Impact Evaluation of Air Sealing and Insulation in Multifamily Buildings Pilot Program

Contents:

This document contains both the final Air Sealing and Insulation in Multifamily Buildings Pilot Program Impact Evaluation and the Puget Sound Energy 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.

Impact Evaluation of Air Sealing and Insulation in Multifamily Buildings Pilot Program

Puget Sound Energy

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1. EXECUTIVE SUMMARY

This is the impact evaluation report for the rolling evaluation of the Puget Sound Energy (PSE) Air Sealing and Insulation in Multifamily Buildings Pilot Program. Whole building air sealing for multifamily is a new measure for PSE and the region and there are no available PSE or Regional Technical Forum (RTF) approved savings estimates. The pilot impact evaluation developed impact results and looked into the options for savings estimates going forward such that the measure can be offered to the mass market. Note that the pilot was limited to multifamily buildings with electric resistance heating and built prior to 1991 Washington State Energy Code.

The impact results from the pilot were promising. Table 3 summarizes the total savings for all evaluated sites and the total savings for different categories of sites. There are two categories for measures as earlier in the program some projects received limited insulation measures and later in the program all measures were included at all sites. The category "All Measures" best represents the pilot and future program. The program also tracks whether buildings were previously insulated by the PSE multifamily retrofit program and only air sealing was performed. Overall the pilot realized 87% of the expected energy savings (87% realization rate). Two interesting findings were that the energy savings realization rate for previously insulated buildings was 97% and for 2-8 Unit buildings was 100%. We feel that the results from previously insulated buildings show that the program simulation models may have been better built where the only measure was air sealing. When measures included insulation as well there may have been more errors in the program models, but there was no systematic inputs that were changed. The 100% realization rate result for smaller buildings may stem from the fact that tenant turnover appeared to be random and easier to identify and address in the calibration for smaller buildings. In the larger buildings there were larger swings in overall occupancy.

Table 1: Summary of Ex Ante and Ex Post Annual Energy Savings

Category	Sample Size	Ex Ante Savings	Ex Post Savings	Realiz-ation Rate	Total CFM-Pre	Total CFM-Post	Total CFM Reduc-tion	% CFM Reduc-tion
Total	36	319,562	277,875	87%	245,049	156,213	88,836	36%
Total All Measures	22	237,343	201,920	85%	150,881	84,329	66,552	44%
Total Single Measures	14	82,219	75,955	92%	94,168	71,884	22,284	24%
Total Previously Insulated	21	128,803	124,543	97%	139,476	94,269	45,207	32%
Total Not-Previously Insulated	15	190,759	153,331	80%	105,573	61,944	43,629	41%
2-8 Units	17	136,462	137,086	100%	91,012	59,858	31,154	34%
9-20 Units	19	183,099	140,788	77%	154,037	96,355	57,682	37%

Ultimately we recommend an approach of using a deemed savings for the two smaller unit categories and to continue collecting pre and post sealing blower door measurements on a sample. This requirement may be dropped in the future, but it should allow for broader program expansion while collecting some additional data to further refine the savings. We concluded that applying the realization rates to the ex ante savings for all projects offers the best option. The variability in CFM reductions and ex ante savings were more stable and consistent and by applying the realization rates the magnitudes of savings would agree with the evaluation results.

For larger buildings we recommend a prototype model and to collect blower door data on at least a few buildings before the end of 2015 to inform the prototype. The evaluation approach for large buildings would require sampling and site specific modelling. We do recommend blower door testing before sealing on as many large buildings as feasible within the program budget as this data would be impossible to recreate during evaluation.

The final decisions on scaling up from the pilot should consider that collecting infiltration data for a sample will lead to more reliable estimates of savings and improve future evaluation. Measuring all buildings is an evaluator's dream, but it is not cost feasible at a large scale and creates a barrier to getting property managers to enrol in the program. Stopping all testing would increase the risk that future measures would not have the same realization rates exhibited in the pilot. The sampling approach allows for the pilot data to form a foundation that can be built upon with additional data from a wider variety of multifamily buildings. This can be done over time to balance critical data gathering and keeping the program itself cost effective and able to reach enrolment goals.

2. Introduction

This is the impact evaluation report for the rolling evaluation of the Puget Sound Energy (PSE) Air Sealing and Insulation in Multifamily Buildings Pilot Program. This section provides background and program information. The sections that follow present the impact evaluation activities, the impact results, estimated population size and savings variability, and conclusions and recommendations.

2.1 Background

Many multifamily buildings in PSE service territory use electric resistance heaters to maintain space comfort for tenants. Lack of insulation and air leaks cause heat in the tenant units to be lost, costing the tenant additional money and wasting energy resources. Adding insulation and sealing air leaks is an effective way to prevent heat loss and save energy. Adding insulation increases the ability of walls, ceilings, and floors to resist heat loss, and in the energy efficiency industry this is sometimes called increasing the R-value. Sealing air leaks reduces the flow of air volume leaving the space and in the energy efficiency industry this is sometimes called decreasing the air changes per hour (ACH) or reducing the infiltration cubic feet per minute (CFM).

2.2 Purpose

PSE wants to use the results of this pilot evaluation to estimate savings by project (i.e. provide deemed savings) without the need for pre- and post-testing per residential unit for each multifamily weatherization project. This report outlines the methods used to assess savings of pilot projects and describes the process and any limitations associated with creating deemed values and/or a calculator to estimate savings.

2.3 Pilot Program Description

PSE's Multifamily Air Sealing Pilot Program began in January 2012 and had two offerings which PSE was interested in evaluating. The first offering was a standalone air sealing measure, provided to buildings which have previously been insulated; and the second offering was a combined air sealing with insulation measure, provided to buildings which were in need of both insulation and air sealing. The qualifications for the offerings are outlined below:

1. Buildings must be four residential stories or less
2. Buildings must have at least five attached dwelling units
3. Building was built before 1991
4. Buildings must have electricity as their primary heat source
5. Buildings must have an attic and/or crawl space
6. Buildings must be in the PSE electric service territory
7. Building has not previously been air sealed
8. Building must not have any combustion zones
9. Building must not have received efficient upgrades for at least one year prior to sealing

In order to participate, building owners were required to sign an agreement to forgo installation of any other efficient equipment or upgrades for at least one year after air sealing was completed, which would enable PSE to evaluate the programmatic impact on energy usage without worrying about isolating the impacts of other efficiency measures. Table 1 provides details of the pre and post conditions of buildings which qualify for the Air Sealing with Insulation offering.

Table 2: Pre and Post Program Building Conditions for Air Sealing with Insulation

MEASURES	PRE-EXISTING CONDITION	POST CONDITION
Attic / Crawl Air Sealing	Pressure Boundary Penetrations	Sealed @ Pressure Boundary
Attic Insulation	R19 or Less	R38
Crawl Insulation	R11 or Less	R30 or Full Cavity
Wall Insulation	R11 or Less	Dense Pack Full to 80" of Water Column Pressure
Door Kits	Not Present	Door Gasket and Sweep
Can Covers	Non Air Tight Can	Sealed with Can Cover

In the early stages of the pilot DNV GL conducted a literature review of impact evaluation and infiltration testing methods, concluding with the recommendation that the program continue with the multi-unit blower door testing currently being conducted by Arrow Insulation. Arrow uses a multi-blower door testing method to analyze the air infiltration leakiness of an entire building. In this approach each unit is pressurized to the same degree relative to outdoor (ambient) pressure. With this technique, the net leakage between units is eliminated and whole building leakage is accounted for. The key result from the Arrow testing is an airflow rate called CFM50[1], a single indicator of a building's overall "leakiness," which corresponds to a building's infiltration heat loss under standard test conditions.

The pilot program attempts to collect sufficient data to fully characterize all the important variables that affect the energy use of a building, as modeled with the TREAT simulation software. This information includes data collected during the blower door testing, the CFM50 value, as well as details about a building's level of insulation, its operating schedules and occupancy patterns, and specifics about the buildings' energy systems and how energy is used by residents.

If there is sufficient accuracy and detail of TREAT models inputs, the models can be used to predict the energy use of buildings after energy efficiency measures have been installed. For the program, the energy efficiency measures (EEMs) are dense pack insulation and air sealing. TREAT models were developed and calibrated to match each building's historical energy usage before energy efficiency measures are installed, establishing an energy use baseline. Once calibrated, the TREAT models are adjusted to incorporate the energy efficiency treatments that reduce infiltration.

[1] CFM50 is defined as the airflow rate in cubic feet per minute (CFM) at an indoor pressure of 50 Pascals lower than the measured pressure outside, which is equal to atmospheric pressure for that location's elevation above sea level and real time wind conditions.

The pilot program included TREAT modeling in 2012 and 2013, but then stopped the modeling process in 2014. The program continued to perform pre- and post-infiltration testing in 2014 and into 2015. Savings for projects in 2014 and 2015 were estimated using a simplified calculator developed from evaluating initial pilot sites.

2.4 Savings Calculator

The basic approach to developing a spreadsheet calculator was to use early evaluation results from the first phase of the project to develop a rough draft of the air sealing calculator for interim use to project program savings. A sensitivity analysis was performed with the modelling software to validate the savings calculator results and to set up quality control checks within the calculator.

The calculator was simple in terms of inputs and only required the measured amount of CFM reduction, an input for county, and total building annual energy consumption. It was designed to enable comparison to some of the actual evaluated projects to aid in future development and refinement of the calculator. The calculator was designed for pilot program implementation with blower door testing and requires redesign for any future programs without those measurement requirements.

The air sealing calculator requires input of whole-building blower door measurements both before any measures are installed, and after all measures are installed. The blower door entries can be any numeric value and savings are based on modelling sensitivity analysis and trued up using initial evaluation results from earlier in the pilot study. The savings can be updated once more site evaluations are completed. The calculator spreadsheet is set up with checks to show flags if the CFM reductions or savings are higher than expected based on evaluation results. The current calculator does not have a lower limit check.

A screenshot of the Calculator is below.

