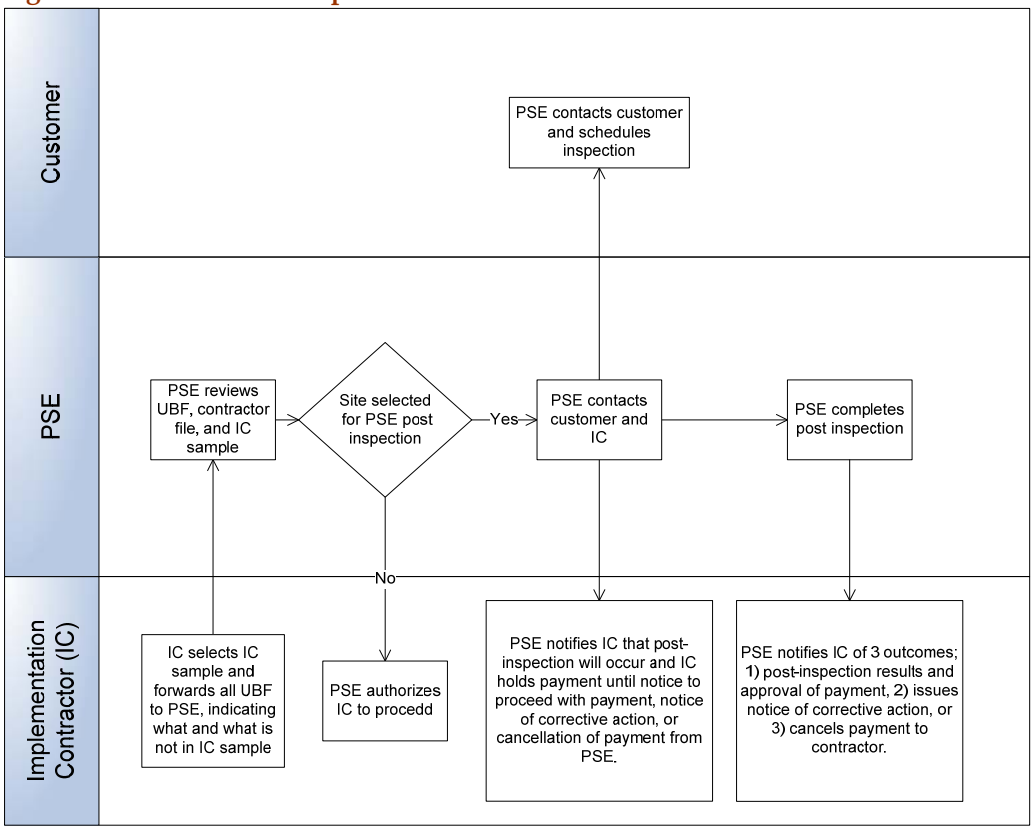


Figure 14. Revised Post-Inspection Process Flow



Appendix A

Results of Linear Fixed Effects Regression Model of Daily Therm Consumption

Table A-1. Results of Linear Fixed Effects Regression Model of Daily Therm Consumption