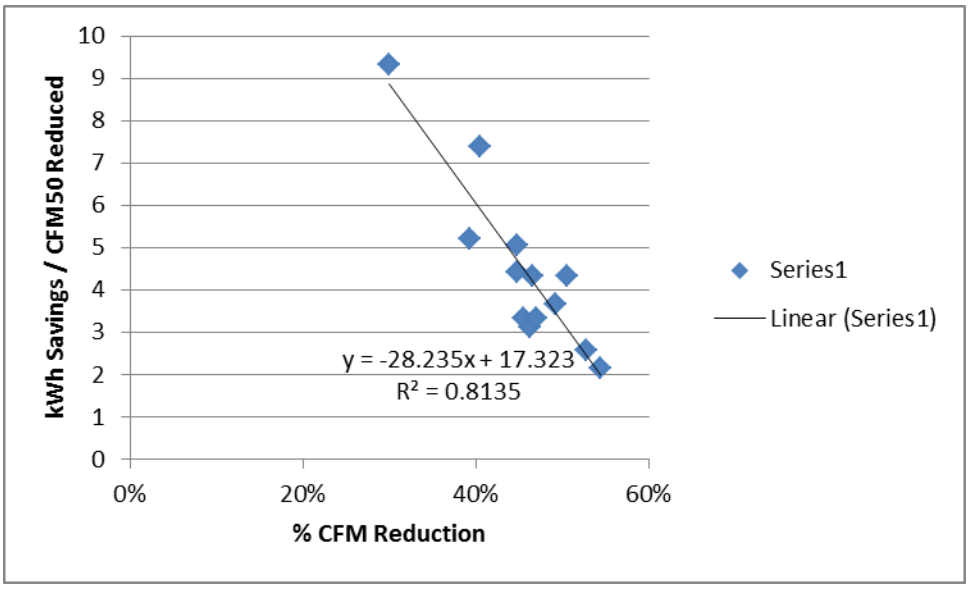
Figure 1: Calculator Input and Output Screen

1								
2		ENTER DATA IN YELLOW CELLS	BLUE IS CALCULATED			Air Sealing SAVINGS KWH	Check 1 - CFM Reduction	Check 2 - Relative Savings
3						9,090.91	OK	OK
4		BILLING DATA USE	ROUGH ESTIMATE OF HEATING KWH					
5	ENTER	100,000	65,000					
6		COUNTY	HEATING %					
7	ENTER	Whatcom	65%					
8								
9	Measure Type	Measures	Actual Existing		Actual Post Value	UnScaled Savings		
10			CFM PRE		CFM POST			
11	AirSeal	Attic / Crawl Air Sealing	5000		3500	1500	CFM	
12	AirSeal	Door Kits						
13	AirSeal	Can Covers						
14					Savings per CFM Reduced	5.00	kWh	
15					Relative Reduction	30%		
16								

The calculator also provides the RTF approved savings estimates for wall insulation based on the wall surface area insulated. PSE claims other insulation saving for Attics and Floors at the program level and thus these calculations are not included in the calculator.

Looking forward beyond the pilot program, it is understood that projects will implement all measures for all surfaces. Looking only at the17 projects from the first phase of the pilot evaluation led to a fairly strong correlation between relative CFM50 Reduction and savings per CFM50 reduced. This correlation begins to form the basis for future calculations; data from additional air sealing projects will improve calculator accuracy. The correlation is linear, showing that large relative reductions have lower savings per CFM reduced, so a fixed value used as a deemed ratio will overestimate the savings for large relative reductions. It is also true that lower relative reductions will have savings underestimated. The calculator places limits on the kWh savings per CFM50 on the high side.

Figure 2: Savings per CFM50 Reduction as a Function of Total Relative CFM Reduction



The 2012 sensitivity analysis produced a result of about 3 kWh of heating savings per CFM50 leakage reduction. The total across the first 17 "all measures" evaluated projects in the pilot evaluation was 4.3 kWh of savings per CFM50. The single measure sites are higher (7.9) than all measures (3.9), but all measure sites had more total savings and higher realization rates. The average for previously insulated and not previously insulated building categories were both 4.3kWh/CFM50.

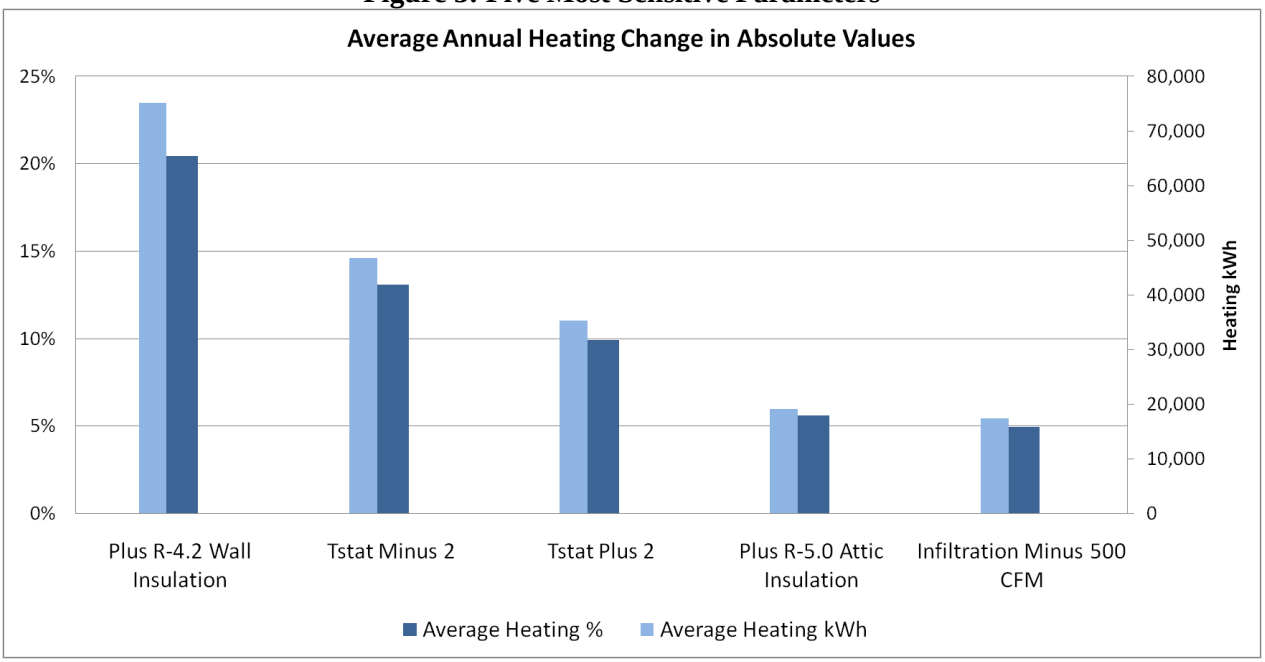
3. IMPACT EVALUATION ACTIVITIES

In 2012, Puget Sound Energy's Multifamily Air Sealing Team hired DNV KEMA to provide a comprehensive review of prospective methods that could be used for the impact evaluation of PSE's Multifamily Insulation and Air Sealing program. Methods considered ranged from regression analysis of pre/post utility bills for the population of participant multifamily buildings, to detailed simulation models of a sample of participating buildings. DNV GL recommended an impact evaluation approach that leverages the site-specific data and savings estimates that were part of the pilot program. To ensure both completeness and accuracy of the original TREAT models, DNV GL recommended amendments of the data collection (the audit form) to refine details about building insulation levels, occupancy patterns, and internal loads. This established a data collection methodology for estimating pilot impacts.

The primary pilot evaluation activities were to collect additional data from surveys and post retrofit billing data to refine or "true-up" the original site specific savings estimates. The surveys focused on collecting data on changes to tenant behavior or internal loads that would affect energy consumption, especially those changes that fall outside of program rules for preventing other energy efficiency upgrades after the air sealing treatment.

In the previous 2012 study on evaluation methods, a sensitivity analysis was performed to quantify which model input parameters had the greatest impact on energy savings. The sensitivity analysis identified that the thermostat settings were the most important parameter not being collected by the program for energy savings as small changes had a large impact on usage and savings. The other important changes were all program measures and were measured directly pre and post retrofit. The sensitivity was an average of 1700 to 2300 kWh heating savings per degree of setpoint change. Thermostat settings were modified by two degrees (Tstat Minus 2, Tstat Plus 2) and infiltration was varied in increments of 500 CFM. See Figure 1 for the overall results.

Figure 3: Five Most Sensitive Parameters



The sensitivity analysis noted that the characteristics of the hot water system had less of an effect, but in this evaluation we realized that when the DHW multiplier is used for calibration the monthly load shape changes. This means that while the total consumption (all end uses) can be within the calibration range (1-2%), but the heating consumption may not be within the calibration range because the DHW multiplier adds consumption uniformly across months. The detailed survey results also included specific questions about equipment and their use which is detailed in Appendix A, B, C, and D.

PSE also needs an evaluation strategy based on future program implementation that would eliminate infiltration testing prior to scaling up implementation to a full scale program. DNV GL still maintains the position that test-in / test-out data is critical and there is no substitute to having this information. We do agree with PSE that a cost effective option would be developing a statistical framework where buildings tested in 2012-2015 pilots serve as a sample to inform future savings estimates on buildings that are not tested. The framework will need to account for the fact that buildings similar to the 2012-15 tested buildings will have less uncertainty compared to buildings that are not similar to those previously tested. The ultimate goal is to set a sample target for all building categories that could be program-eligible in the future.

The following section describes the method used to estimate pilot impacts and to assess the sample targets for additional testing going forward.

3.1 Pilot Impact Evaluation Data Inputs

Completed sites with one or more year post retrofit billing data proceeded to have their models calibrated for both post-retrofit usage and to calibrate savings. In this task, the original pre-retrofit bills were reviewed such that any significant gaps in tenant unit data were flagged. Although surveys were attempted with all tenants for a given building, there were cases where they could not be completed. The analysis of gaps or changes in overall trends in billing data was available for all units in the evaluated projects. We assumed all pilot projects completed in 2012-14 would meet the post retrofit billing data criteria but completing surveys places a second constraint on the sample size.

Details about the survey and survey results are presented in Appendix A through D. Future evaluations should repeat the survey effort to determine if survey results are still relevant as the program expands. Updates to the calculator or deemed savings may be necessary if there are major differences in tenant behavior.

3.2 Pilot Impact Evaluation Modelling Analysis

The primary activities for our analysis were adjusting the site level TREAT models, conducted on each building evaluated as part of the Air Sealing Pilot Program, based on new data from the survey results and post retrofit billing data. In addition, one of the recommended analysis steps was to gather data on wind sheltering which may impact the annual infiltration rates both before and after retrofit.

A Google Earth review of the evaluated projects was low cost and accurate enough to establish exposure based on trees, buildings, hills, and other external wind sheltering. We also reviewed wind speeds and directions in long term average weather files (TMY3). The analysis was be used to modify the exposure input in the TREAT model for evaluated projects based on map and weather data file analysis.

An additional task was also undertaken to review detailed blower door test files using TECLOG software. The analysis allowed the team to review the correlation of treatments to infiltration profiles and also to determine whether the sources of leaks were cracks or holes. Additional modeling considerations and the TECLOG analysis are presented in Appendix E. Overall the findings may be useful in determining if more of the leakage in different treatments is from plumbing and electrical penetrations (holes) or areas where surfaces meet – where walls meet attics and floors (cracks).

3.3 Create Categories and Sample Targets for Multifamily Air Sealing Performance Data

Another task was undertaken to better characterize the buildings that participated in the multifamily air sealing pilot and understand how results may be applicable going forward. The objective was to determine the variability in air sealing reductions and in savings. We further wanted to look at whether savings correlated to building characteristics. The number of dimensions were limited as much as possible and focused on those that affect air sealing benefits. These included heating fuel type, number of stories, number of units bins (example 2-8, 12-20, 21-50, 50+), location/climate, and vintage. For vintage

we also considered a combination of year built and whether site was previously insulated by programs. Ultimately we focused on a category of building size as we also needed to determine the population of buildings in each category.

DNV GL worked with PSE program staff and 2012-13 MF Existing Evaluation team to develop categories of buildings. Using data from the full scale MF existing program we estimated the PSE population within each category. The quantity did not need to be exact, but provided an order of magnitude to inform sampling statistics calculations. The pilot has only completed projects that fall into the 2-8 unit and 9-20 unit categories. Modeling has already been dropped in 2014 and testing is being dropped after 2015. For large buildings, models will need to be created and units sampled for blower door testing if units have individual exterior doors. This is key given the hardware, software, and logistical limitations of simultaneous blower door tests on buildings with more than 20 units. For building where there is one or two exit doors per floor then a multiple fan per door setup can pressurize the entire floor. For very large buildings there may be no way to have simultaneous measurement of all floors which would be another case for within building sampling.

We then assigned each building from 2013-15 air sealing pilot program to the categories. We assessed the variation in CFM pre, CFM post, and CFM reduction by category. For evaluated projects we assessed energy savings by category to develop uncertainty estimates for each category and overall. Once an error ratio/coefficient of variation is assigned to each category and we have a population estimate we can develop sample sizes. The coefficient of variation (CV) is a standardized measure of dispersion of a probability distribution or frequency distribution. It is defined as the ratio of the standard deviation to the mean. The ultimate goal was to produce a table that includes the population, variation, and sample size for each category needed to achieve specified levels of relative precision at the category level and the overall level. We anticipated the desired precision levels will be 10% relative precision at the 90% confidence interval (90/10). Alternative samples can easily be developed as needed for 80/20 or mixed targets such as 90/20 by category and 90/10 overall. DNV GL also took the results of this analysis and inserted them into a sampling tool developed under another project to allow PSE to look at these various scenarios. Since the large building population and sample was zero for this report a recommended approach is to use a prototype model with a conservative infiltration reduction as an initial estimate until there is a population and sample to evaluate.

4. IMPACT RESULTS

The primary evaluation activities were to collect additional data from surveys and post retrofit billing data to refine or "true-up" the original site specific savings estimates. The surveys focused on collecting data on changes to tenant behavior or internal loads that would affect energy consumption, especially those changes that fall outside of program rules for preventing other energy efficiency upgrades after the air sealing treatment.

The final results are summarized in two tables below: Table 3 summarizes the total savings for all evaluated sites and the total savings for different categories of sites and Table 4 provides site specific results. There are two categories for measures as earlier in the program some projects received limited insulation measures and later in the program all measures were included at all sites and the category "All Measures" best represents the pilot and future program. The program also tracks whether buildings were previously insulated by the PSE multifamily retrofit program and only air sealing was performed. Overall results are promising that the realization rates overall is 87%. This is lower than initial results that were greater than 100% when the sample size was about half in Phase 1. More interesting are the results that realization rates for previously insulated are 97% and for 2-8 Units is 100%. We feel that the results from previously insulated show that the program models may have been better built where the only measure was air sealing. When measures included insulation as well there may have been more errors in the program models, but there was no systematic inputs that were changed. The result for smaller buildings may stem from the fact that tenant turnover is easier to identify and address for smaller buildings.

Table 3: Summary of Ex Ante and Ex Post Savings

Category	Sample Size	Ex Ante Savings	Ex Post Savings	Realiz-ation Rate	Total CFM-Pre	Total CFM-Post	Total CFM Reduc-tion	% CFM Reduc-tion
Total	36	319,562	277,875	87%	245,049	156,213	88,836	36%
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9-20 Units	19	183,099	140,788	77%	154,037	96,355	57,682	37%

For small leakage reductions, the savings may be small or even negative as the variation in usage from pre to post is greater than the amount of savings we are trying to investigate. Because the methodology relies on billing data to calibrate the models, the high tenant turnover rate from pre- to post can affect the results despite our efforts to normalize for weather and occupancy. If ex post savings was negative we list the realization rate as 0%. If the ex ante was small and ex post significant (PSE-6) the site realization is listed as >1000%. The site level realization rates are not as important as the site savings and overall program realization rates. Sites were only excluded from the analysis if the data was missing to build and calibrate a model.

Table 4: Site Savings Results

Project ID	Previously Insulated	All Meas.	Num. of Tenant Units	Unit Bin	Ex Ante Savings TREAT	Ex Post Savings	Realization Rate	CFM-Pre	CFM-Post	Reduction
PSE-20	No	x	8	2-8 Units	14,904	10,686	72%	5,293	2,830	2,463
PSE-26	No	x	8	2-8 Units	18,961	13,941	74%	7,025	3,881	3,144
PSE-27	No	x	8	2-8 Units	18,156	9,213	51%	6,771	3,203	3,568
PSE-28	No	x	6	2-8 Units	10,113	6,974	69%	3,075	1,698	1,377
PSE-29	No	x	10	9-20 Units	16,131	21,080	131%	7,044	4,190	2,854
PSE-30	No	x	8	2-8 Units	9,670	10,882	113%	6,100	3,459	2,641
PSE-31	No	x	8	2-8 Units	10,349	10,848	105%	5,370	3,190	2,180
PSE-32	No	x	16	9-20 Units	14,028	14,551	104%	11,836	6,794	5,042
PSE-33	No	x	19	9-20 Units	15,166	17,534	116%	10,979	3,626	7,353
PSE-37	No	x	14	9-20 Units	14,813	(1,285)	0%	5,708	2,777	2,931
PSE-38	No	x	10	9-20 Units	12,132	(1,901)	0%	7,175	4,093	3,082
PSE-16	Yes	x	8	2-8 Units	4,236	14,607	345%	5,238	3,669	1,569
PSE-17	Yes	x	8	2-8 Units	6,208	12,234	197%	5,990	3,635	2,355
PSE-18	Yes	x	8	2-8 Units	9,485	5,849	62%	5,032	2,300	2,732
PSE-21	Yes	x	12	9-20 Units	11,069	14,451	131%	6,576	3,250	3,326
PSE-22	Yes	x	12	9-20 Units	4,777	11,533	241%	6,380	3,240	3,140
PSE-23	Yes	x	12	9-20 Units	6,455	12,197	189%	8,062	4,401	3,661

PSE-24	Yes	x	12	9-20 Units	11,947	11,256	94%	7,771	4,174	3,597
PSE-25	Yes	x	8	2-8 Units	5,812	7,425	128%	4,755	2,524	2,231
PSE-34	Yes	x	16	9-20 Units	6,929	(9,850)	0%	7,092	4,888	2,204
PSE-35	Yes	x	20	9-20 Units	8,190	(1,381)	-17%	9,355	6,351	3,004
PSE-36	Yes	x	20	9-20 Units	7,810	11,076	142%	8,254	6,156	2,098
PSE-3	No		12	9-20 Units	12,497	10,035	80%	7,613	6,890	723
PSE-4	No		13	9-20 Units	6,891	11,877	172%	9,929	7,308	2,621
PSE-7	No		6	2-8 Units	2,039	8,940	438%	3,623	3,128	495
PSE-2	Yes		6	2-8 Units	13,273	(8,374)	0%	3,747	3,727	20
PSE-5	Yes		6	2-8 Units	1,393	(4,770)	0%	3,833	3,220	613
PSE-6	Yes		6	2-8 Units	(20)	4,579	>1000%	4,473	4,484	(11)
PSE-8	Yes		8	2-8 Units	760	7,345	966%	4,972	4,700	272
PSE-14	Yes		13	9-20 Units	5,800	8,929	154%	8,600	8,564	36
PSE-15	Yes		8	2-8 Units	2,761	8,887	322%	5,843	4,602	1,241
PSE-41	No		18	9-20 Units	14,907	9,957	67%	8,032	4,877	3,155
PSE-44	Yes		12	9-20 Units	3,879	35	1%	7,840	5,024	2,816
PSE-47	Yes		12	9-20 Units	3,024	(7,879)	0%	6,378	3,431	2,947
PSE-51	Yes		12	9-20 Units	6,654	8,572	129%	9,413	6,321	3,092
PSE-55	Yes		8	2-8 Units	8,361	17,821	213%	9,872	5,608	4,264

The original model developed by the pilot program team was used as the baseline condition except in select cases where the pre-retrofit model used too many unit bills in the calibration, this occurred for only a few sites. We encountered problems when audit forms contained vague or missing information that could not be resolved using the surveys. This also only occurred for a few sites. In these cases we retained the original model assumptions. We did note where the model assumptions varied between ex ante and ex post calibration. Additional site details are provided in the Appendix F. We did note that larger buildings were being sealed later in the pilot program (2014). There was more opportunity for occupancy changes with more tenant units, meaning the larger the building the more difficult the evaluation of savings. If only a few tenants change in a large building there was not an issue, but in the pilot the large buildings had significant swings in overall occupancy.

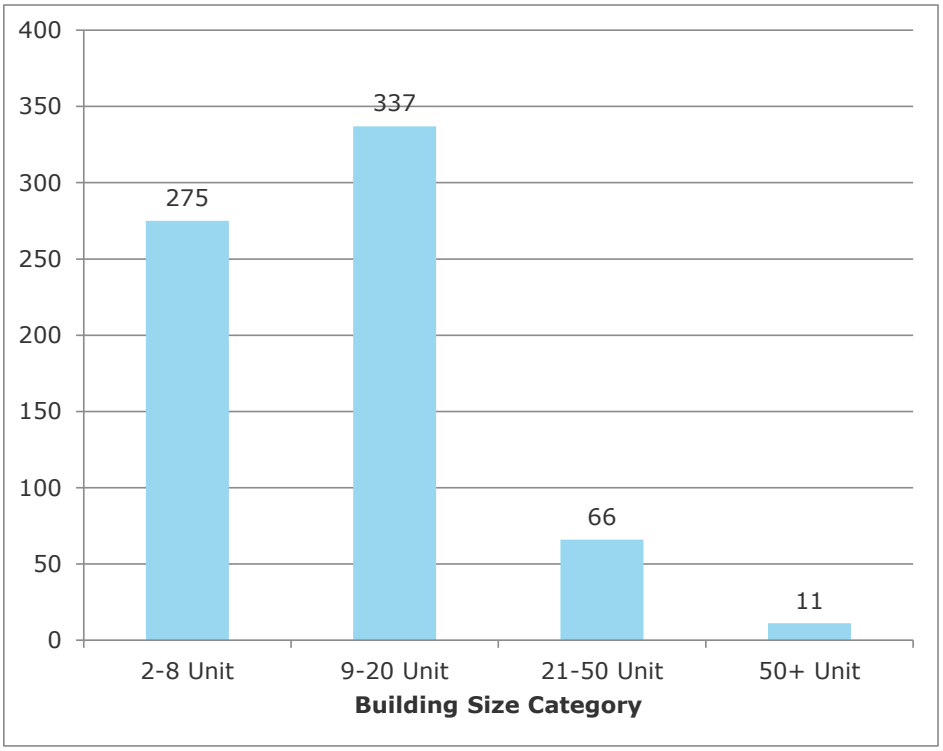
5. POPULATION AND VARIABILITY ESTIMATES

5.1 Multifamily Building Population

First we wanted to estimate the number of buildings in PSE's multifamily program that could receive the air sealing measure. This section outlines how we estimated the counts of building categories for the 2012-13 program population. Buildings are categorized based on the number of units in them. In our case, we have four categories; 2-8 units, 9-20 units, 21-50 units, and over 50 units.

We began with sixty two sample sites for which we counted the number of units in each building on a particular site. Based on the distribution of number of units on those sites, we came up with the four categories of buildings mentioned above. The distribution of the categories in our sample is shown in Figure 4.