	Heating Season			Non-Heating Season		
Parameter	Estimate	Standard Error	Sig. Level	Estimate	Standard Error	Sig. Level
HDD	0.18783	0.001186	<.0001	0.123405	0.001142	<.0001
Attic Insulation	-0.12817	0.044022	0.0036	-0.0189	0.01301	0.1463
Duct Insulation	-0.40334	0.065085	<.0001	-0.11971	0.022352	<.0001
Duct Ninja with Furnace	-0.13485	0.111292	0.2257	-0.04133	0.031069	0.1835
Duct Ninja (without Furnace)	-0.40538	0.110507	0.0002	-0.08896	0.038075	0.0195
Duct Sealing	0.290024	0.110153	0.0085	0.017129	0.036834	0.6419
Floor Insulation	0.127413	0.050936	0.0124	0.053915	0.019286	0.0052
Wall Insulation	0.416038	0.046001	<.0001	0.102456	0.014521	<.0001
Duct Ninja & Duct Ins	0.376197	0.179252	0.0359	0.168509	0.059597	0.0047
Duct Ninja & Attic Ins	0.442761	0.213918	0.0385	0.033613	0.071139	0.6366
Duct Ninja & Floor Ins	-0.07825	0.161653	0.6284	-0.07747	0.053281	0.146
Duct Ninja & Wall Ins	0.357476	0.247337	0.1484	0.173705	0.062082	0.0052
Duct Ninja & Duct Ins & Attic Ins	-0.07008	0.194238	0.7183	-0.04548	0.062164	0.4644
Duct Ninja & Duct Ins & Floor Ins	0.098797	0.190176	0.6034	-0.00295	0.061318	0.9617
Duct Ninja & Duct Ins & Wall Ins	-0.3509	0.25807	0.174	-0.17956	0.065216	0.0059
Duct Ninja & Attic Ins & Floor Ins	-0.27246	0.190363	0.1524	0.057431	0.060733	0.3444
Duct Ninja & Attic Ins & Wall Ins	-0.36602	0.22266	0.1003	-0.06429	0.060751	0.29
Duct Ninja & Floor Ins & Wall Ins	0.054533	0.24982	0.8272	0.023285	0.061701	0.7059
Duct Ninja * HDD	-2.3E-05	0.004916	0.9963	-0.00764	0.005745	0.1837
Duct Ninja with Furnace * HDD	-0.00888	0.004744	0.0614	-0.0034	0.004414	0.4413
Duct Ins * HDD	0.007565	0.002502	0.0025	0.006324	0.002341	0.0069
Duct Sealing * HDD	-0.01989	0.003571	<.0001	-0.01188	0.003576	0.0009
Attic Ins * HDD	-0.0158	0.00184	<.0001	-0.01097	0.00168	<.0001
Floor Ins * HDD	-0.01341	0.002003	<.0001	-0.01725	0.001844	<.0001
Wall Ins * HDD	-0.0316	0.001828	<.0001	-0.02599	0.001667	<.0001
Duct Ninja & Duct Ins * HDD	-0.00311	0.007624	0.6837	-0.00733	0.008614	0.3947
Duct Ninja & Attic Ins * HDD	-0.01106	0.009	0.2193	0.011726	0.010251	0.2527
Duct Ninja & Floor Ins * HDD	0.008553	0.006869	0.2131	0.017594	0.00761	0.0208
Duct Ninja & Wall Ins * HDD	-0.01732	0.01076	0.1075	-0.01957	0.009297	0.0353
Duct Ninja & Duct Ins & Attic Ins * HDD	-0.00563	0.008254	0.4949	-0.00529	0.0088	0.5481
Duct Ninja & Duct Ins & Floor Ins * HDD	-0.00698	0.008134	0.3912	0.000478	0.00898	0.9575
Duct Ninja & Duct Ins & Wall Ins * HDD	0.003904	0.011331	0.7304	0.01463	0.009834	0.1368
Duct Ninja & Attic Ins & Floor Ins * HDD	0.008365	0.007959	0.2933	-0.01253	0.008857	0.1574
Duct Ninja & Attic Ins & Wall Ins * HDD	0.031225	0.00947	0.001	0.019261	0.00883	0.0292
Duct Ninja & Floor Ins & Wall Ins * HDD	0.010411	0.010578	0.325	0.001417	0.008944	0.8741

Interview Instrument for Duct Sealing Contractor Interviews

Interview Methodology

Navigant expects to complete 15 telephone interviews with duct sealing contractors participating in Puget Sound Energy's (PSE) Duct Sealing & Repair Program. Of this sample, 12 telephone interviews will be with contractors that collectively represented 80% of program activity[30] in 2009 – 2010. The remaining 3 telephone interviews will be with less active contractors to gain a better understanding of their perspective on the program and reasons behind their limited participation.

Table 1. Process Evaluation and Program Redesign Interview Sample

Program Contractor	PY 2009 – 2010 Program Activity
Clean Crawls	27.8%
American Crawlspace Cleanouts	6.5%
Burnham Insulation North	5.9%
Eastside Crawlspace & Attic Restoration	5.6%
Classic Insulation	5.3%
Boulton Insulation	5.1%
Capitol Duct Cleaning	4.9%
Einar Johanson	4.3%
Arrow Insulation	4.2%
RCC	3.5%
Gale Contractor Services North	3.2%
Turner Insulation	3.0%
Carrig & Dancer	0.7%
United Insulation Solutions	0.2%
American Home Weatherization	0.1%
Total	**80.3%**

It is expected that the surveys will take approximately 25 minutes to complete. Initial testing results are consistent with this estimate, recognizing however, that questions may need to be modified in scope pending contractor response length.