Figure 4: Number of Unique Buildings in Sample of 62 "Sites"



These sample sites were drawn from various strata (created during the sample design phase) based on total energy usage. Therefore, we first created strata weights based on the total number of sites in the sample, total number of sites in the population, and the total number of buildings within the sample sites in a particular stratum. Specifically, stratum weight was calculated as:

$$StratumWeight = \frac{\sum NumberofSite \sin Population}{\sum NumberofSite \sin Sample * \sum NumberofBuilding \sin Sample}$$

For each building category in a stratum, we calculated the estimated proportion of each building category. For example, in our sample for stratum X, there are 4 buildings of type A, and 6 buildings of type B. The proportion of building type A would be 40 percent. These proportions are then multiplied by the stratum weight to estimate the number of buildings of that type in the population. At the end, an estimate of the distribution of each building category in the population is obtained. The estimated distribution of building categories in the population is shown in Figure 5.

Figure 5: Number of Unique Buildings Estimated in the Population

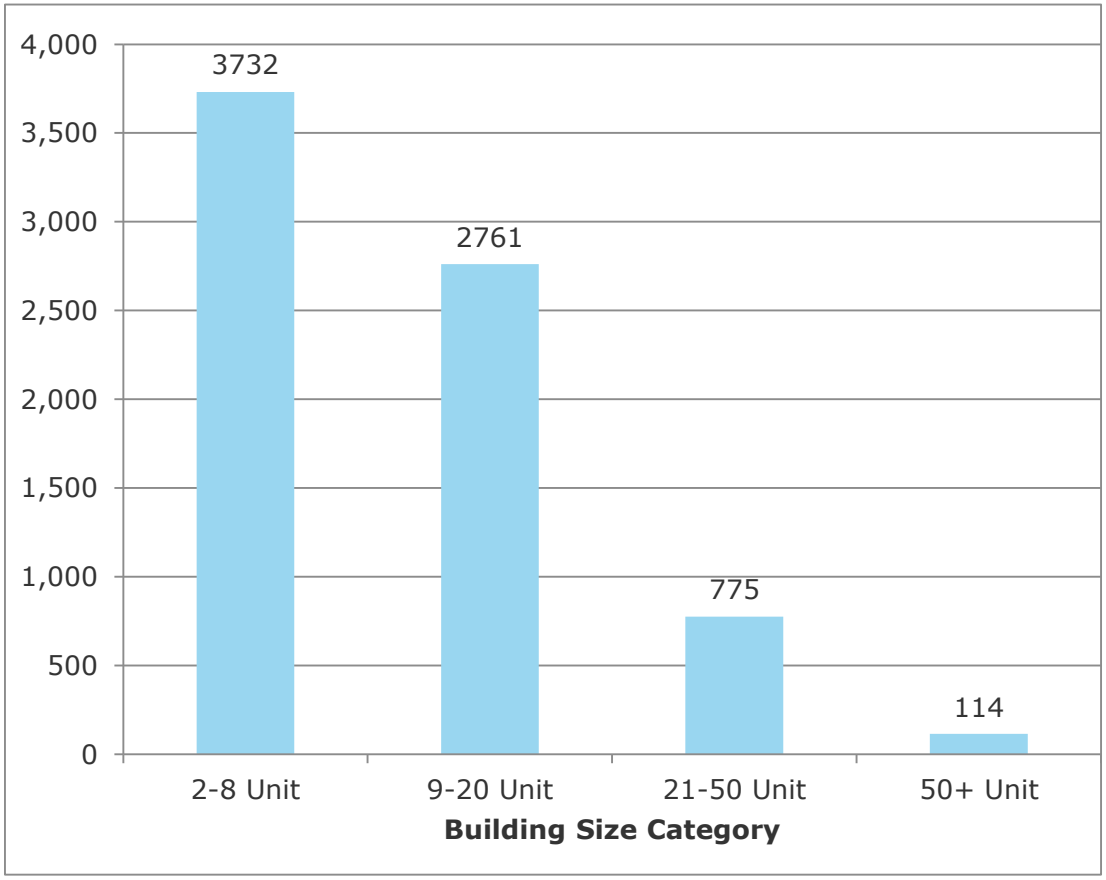


Table 4 summarizes the counts and percentages in the sample and the population.

Table 5: Number of Unique Buildings Estimated in the Population

Number of Units	Sample		Population	
	n	Percent	N	Percent
2-8 Unit	275	40%	3,732	51%
9-20 Unit	337	49%	2,761	37%
21-50 Unit	66	10%	775	10%
50+ Unit	11	2%	114	2%
Total	**689**	**100%**	**7,382**	**100%**

5.2 Variability in CFM Reductions and Savings

Our investigation looked at the variability in CFM reductions for all projects and variation in savings for evaluated projects. Not all projects could be evaluated. Once we define the variation in savings we can estimate the required sample size for additional testing in the future. Simply looking at the variation and averages for CFM reductions may also help determine deemed estimates.

Table 6: Variability Using CFM Reductions for reductions for All Projects

When regarded as population			When regarded as a sample		
Size	Standard Deviation	Coefficient of Variation	Size	Standard Deviation	Coefficient of Variation
For 2-8 units (N=30)	1051	0.63	For 2-8 units (n=30)	1069	0.64
For 9-20 units (N=29)	1273	0.43	For 9-20 units (n=29)	1296	0.44
Overall (N=59)	**1325**	**0.59**	**Overall (n=59)**	**1337**	**0.59**

In determining required sample sizes for the large building categories where savings information is not yet available we recommend using the overall estimate for the coefficient of variation (CV), a value of 0.59. This is true because the savings is strongly correlated to the leakage reduction.

The variability in evaluated savings is greater than the variability in CFM reductions. The ex ante savings had an overall CV of 0.57 and the evaluated savings had an overall CV of 0.98. This is driven by the large projects where ex ante CV was 0.44 and evaluated was 1.16.

Table 7: Variability Using Savings for Evaluated Projects

When regarded as population			When regarded as a sample		
Size	Standard Deviation	Coefficient of Variation	Size	Standard Deviation	Coefficient of Variation
For 2-8 units (N=17)	5736	0.71	For 2-8 units (N=17)	5913	0.73
For 9-20 units (N=19)	8337	1.13	For 9-20 units (N=19)	8566	1.16
Overall (N=36)	**7442**	**0.96**	**Overall (N=36)**	**7548**	**0.98**

We finally looked at the savings per CFM reduction since that formed the basis of the savings calculator. It was also seen as an option to reduce some of the variability in the absolute savings. These variations were quite high mainly driven by outliers where there were savings for small CF reductions and where there were negative savings regardless of CFM reduction.

We concluded that applying the realization rates to the ex ante savings for all projects offers the best option. The variability in CFM reductions and ex ante savings were more stable and consistent and by applying the realization rates the magnitudes of savings would agree with the evaluation results.

5.3 Sample Sizes for 90/10 Precision

The ultimate goal was to produce a table that includes the population, variation, and sample size for each category needed to achieve specified levels of relative precision at the category level and the overall level. We anticipated the desired precision levels will be 10% relative precision at the 90% confidence interval (90/10). Alternative samples can easily be developed as needed for 80/20 or mixed targets such as 90/20 by category and 90/10 overall. DNV GL also took the results of this analysis and inserted them into a sampling tool developed under another project to allow PSE to look at these various scenarios. Since the large building population and sample was zero for this report a recommended approach is to use a prototype model with a conservative infiltration reduction as an initial estimate until there is a population and sample to evaluate.

The results can be show in many ways. We chose to show the estimated sample size needed to achieve size category precision that is not as good as 90/10 with a goal of 90/10 overall. This yielded a lower target for the categories with more variability. It shows that the current precision estimate is around 21% and shows that relatively small additional samples in each category (10 to 13 more sites each) will reach this distribution of precisions and 90/10 overall.

Table 8: Variability Using Savings for Evaluated Projects

Category	Eligible Population Size (2012-14)	CV	Confidence Interval	Target Precision	Needed Sample Size	Current Sample Size	Current Precision
2-8 Unit	3,732	0.66	90%	17%	41	30	20%
9-20 Unit	2,761	0.44	90%	11%	43	29	13.5%
20-50 Unit	775	0.59	90%	30%	11	-	NA
50+ Unit	114	0.59	90%	30%	10	-	NA
Overall	7,382		90%	10%	105	59	21%

6. CONCLUSIONS AND RECOMMENDATIONS

The Regional Technical Forum has three categories of energy efficiency measures: deemed, simplified M&V and full M&V. For the pilot MF Air Seal Program and for high rise multifamily the recommended path is full M&V with a site specific complex modelling with some pre and post measurements. In comparison, tenant space measures like lighting and appliances are typically deemed savings measures. For MF Air Seal the current program lends itself to simplified M&V and as a recommendation this evaluation attempts to define what that means for savings claims. As more data is collected through the program some categories can be deemed.

If the goal of a simplified approach is to save time/money then modifying a prototype may actually be a similar level of effort. There are a few scenarios to consider. In the PSE Evaluation Guidelines the discussion focused on evaluation budget vs. evaluation accuracy. Maybe expanding this to look at total program cost (with M&V) vs. evaluation accuracy adds what we need to consider for Multifamily Air Sealing. The scenarios are:

- Pilot – Site Specific Calibrated Model, Contractor Data Collection and Centralized Modelling, okay ex-ante accuracy, M&V review/re-calibration of models, low evaluation cost
- Prototypes - Limited inputs from contractor data collection and modelling, worse ex-ante accuracy, M&V sample more expensive to collect data to confirm or revise all prototype "assumptions". Necessary if no available data, such as large buildings with more than 20 units
- Savings calculator – savings scaled to actual reductions, process collects primary pre and post data without added modelling cost, medium evaluation cost
- Deemed – Requires sufficient samples to provide a reliable estimate. Precision for each category can be less than 90/10 if the overall values across categories achieve 90/10

Prototyping energy models is a shortcut that does not give you very good information to make informed decisions, it is a useful approach to come up with estimates of savings in the absence of more specific data. The intent is to end up with standardized results for each measure, which means that the results are averaged out to a point where you don't really know if it is a cost effective measure to implement on a specific site. This may be fine for well vetted deemed measures, but make it difficult in early stages of full program roll-out with a new measure like air sealing. The hope is that the measure on average across buildings will be cost effective.

Given the goal of creating savings claims going forward, another alternative is updating the savings calculator until the samples are large enough to deem all projects. If some projects use average CFM reductions to run the calculator and a sample within the program receives pre-post testing, the calculator would still require key inputs of billing data and blower door test-in and test-out data as well as selection of changes in insulation levels. The calculator does not have the accuracy of site specific models, but does leverage actual completed buildings in the assumptions. The prototype approach and the calculator approach both have limitations, but the calculator may have lower costs and both methods would require similar EM&V to go out and model and calibrate a sample of actual projects. The calculator would archive the actual changes in infiltration which can also be used in evaluation sample designs and baseline model development.

Ultimately we recommend an approach of using a deemed savings for the two smaller unit categories and to continue collecting pre and post sealing blower door measurements on a sample. This requirement may be dropped in the future, but it should allow for broader program expansion while collecting some additional data to further refine the savings. For larger buildings we recommend a prototype model and to collect blower door data on at least a few buildings before the end of 2015 to inform the prototype. The evaluation approach for large buildings would require sampling and site specific modelling. We do recommend blower door testing before sealing on as many large buildings as feasible within the program budget as this data would be impossible to recreate during evaluation.

The final decisions on scaling up from the pilot should consider that collecting infiltration data for a sample will lead to more reliable estimates of savings and improve future evaluation. Measuring all buildings is an evaluator's dream, but it is not cost feasible at a large scale and creates a barrier to getting property managers to enrol in the program. Stopping all testing would increase the risk that future measures would not have the same realization rates exhibited in the pilot. The sampling approach allows for the pilot data to form a foundation that can be built upon with additional data from a wider variety of multifamily buildings. This can be done over time to balance critical data gathering and keeping the program itself cost effective and able to reach enrolment goals.

7. APPENDIX A: SURVEY AND SURVEY RESULTS

This section of the report provides a background of the survey instrument elements and summary of survey completions. Results used for the energy modeling are in the following Appendix B. A component of the survey also measured customer satisfaction. The survey instrument, satisfaction results, and demographics results are in Appendix C and D.

7.1 Survey Instrument Design and Implementation

The survey of tenants was designed to collect important parameters that would refine the estimate of energy savings from the Multifamily Air Sealing Program. The survey identified energy using equipment, within their unit, that would impact the energy saving estimates predicted in our model and measure customer satisfaction with the program. Site level responses were used in the model calibration process. The complete survey instrument is available in Appendix A.
The following list of key parameters was presented in the 2012 Evaluation Guidelines as the most important based on the model sensitivity to each input, see Figure 1.
The results for each of the investigated parameters are summarized in the next Appendix.

Thermostat types and usage patterns - The survey characterized the manipulation of heating setpoint to develop values and schedules for each model. The format included settings for day and night and weekday and weekend set points for a total of four setpoints per tenant. The survey results were averaged and input as a heating setpoint schedule in each building model.

Inventory of lighting and change in usage since treatment - Supplemental data was collected on lighting type (CFL, Incandescent) and wattage for audits that did not include these details. Usage was characterized in the same periods as thermostats, day/night and weekday/weekend - and the evaluated inputs were based on survey data.

Presence and change in usage of internal electric loads since treatment - Supplemental data was collected on non-audited plug-in appliances. An attempt was made to create a full inventory of regular kW loads during the heating season, but this did not need to include irregularly used items that are usually unplugged. Like lighting, these internal loads were analyzed in the same periods as thermostats, day/night and weekday/weekend, and the evaluated inputs were based on survey data.

Number of occupants – The survey asked questions to assess change in occupants since program audit and measure installation.

Tenant loads versus any common area loads on different meters – Clarify information that can be used to revise TREAT inputs. This included questions to determine the appropriate location of laundry appliances, whether they are in a common area or in each unit.

To improve the energy saving estimates associated with the program, DNV KEMA contacted tenants who lived in buildings where the treatment occurred (air sealing and/or insulation improvements). English and Spanish speaking tenants were surveyed by phone throughout the month of August 2013. The survey length was on average 12-20 minutes in length. To improve telephone survey response rates tenants were contacted in advance in the form of a notification letter that was distributed by their property manager and upon completion of the survey they were offer a $5 or $10 gift card as a thank you for their contribution to the study. The value of the gift card increased among respondents who were unresponsive after numerous voice mail messages.

7.2 Final Response Rates

DNV KEMA staff fielded telephone calls during the month of August 2013 to a total of 259 customers. Calls were placed primarily in the evening and occasionally during the day and on once on a Saturday. The 49 completed survey respondents were predominately English speakers but about one fourth spoke Spanish. As previously stated in a progress report memo prepared for PSE on August 19, 2013, the original population received from PSE contained 3414 records of which more than 92% were not eligible for the survey. Ineligible sample was identified as:

1) Tenants who have moved out and no longer rent at the property (the leading cause for exclusions),
2) Tenants who have recently moved in and were not living in the facility when the Arrow Insulation "treatment" to the building occurred, and
3) Tenants who occupy units that are not in the current phase of this evaluation (treatment cut-off is June 2012).

About mid-way through the month of August all the eligible sample (about 100 customers) were exhausted. At that point we made two changes to our calling strategy:
Increased the survey respondent's gift card incentive from $5 to $10, and
Began calling customers who fell into the not eligible category #2; (those who moved in after the treatment occurred) and limited calls to those who occupied the unit during the core winter months (E.g. December, January)

To calculate the response rate we used the American Association for Public Opinion Research's (AAPOR) response rate calculator where response rates includes an estimate of what proportion of cases of unknown eligibility are actually eligible. This calculator is useful when the sample includes a lot of ineligible cases; the calculator estimates about 53 percent of customers called would be eligible. As illustrated in Table 9 the final response rate was 36 percent.

Table 9: Response Rate Calculator and Rate

	%

$RR3 = \frac{Complete1}{Complete1 + Refused2 + NC\_Eligible3 + [(PctElig)*(NC\_UnknownElig4)]}$	36%

Table 10 contains the sum of calls by their final dispositions and then grouped by the AAPOR response rate categories. Customers with dispositions such as wrong number, disconnected, and out of services would have likely been not eligible had we been able to reach them and are therefore grouped in this category. The most common survey disposition was "max attempted reached" at total of 62. Customers were no longer called after six attempts were made.

Table 10: Survey Dispositions

APPOR Categories	Survey Dispositions	Count
Completed	Completed	40
	Partial Survey (counted as complete) Didn't live there during treatment month	9
Refused	Refusal - Respondent	15
	Refusal - Non-respondent (ex. receptionist or another household member)	1
Not Complete Eligible	Answering machine -message left	16
	Answering machine -no message left	18
	Hang Up	5
Not Complete, Unknown Eligibility	Max Attempts Reached	62
Not Eligible	Disconnect/non-working	27
	Wrong number	35
	Fax/data line	1
	Temporarily out of service/Mailbox full, try again another time	11
	Not Qualified - Out of sample	9
	Unaware of Improvements	4
	Moved, sample limited to service address	5
	Duplicate Number	1

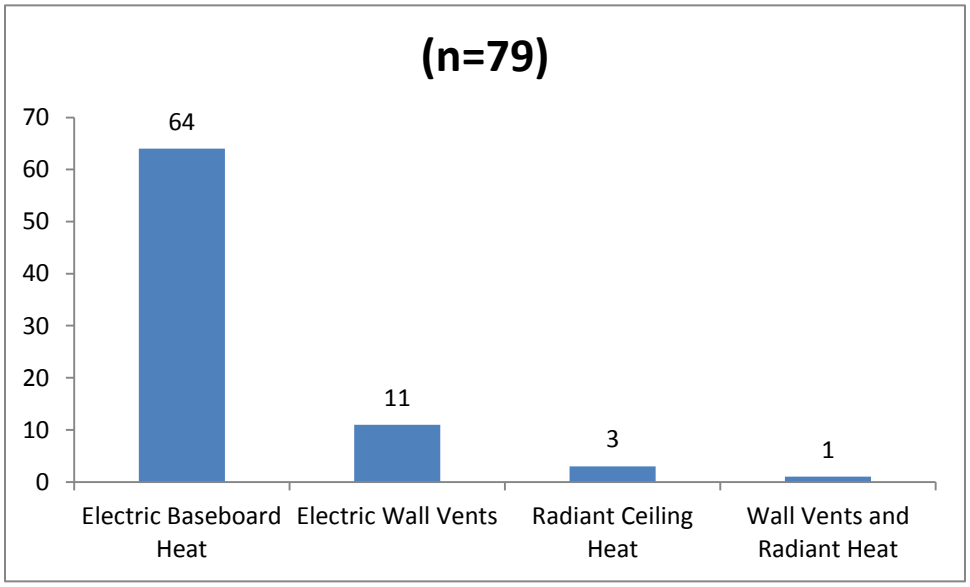
8. APPENDIX B: MODELING CALIBRATION FINDINGS FROM SURVEYS

Survey data was used on a site by site basis to calibrate the post retrofit model. The two key inputs that were modified most often were thermostat settings and domestic hot water (DHW) multiplier. This section of the report contains respondent's self-reported summary of the energy using equipment present in their apartments.

8.1 Heating Equipment

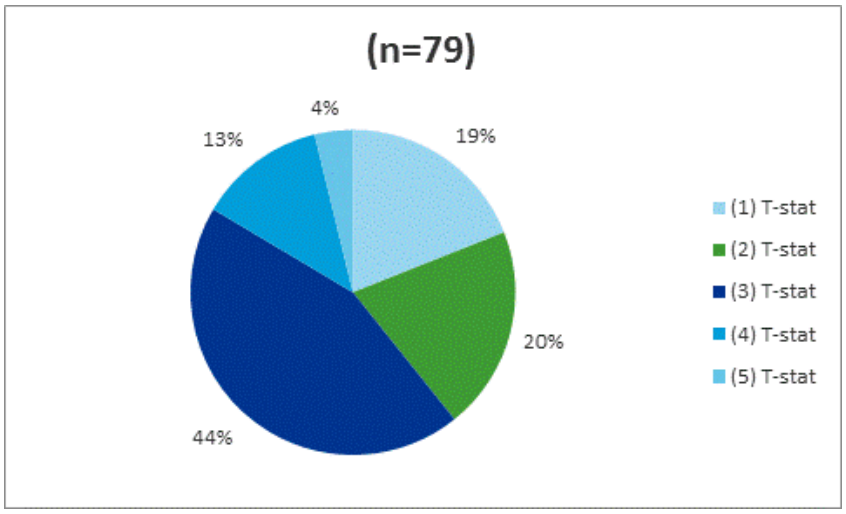
Only buildings with electric heat are eligible to participate in the program thus it is anticipated that electric heat would be the primary heat source. The types of heating equipment varied only slightly with electric baseboard heat being the most common at 81 percent. The second most was electric wall vents at 14 percent. Lesser common equipment included radiant ceiling mounted and wall vents and radiant ceilings mounted heaters.

Figure 6: Primary Heat Source



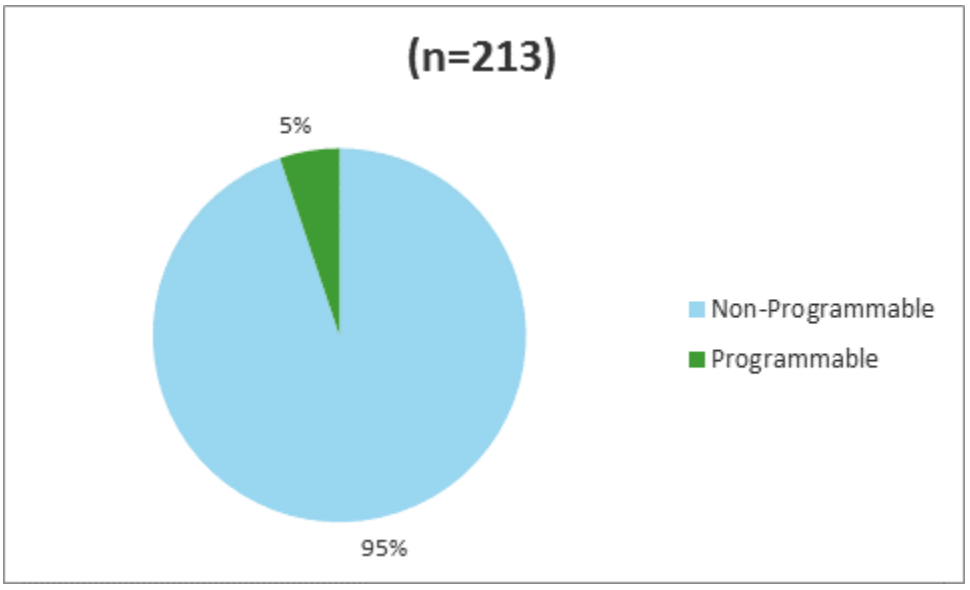
As illustrated in Figure 7 the presents of multiple thermostats to adjust temperature settings were common among respondents; fewer than 20 percent had a single thermostat. Most apartment dwellers had three thermostats (44%), some 20 percent had two thermostats and 17 percent had four or five.