Navigant assumes a 100% interview participation rate in light support from the program manager (e.g., letter from PSE, etc.) and a one-time incentive of $50 to all respondents.

Introduction

Hello, my name is _____ and I'm calling on behalf of Puget Sound Energy to follow up on your discussion with **Lucas Guistra.**

[30] We define "Program Activity" as the percentage of Duct Ninja projects completed by a unique contractor.

As you probably know, PSE has retained our firm (Navigant) to evaluate the Duct Sealing & Repair Program. This really involved two components:

1.) An evaluation of energy savings achieved through the duct sealing services you provide

2.) A discussion with duct sealing contractors to solicit feedback on experiences with the program and to identify opportunities for improvement in future cycles.

However, I would like to reiterate that your responses will remain completely confidential. All reporting is aggregated and individual responses will NOT be disclosed. We just have a few preliminary questions.

Screener Questions

S1. Do you subcontract out the weatherization services offered through PSE's Weatherization Program?

S2. Do you subcontract out the Duct Sealing services offered through PSE's Duct Sealing & Repair Program?

S3. Are you a duct sealing contractor for SnoPUD's Duct Sealing Program?

Familiarity with Program Qualifying Criteria

I'd like to talk about the qualifying criteria for program.

Q1. How many homes have you weatherized in the past year through PSE's Weatherization Program? **[ROUGH ESTIMATE]**

Q2. Of those homes that were weatherized, how many qualified for Duct Ninja services? **[ROUGH ESTIMATE]**

Q3. How many of those qualifying homes actually received Duct Ninja services? **[ROUGH ESTIMATE]**

Q3A. Based on your experience, why do some customers that qualify for Duct Ninja choose not to participate in the Program?

Q4. Can you describe how you would *qualify* a home for Duct Ninja services? **[PROBE INTO THE QUALIFICATION METRICS IN TABLE 2]**

Table 2. Duct Ninja Qualification Procedure

Qualification Metric[31]	Interview Response
Duct Location (e.g., Basement, Crawl Space, Attic)	
Duct Condition / Need for Replacement & Repair	
Pre-Existing Duct Insulation Condition and Coverage	
Age of Home	
Other 2	

Q5. What are the training procedures for the Duct Ninja Program? **[PROBE INTO ON-SITE VISITS]**

Q5A. Does your sales team receive the same training as your duct sealing contractors? **[IF NO, PROBE]**

Q5B. Are new staff trained internally, or are there additional training seminars offered through the Program?

Q6. Can you describe the condition of an *average* duct system that receives Duct Ninja services? **[PROBE INTO THE QUALIFICATION METRICS IN TABLE 2]**

[31] Duct Ninja with Furnace - Crawlspace questions 2009-06-15.ppt

Q7. Do you have any comments or recommendations regarding the Duct Ninja qualifying criteria? **[PROBE INTO Q7a]**

Q7a. Comment on a system that is "Not in Disrepair, Over 30% of Ducts Accessible from the Exterior." **[PROBE FOR RESPONSE ON CLARITY OF QUALIFIER, ACCURACY OF QUALIFIER, QUALITY/LOCATION OF DUCT SYSTEMS SATISFYING THIS CRITERIA]**

Improved Documentation of Participating Duct Systems

Q8. I'd now like to ask you about the *type* of Duct Systems encountered in participant homes. Can you please tell me how often you encounter the following duct systems in participant homes?

Table 3. Duct Ninja System Types

Duct System Types	% of Projects	Approx Vintage Range (Most prevalent Years)	Comments
All Sheet Metal (Sheet Metal Spider)			
Central Sheet Metal Trunk with Flex from the Trunk to the Boot			
Flex from plenum to boot (Flex Spider or (Octopus)			

Q8a. Are there any other systems that you encounter at participant homes?

Q9. In the section labeled "Duct Insulation," about half way down the form, the UBF asks the applicant to check a box if the existing duct insulation is 'up to 1" (1-Inch) on sheet metal ducts in crawl space, attic, and garage.' Do you feel this is an adequate way to describe existing duct insulation?

Prescriptive Duct Sealing Practices

I'd now like to discuss your prescriptive duct sealing practices associated with Duct Ninja.

Q10. I will now list six common Duct Ninja practices; can you please tell me what percentage of participating homes receive the following duct sealing activities:

Table 4. Prescriptive Duct Sealing Activities[32]

Other Duct Ninja Actions	% of Projects	Comments
Re-attaching Boot and Registers		
Sealing Take Offs		
Sealing Base Can Seams		
Repairing Disconnects		
Tightening Connection Points		
Repairing Ductwork		
Replacing Ductwork[33]		

Q10A. Are there any other duct sealing activities routinely performed through Duct Ninja services? **[PROBE]**

Table 5. Other Prescriptive Duct Sealing Activities

Other Duct Problem	% of Projects	Comments
Other 1		
Other 2		
Other 3		
Other 4		
Other 5		

[32] Duct_Ninja_Duct Sealing and Repair Guide.pdf
[33] This includes the use of Crimping, Flex Duct Knife, Notcher, and Tensioning Tools

Q11. I'd like to solicit your opinion on some other subjective decisions that are unique to each home and their frequency: **[PROBE]**

Table 6. Other Prescriptive Duct Sealing Activities

Subjective Duct Sealing Scenarios	Y/N/NA	% of Projects	Comments
Are Supply and Return Ducts Treated Equally?			
Do You Seal Square Sheet Metal Ducts?			
Do You Seal Ducting Located Between Two Joists?			
Do You Seal Ducting Fastened to the Ceiling or Sub-Floor?			
Do You Seal Panned Duct Systems?			
Do You Seal Flex-Duct Systems?			

Q12. What do you do if your contractors encounter a duct system that has pre-existing duct insulation? **[IF ASKED FOR OPTIONS: "SEAL UNDER INSULATION," "DON'T SEAL SYSTEM," "REMOVE INSULATION," "SEAL WITHOUT PUTTING BACK ON," AND "REMOVE, SEAL, AND REPLACE INSULATION"]**

Table 7. Duct Inspection Findings

Pre-Existing Duct Insulation	% of Participants	Action
No Duct Insulation?		
Some Duct Insulation? (R-2 – R-4)		
Full Duct Insulation? (R-8 – R-11)		

Q13. Can you describe a duct system that you would NOT seal? **[PROBE]**

Q14. Are there any other unique and subjective decisions that must be routinely made for each participating home receiving Duct Ninja services? **[PROBE]**

Verifying Eligibility of Participants Using a 2-Tier Inspection Process

To better understand their customers and programs, PSE is reviewing a new process which may involve

1.) Collecting more comprehensive participant baseline information to better understand existing home conditions prior to Duct Ninja services
2.) Conducting pre-/post-inspections on a sample of homes slated to receive Duct Ninja services.

I would like to ask you a few questions related to these revised program protocols:

Q15. What percentage of projects are bid and sealed during the same visit?

Q16. For those projects that do not receive Duct Ninja services at the time of inspection, please indicate the amount of time between bid and sealing:

Table 8. Duration Between Inspection and Duct Ninja Services

Duration Between Inspection Bid and Duct Ninja Services	% of Projects (Winter)	% of Projects (Summer)	Comments
1 Business Day			
2-3 Business Days			
4-5 Business Days			
6-7 Business Days			
More than 7 Business Days			

Q17. Approximately how long does it take to receive reimbursement from PSE/ECOS for Duct Ninja Services?

Q18. Please rate the amount of effort it would take to comply on a scale of 1 to 5, where 1 is very easy and 5 is very difficult. Please also estimate the added project costs and additional time required to complete these activities:

Table 9. Potential Revisions to Program Protocols

Revisions to Program Protocols	1	2	3	4	5	Added Project Costs	Added Time for Duct Sealing	Comments
Increase Quantitative Documentation of Existing Duct Systems[34]								
Increase Quantitative Documentation of Prescriptive Duct Sealing Activities								
Pre-/Post-Inspections of Participant Homes to Confirm Duct System Conditions[35]								

Q19. Please rate the impact of these processes on sales volume and the ability to close projects on a scale of 1 to 5 where 1 is very negative and 5 is very positive.