Figure 7: Number of Thermostats per Household



Respondents were asked if the thermostats in their home were the programmable type (digital) or the non-programmable (dial) type. As illustrated in Figure 8 only 5 percent of all thermostats are programmable.

Figure 8: Type of Thermostat



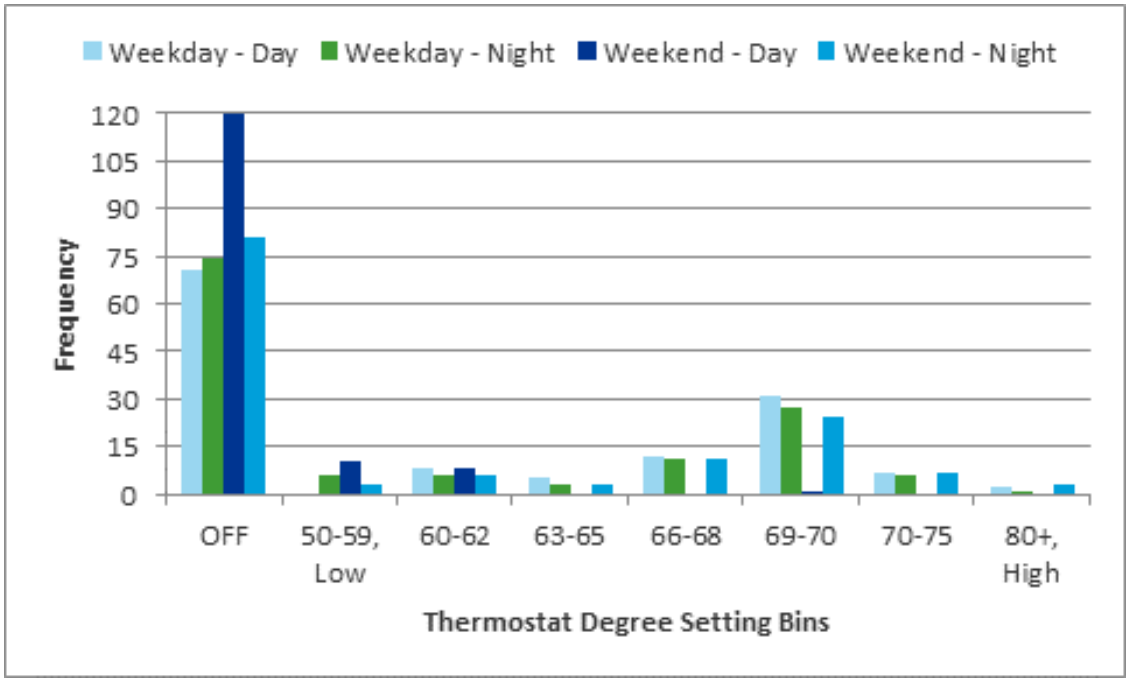
The average temperature heat set points were asked for weekdays days, nights, weekend days and weekend nights. The most common response was heaters were set to Off in all timeframes. Weekdays were more evenly split between setpoints and off and the average was similar but nights had some high settings. These results include responses for each heater thermostat so there are multiple results for

respondents with multiple thermostats. The results are summarized in Table 11 and Figure 9: Distribution of Thermostat Settings.

Table 11: Average Thermostat Settings

Winter Heating Set Points	Weekday - Day	Weekday - Night	Weekend - Day	Weekend - Night
"Off"	85	96	156	98
Count with Set-point	106	93	35	92
Average	**66.8**	**66.9**	**57.1**	**67.6**
Standard Deviation	6.1	6.7	6	6.5
"Low"	0	0	3	3

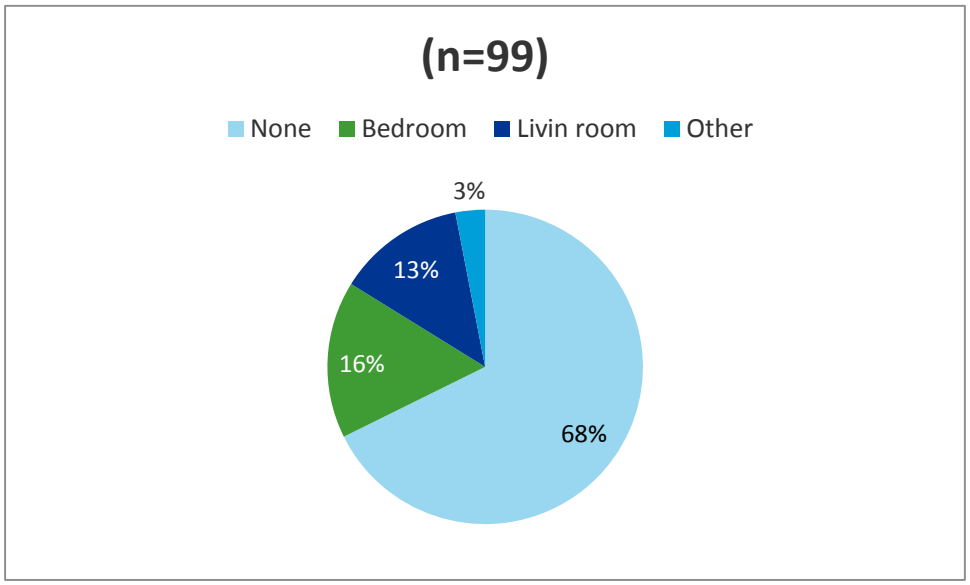
Figure 9: Distribution of Thermostat Settings



The presence of portable space heaters were fairly uncommon, 32 percent had one or more while the remaining 68 percent had none. When asked which room in the apartment the portable heater was located,

as indicated in Figure 10, portable heaters are most often heating the bedroom followed by the living room and a small percent in spaces such as the kitchen and closet.

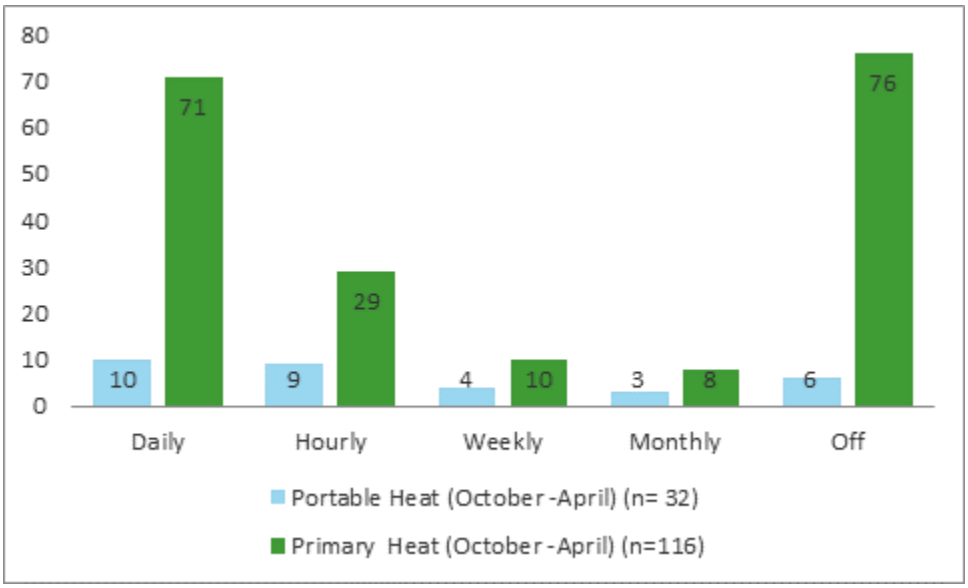
Figure 10: Location of Portable Space Heaters



The survey asked respondents during the colder months of October through April, how often they use their primary heaters and, if applicable, portable space heaters. The question was then repeated for the warmer months of May through September. In the warmer months of the year all respondents reported their primary heater and portable heaters were in the off mode. The use of both portable and primary heaters during colder months of the year is displayed in Figure 11. The results reflect usage for each portable heater and for each thermostat that controls a heater.

Considering the cold Pacific Northwest climate, a large percent of respondents at 66 percent, reported their primary heat source is off in the winter months. A few respondents elaborated on their heating practices and from this information we gather some insight on why they are not using their primary heaters. A couple respondents prefer to use their portable space heaters over their primary (e.g. electric baseboard heaters) and a few simply put on layers of clothing and go without heat.

Figure 11: Use of Primary and Portable Space Heaters



8.2 Lighting Equipment

Respondents were asked to provide a count of light bulbs used in their apartment for the following five light bulb types: light-emitting diode, (LED), halogen, linear fluorescent (FL), compact fluorescent (CFL) and incandescent (INC). To improve the accuracy of their assessment we asked, if willing and able, if they would walk around their apartment while they assess the lights; more than ¾ agreed to. As illustrated in Figure 12 the presence of halogen lamps and LEDs is almost non-existent. All respondents reported replacing light bulbs in their apartments as their responsibility as opposed to the property managers. All of them replaced previously installed INC with CFLs and one respondent replaced T12s with T8s.