Table 10. Impact of Revisions to Program Protocols on Sales Volume

Revisions to Program Protocols	1	2	3	4	5	Comments
Increase Quantitative Documentation of Existing Duct Systems						
Increase Quantitative Documentation of Prescriptive Duct Sealing Activities						
Pre-/Post-Inspections of Participant Homes to Confirm Duct System Conditions						

Q20. Please provide any additional comments and/or recommendations to existing program protocols that would improve PSE's understanding of the participant baseline, prescriptive duct sealing procedures, and post-installation conditions.

[34] The specific changes to documentation protocols will be refined with PSE Staff prior to the interviews with Contractors so that we can provide additional fidelity into each revision.

[35] The specific timeframe for pre-/post-inspections will depend on PSE staff availability. We will continue to work with PSE to estimate the number of homes requiring this practice, along with the time needed.

Q21. What address would you like us to ship the $50 Gift Certificate to?

Complete: Thank you for your time; those are all the questions we have for this interview. Please feel free to contact me anytime with any questions or comments at 925-930-2707. Thank you for your help in this important effort.

Terminate: I'm sorry, but we are looking to speak with duct sealing contractors that are familiar with PSE's Duct Sealing & Repair Program. However, I greatly appreciate your willingness to help us today. Have a nice day.

Telephone Recruitment Script

Hello, May I speak with [Customer Name]?

I am calling on behalf of Puget Sound Energy. The reason I'm calling is because you have previously received a weatherization rebate from PSE and we are looking for qualifying homes to participate in an evaluation project regarding a new weatherization measure. May I take 5 minutes of your time to ask a few questions to see if your home fits the criteria for the project and gauge your interest?

Possible Questions from Customer at this point:

"Do I get anything?"/ "What's in it for me?": If your home fits the criteria for the project there would be a small cash incentive for us to install the measure and monitor it.

Possible Answers to Question:

"No, I'm not interested.": Thank you for your time. Have a good rest of your day.

"Can you call me back later?": What is a good time to call back? I will try to give you a call back, this is a small project, we are only looking for 60 participants, we may reach that number before I am able to call you back. Thank you for your interest. Have a good day.

"Yes/Sure": Proceed with questions

First of all let me confirm that you are still living at [address where weatherization happened previously]. If no – Thank you for your time. We are looking to visit homes that have had previous weatherization done through Puget Sound Energy's rebate programs. Have a good day.

If yes – Great. Does your home have a basement?
If yes - Thank you for your time. We are looking to visit homes that have crawlspaces under the home with no basement. Have a good day.

If no – Great. We are looking for homes that have duct work in the crawlspace under the home where the ducts have not been insulated or sealed. Do you know where the duct work for your home is located?

If no – Because of the nature of the evaluation project I need to find 60 homes that have uninsulated ducts in the crawlspace of the home. If you are interested in participating you may check on the placement and condition of your ducts and give us a call back at XXX-XXX-XXXX. If we haven't already filled the 60 participant slots we would be happy to have you participate if you find that your ducts are uninsulated and in the crawlspace.

If yes – but not in crawlspace, but in walls or attic: Thank you for your time. We are looking to visit homes that have uninsulated ducts in the crawlspace of the home.. Have a good day.

If yes and in the crawlspace, but I don't know if they are insulated or not: Because of the nature of the evaluation project I need to find 60 homes that have uninsulated ducts. If you are interested in participating you may check to see if your ducts are insulated or not. If not you may give us a call back at XXX-XXX-XXXX. If we haven't already filled the 60 participant slots we would be happy to have you participate if you find that the ducts in your crawlspace are uninsulated. You can tell that they are insulated if they are wrapped with any material. Uninsulated ducts are bare metal. In general flexible duct material (looks like the dryer vent hose) will be insulated and sheet metal ducts (the kind you always see people escaping through in movies) are often not insulated.

If "I know they are in the crawlspace and I think they don't have any insulation.": Great. Let me tell you a little about our project. We are looking to monitor the energy usage of homes prior to and after having the ducts sealed using our current method of duct sealing. What this means is that we will be sealing any leaks in your duct system and be using a monitor to measure the level of impact. In order to do this we will need to come by your home and confirm that your duct system does meet the criteria of the study. This is no cost to you and if selected to participate we will be sealing your ducts for free, a $395 value currently provided for free when having other weatherization work done by an authorized contractor. We will also be giving you an additional $100 for helping us out.
If selected we will put the monitor in place and then one of our authorized contractors will contact you and schedule a time to come out to your home to seal your ducts. This will mean that they will need access to your duct system and each of the registers in your home.
May we schedule a time to come out and confirm that your house is a good candidate for the project and if so put a monitor in place?

"Yes": Great, my first available time slot is ….We will arrive at your house, check out your duct system and let you know if it meets the parameters of the study. If it does we will put the monitor in place. If the duct system doesn't work we will be able to tell you right then. (I think they should get a $10 gift card for being home and the inconvenience, budget?)

"No, I don't think I'm interested.": Well I appreciate your time. If you don't mind my asking can you tell me why you aren't interested?[wait for answer, respond appropriately, assuage fears and ask again if they are interested if appropriate. If not appropriate….]Thank you again for your time have a nice day.

Reminder call 2 days prior to visit: Hello I'm calling from PSE's duct sealing evaluation project. I just wanted to call and remind you that we will be coming out to look at your duct system and installing a monitor if appropriate at [day and time]. Let us know if you have any questions or concerns.

Voicemail: Hello I am calling on behalf of Puget Sound Energy looking for homes to participate in a no cost weatherization evaluation project. We are looking for homes with uninsulated duct systems located in the crawlspace. If this describes your home and you are interested in learning more please call us back at XXX-XXX-XXXX. Thank you.

On-Site Participant Eligibility Pre-Screening Instrument

On-Site Evaluation Pre-Screening Form

1) Is the customer a PSE customer who uses **NATURAL GAS** from PSE as the primary heating source?
   a) Yes
   b) No

2) Does the customer qualify for duct sealing with at least 30% of their ducts in the following unconditioned spaces: crawl spaces, garages, attics (conditioned basements do not qualify)?
   a) Yes
   b) No

3) Is the customer willing to participate in on-site metering of their furnace and has signed the ***Letter of Participation***?
   a) Yes
   b) No

4) Is the customer's furnace gas fired?
   a) Yes
   b) No

5) Is the furnace a single- or dual- stage furnace?
   a) Single-stage
   b) Dual-stage

6) Has the furnace been installed within the past 10 years?
   a) Yes
   b) No

7) Does the fan operate intermittently, or is it on continuously?
   a) Intermittent
   b) Continuous

8) Is the utility gas meter readily accessible and equipped with a test hand of 2 cubic feet or less as depicted in Figure?
   a) Yes
   b) No

9) Will the home be unoccupied for more than two weeks at one time between October and March?