Figure 12: Types of Light Bulbs Respondents Use (n=397 lamps)

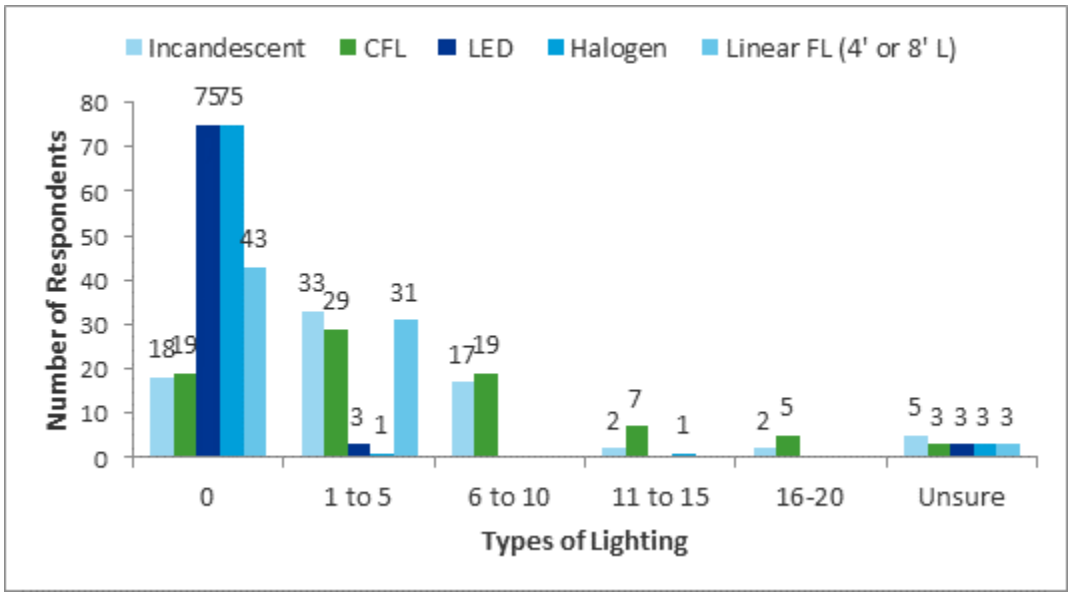
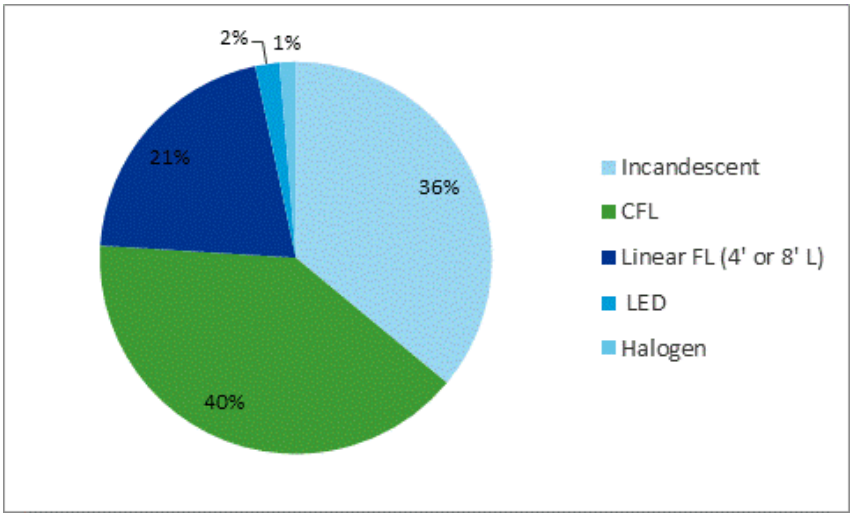


Figure 13, illustrates the distribution of light bulb types by type. As shown, CFLs represent a slight majority at 40 percent followed by incandescent at 36 percent and 21 percent had a linear fluorescent fixture in their apartment.

Figure 13: Distribution of Lights by Lamp Type (n=158 lamps)

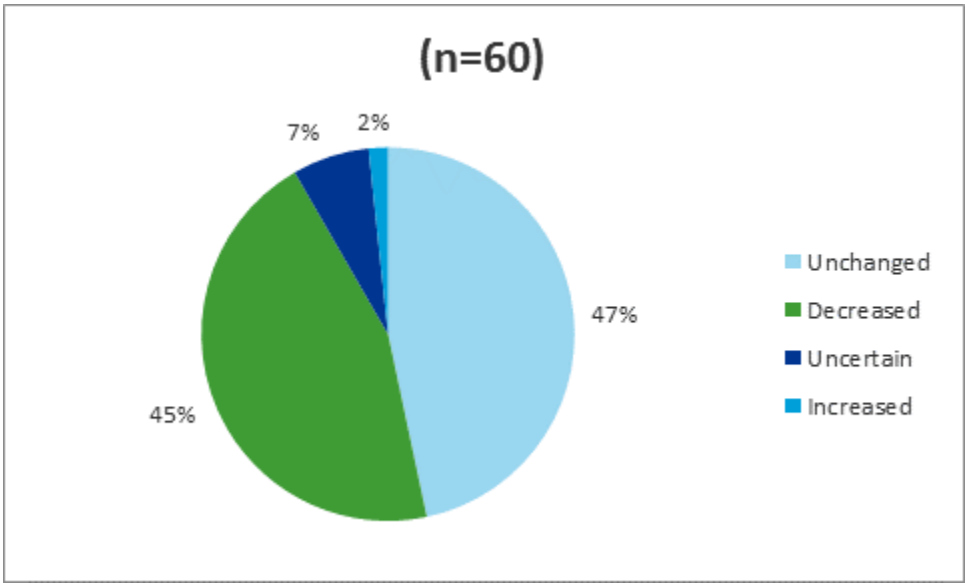


9. APPENDIX C: ADDITIONAL SURVEY RESULTS

9.1 Tenant Satisfaction Results

Survey respondents, tenants, were asked a short list of questions regarding their experience with the program and whether they had observed any changes in their electric bill as a result of the improvements made. The first question on changes in electric bills was limited to respondents who occupied their unit both before and after the treatment. As illustrated in Figure 14 nearly half (45%) noticed a reduction in their bills and a slight majority at 47 percent did not observe any changes. A smaller percent (7%) do not pay attention (auto-bill pay), and single respondent representing 2 percent observed an increase which is likely attributed to the attentional occupants added to their household.

Figure 14: Have Electric Bills Changed Since Treatment?



Respondents were asked to rate satisfaction with program elements on a one to five Likert scale where five represented very satisfied and one not at all satisfied. If respondents rated a score of less than two they were asked a follow up question on why they gave that rating. To ensure the questions were appropriate, respondents were asked two screening questions if they stated "no" to either or both they were not asked the follow up question pertaining to satisfaction with the installation contractor and/or PSE. Because so few respondents, only two, had interaction with PSE the results have been excluded from Figure 15. There was no screening question for "overall satisfaction" with the program.

Screening Questions:

Did you have any interaction at all with the installation crew Arrow Insulation?

Did you have any interaction at all with PSE regarding this project?

Satisfaction Questions:

How would you rate the attitude of the crew in terms of being courteous and professional?

How would you rate your satisfaction with PSE?

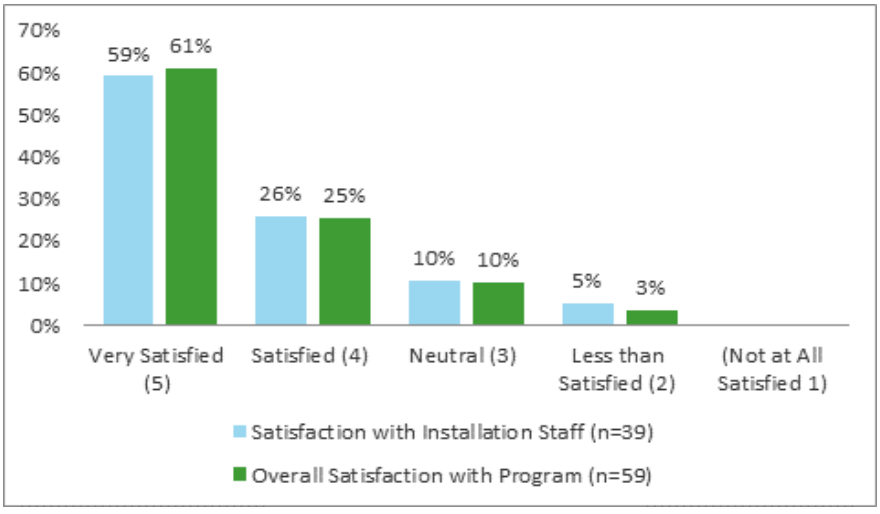
How would you rate your experience with this program as a whole?

Given the intrusiveness of the program, satisfaction with "overall program delivery" and with the "installation contractor" was relatively high. The results for these two program elements mirror one another where 85 percent rated a 4 or 5 for program delivery and 86 percent rated a 4 or 5 for satisfaction with the installation contractor such that if the contractors did a poor job we would expect the program marks to be low. DNV GL considers satisfaction ratings on measures like these above 90 percent to be good, 80 to 90 percent to be acceptable, and less than 80 percent to indicate a need for improvement. There was a consistent theme among respondents who were less than satisfied the issues centred on the preparation and cleanliness of the insulation crew. In phase two of the program evaluation there were overall fewer responses concerning this issue but it has not been completely addressed. Additionally one respondent cited concerns with the sensitive subject matter of the questions ask by the contractors. The respondent did not feel it was appropriate to inquire about the cost of their rent and number of occupants.

Respondents would like the contractors to: Cover screens to reduce or eliminate the possibility of insulation getting wedged into them. Make sure there isn't too much insulation installed Re: "The back door separated from wall as a result of too much new insulation; I wasn't happy about that." By mindful of the mess generated both inside and outside. Re: "The crew that did the testing was great, a five. The crew that did the work was messy and left lots to clean up, a two (on a 1 to 5 scale)." And "The crew left a big mess in the bathroom."

As for the program overall, three respondents had concerns: one pertained to a power supply issue, another was less than satisfied because they experienced no difference in their electric bill since the treatment occurred, and the third and no specific concerns but felt the program was: "Not outstanding but no complaints."

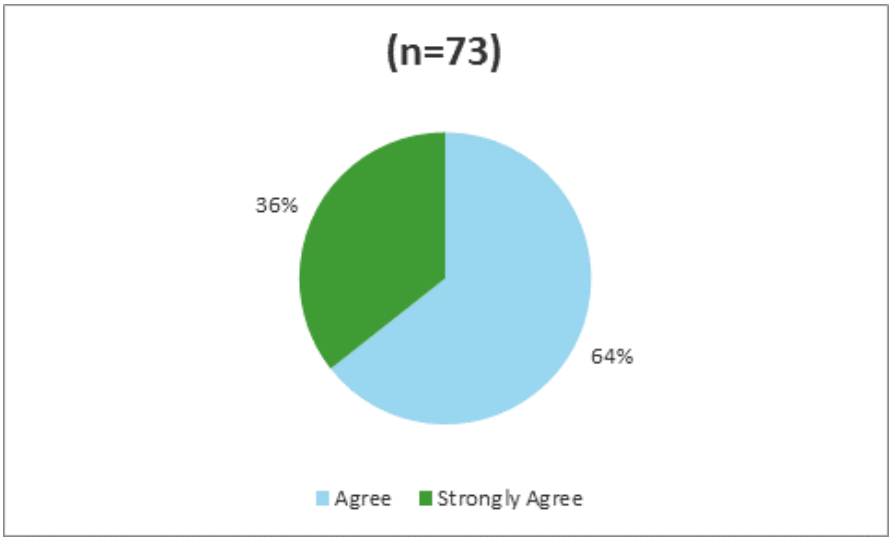
Figure 15: Tenant Satisfaction with Installers and the Program



Tenants were asked an agreement/disagreement question as another measure of satisfaction with program delivery and whether the experience influenced their overall opinion of PSE. Similar to a Likert scale question they were asked to rate their agreement and were presented with several options of strongly agree, agree, disagree or strongly disagree. As illustrated in Figure 16 none of the respondents disagreed or strongly disagreed. The majority at 64 percent agreed and 36 percent strongly agreed to the statement that "Program's such as these demonstrate PSE's commitment to providing their customers with high

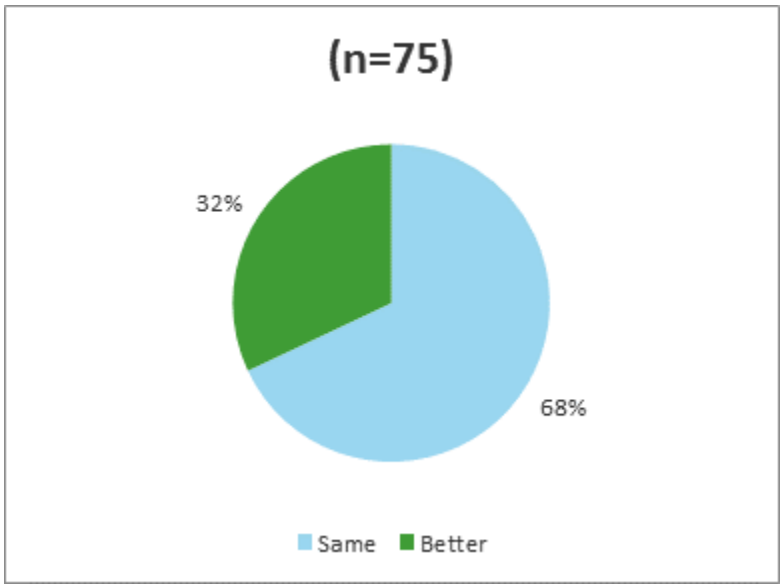
quality products and services". The results presented in the figure include responses from both phase one and two of the study. Responses from phase one were nearly identical with 65 percent agree and 35 percent strongly agree.