a) Yes

b) No

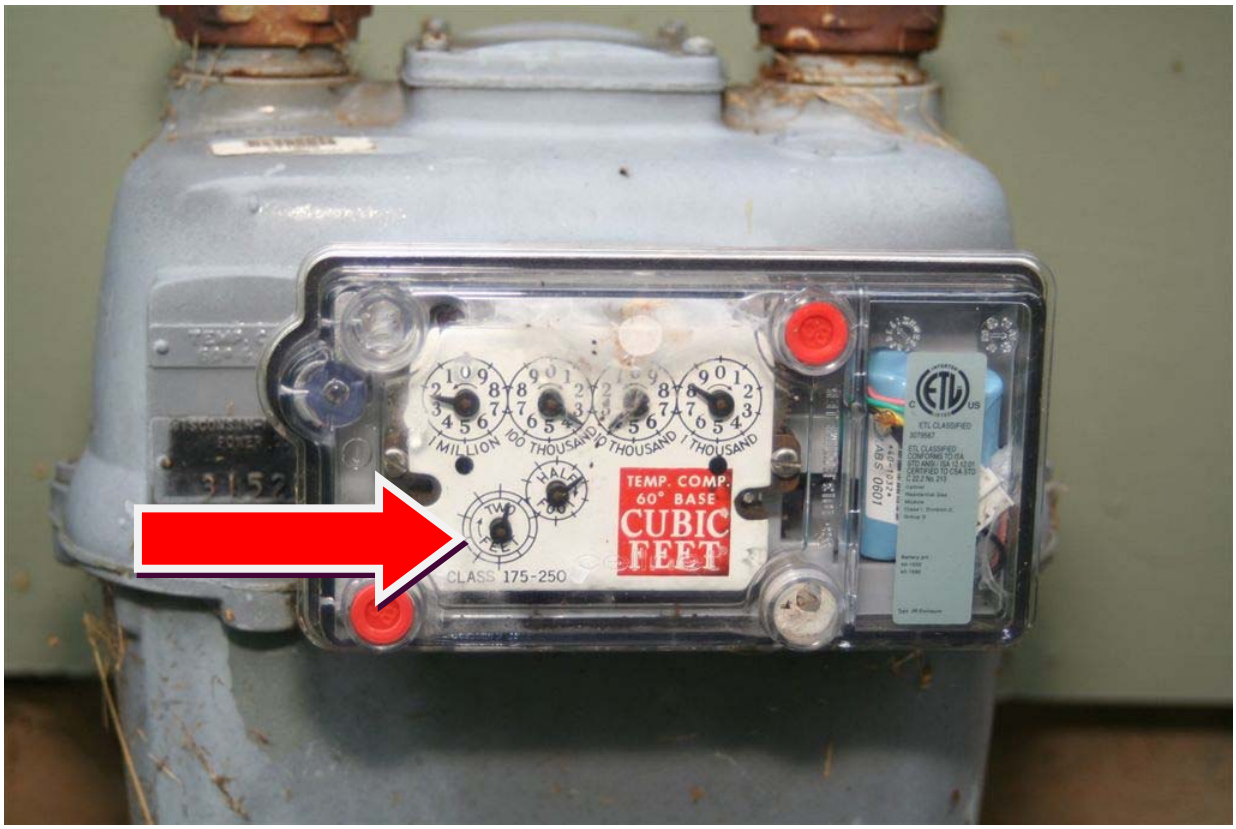


Figure1. Example of 2 foot test hand on Utility Gas Meter (source: www.diychatroom.com)

On-Site Participant Recruitment Letter

[Date]

Dear Customer:

Thank you for participating on the evaluation of energy savings from the Puget Sound Energy (PSE) Duct Sealing & Repair Program. This evaluation will assist PSE in better understanding and tracking how our customers will realize measurable improvements in managing their energy usage as a result of PSE energy efficiency services.
PSE has commissioned Navigant Consulting (NCI) to prepare an independent evaluation of this program. A representative from NCI, is visiting you today to perform the following:

- Install data logging equipment on your furnace, at your thermostat, and in the duct location
- Take measurements of gas and electrical consumption of your furnace
- Collect data regarding the construction of your home

In the first week of December, your contractor will be calling to schedule your duct sealing appointment. In late January or early February, NCI will call you to schedule a pick-up of the metering equipment.
Thank you very much for allowing us to complete this important work, as it will serve to further assist PSE in delivering energy efficiency programs that help residents use energy wisely. Should you have any questions or concerns, please contact Bobette Wilhelm at Puget Sound Energy (425-462-3432).

[Signature]
Bobette Wilhelm
Puget Sound Energy

Evaluation Report Response

Program: Single Family Weatherization

Program Manager: Malcolm McCulloch & Luke Giustra
Study Report Name: Duct Ninja Evaluation

Report Date: 7/18/2011

Evaluation Analyst: Bobette Wilhelm

Date ERR Provided to Program Manager: 8/10/2011

Date of Program Manger Response: 8/22/2011

Key Impact Evaluation Report Recommendations:

The Impact Evaluation indicates adjusted site savings associated to sealing supply-side duct work through the prescriptive Duct Ninja (DN) methodology. When conducting the billing analysis, it was found that DN was often installed with other weatherization measures, so the scope of the analysis was broadened to determine the impact to savings in these occurrences. The most frequent measure installed with DN is duct insulation. Consequently, the billing analysis indicates that when DN is installed in conjunction with duct insulation the estimated annual savings for combined measure is 75.32 therms per household per year. DN installed alone yields an adjusted savings of 28.90 therms per household per year. These savings estimates account for the weighted mix of weatherization measures installed with DN, i.e. attic, floor, and wall insulation.

The Impact Evaluation indicates the variability in the DN delivery practices directly result in the fact of existing duct insulation being present. Through the current DN standards, it is encouraged to not remove existing insulation and to identify duct leakage through visual cues (discoloration) on the insulation. This standard reduces the ability of the installer to quickly and adequately identify key duct leakage points. Navigant recommended coupling duct insulation with DN as a paired measure to streamline the DN approach.

The Impact Evaluation indicates that most contractors note limited prospect for profitability through the current fixed incentive limit. The current fixed incentive (free to the customer) leaves potential for the contractor to be subjected to increased overhead costs in the event of two conditions: needs to repair more than three linear feet of ducting; large homes with potential of multiple crawl space/attic accesses. Navigant recommended looking at a base incentive for DN services, as well as incremental increases in the incentive based on ranges of square footage in the home. This base compensation will allow contractors to bid out additional expenses for extensive repairs and larger homes.

The Impact Evaluation indicates high variability in how contractors qualify and deliver DN projects. The high variability is relative to high turnover of internal staff at participating weatherization companies in the program. Navigant recommended implementing semi-annual training seminars to “educate new staff and refresh older contractors…to reduce variability of DN practices and procedures.” Navigant also recommended that PSE improve the accountability of participating contractors by having both lead installer and qualifier sign the Uniform Bid Form that is submitted in conjunction with processing the DN rebate.

Discussion of Key Findings/Analysis:

Regionally, utility weatherization programs have both adopted and shown interest in the prescriptive duct sealing approach. Snohomish PUD has adopted a prescriptive duct sealing program. This program is delivered in conjunction with the replacement of duct insulation therefore supporting Navigant's recommendation of delivering the measures together. Energy Trust of Oregon program administrators have recently inquired with PSE staff about the delivery of DN and a prescriptive duct sealing approach in preparation of delivering the measure through the Clark County PUD weatherization program. These two examples indicate a market readiness for the prescriptive duct sealing approach.

As the findings of this report support significant savings derived from the prescriptive approach, and since there is both an established market and a trained trade ally network, it can be concluded that applying some of the lessons learned from the evaluation will result in the delivery of a more comprehensive and cost effective program.

Finally, results from contractor surveys (including the Navigant study) support adjusting the structure of the duct sealing incentive: provide a tiered or base-level rebate that allows contractors to bid additional services for extensive repairs to the duct system and account for larger projects; and, couple the duct sealing incentive with duct insulation. PSE agrees that these considerations are reasonable adjustments to the duct sealing measure, yet require establishing baseline conditions for both square footage of the home and pre-existing duct insulation levels.

Subsequent Program Adjustments:

1. Modify the Duct Ninja program to offer a **comprehensive duct sealing and duct insulation measure** beginning January 1st, 2012.
    a. Qualifications for pre-existing duct insulation levels will be established
    b. Subsequent program energy savings will utilize 75 therms for the combined measure completed in eligible homes
2. Determine cost effectiveness to provide **flex system DN measure** beginning January 1, 2012.
    a. Program energy savings for DN will utilize 29 therms in eligible homes.
3. Provide base-level instant rebate to customers that allows contractors to bid additional labor associated with a particular job
    a. Explore tiered base-level instant rebates relative to conditioned floor area of the home, linear feet of ducting, etc.
    b. No longer market program as free to customer
4. Provide additional training seminars to contractors to account for high turnover in staff and inconsistencies in delivery
5. Create new documentation or edit Uniform Bid Form to increase accountability of installers and estimators through contractor documentation and completion of DN
6. Integrate rigorous QA process for the purpose of documenting and tracking results and determining and evaluating best practices
    a. Improve future delivery of program
    b. Assess training needs for contractors