Figure 16: Tenants Opinion of PSE's Commitment to Quality



The last qualitative question asked respondents to reflect on their opinion of PSE before and after their experience with this program. Specifically they were asked: "Compared to how you felt about PSE before this project, would you say overall your satisfaction with PSE is better, worse, or about the same?" Given respondents received the program services at no cost we would anticipate opinions to be favourable as long as the service was performed thoughtfully and properly. However the level of intrusiveness is a justifiable reason to be less than satisfied, given they had no option to opt-out, as-is the post project clean-up if not done correctly. As illustrated in Figure 17 the results are generally positive. None of the respondents felt worse, 68 percent felt the same, and 32 percent felt better.

Figure 17: Satisfaction Comparison Pre/Post Program Delivery



If respondents indicated they felt “better” or “worse” a subsequent open-ended question asked why they gave that rating. In general respondents appreciated: reduced electricity costs, PSE’s high quality services, and improved comfort, free services that improves to their apartment and supporting efficiency “being green”. Provided is a collection of responses that captures each of these unique categories:

Reduced electricity: "Because the bills have decreased!"

“The efficiency work shows up financially. There was an immediate savings in my energy bill. How could you not be pleased?”

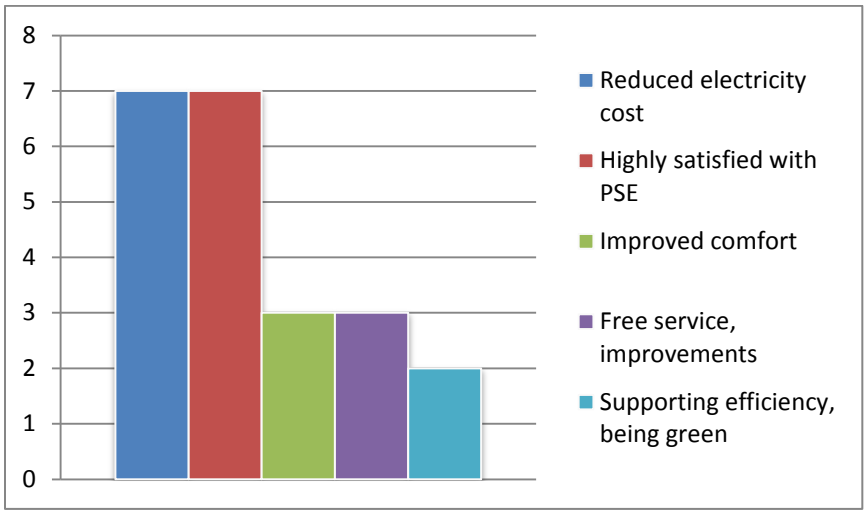
Highly satisfied with PSE: "Coming from Texas where utility companies made no effort better relationship with clients PSE is the best utility company I've been with to date. Customer service is great too."

Improved comfort: "Even (though) the bill is the same the apartment heats up faster."

Free service, improvements: "(Program) doesn’t cost me anything and saves me money."

Supporting efficiency, being green: "Because they're providing tips on saving energy. They're trying to go green and I think that's the right direction”.

Figure 18: Why Respondents are Highly Satisfied (multiple-response n=19)

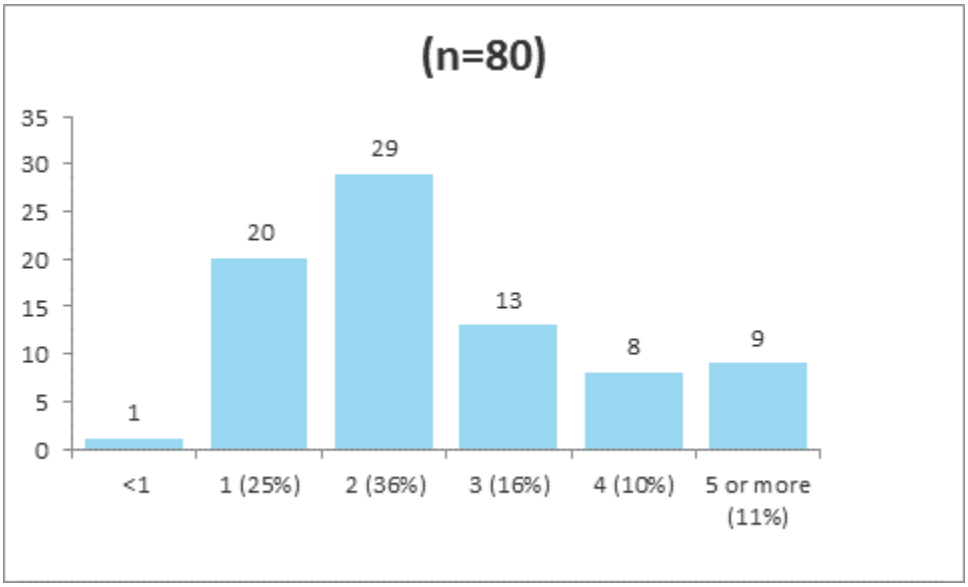


9.2 Demographics

This section of the report contains results of the demographic questions that may impact energy saving estimates.

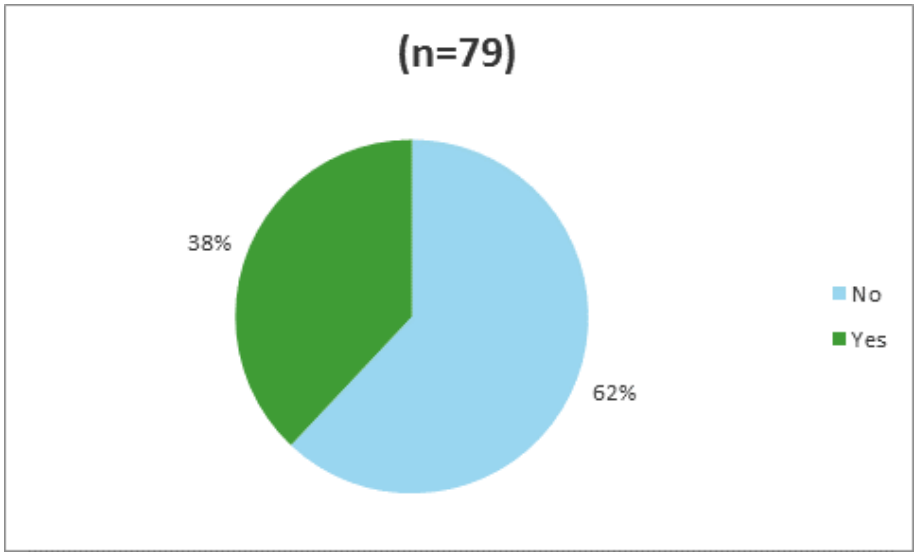
Respondents were asked to provide a count of occupants who live in their apartment year-around. Nearly half, 49 percent of respondents have one or two year-around occupants, 21 percent have three or four occupants, 9 percent have five or more (max of seven). And a single respondent had less than one year-around occupant.

Figure 19: Number of Household Occupants



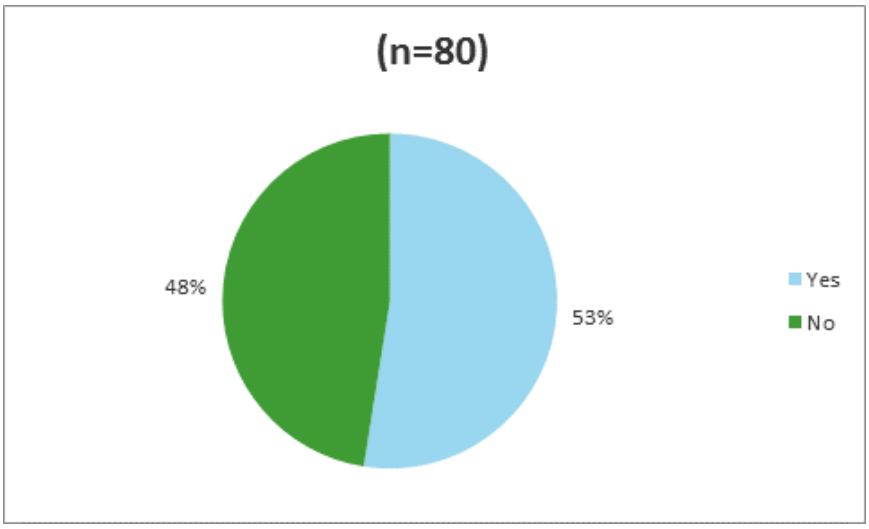
Respondents were reminded of the month and year the treatment occurred and asked if the number of occupants had changed; had anyone moved in or moved out? Changes were fairly common, 38 percent had a change in occupancy with the majority of new tenants having persons moving into their home. Some 62 percent stated there were no changed in occupancy.

Figure 20: Changes in Occupancy Since Treatment Occurred



To better understand day-time energy usage respondents were asked if there were any occupants who were home most or all of the day. Examples included a person who worked from home, a stay at home individual, a childcare provider, or an elderly-retired individual. As illustrated in Figure 21 daytime occupancy was about evenly divided with a slight majority at 53% percent with one or more person's home during the day and 48 percent had no person's home during the day.

Figure 21: Percent of Daytime Occupants



10. Appendix D: Survey Instrument

- ***Tenant Information***

Customer Name: _____

Building Property Name:_____

Address 1:_____

City:_____Zip:_____

Telephone 1: (___) ____ - ____ KEMA ID:_____;

Month treatment was completed: ___MO/YR_

- ***Call Tracking Log***

Call #	Date	Time	Notes (include message left, best time to call, best way to contact, and whether survey was completed)
1			
2			
3			
4			

Interviewers will not read text in the square brackets [ ] to interviewees unless instructed. References throughout the survey referring to the "last 12 months" is relative to the treatment completion month and year, respondent will be reminded interviewee of this time frame as needed.

[PLEASE READ]

Hello, <INTERVIEWEE>. My name is <INTERVIEWER> I'm calling on behalf of Puget Sound Energy and Arrow Insulation. PSE has hired my company DNV KEMA to evaluate energy savings associated with weatherization improvements that were completed at your building. You may recall having received a letter about this and an offer for a $5 gift card for your participation in a phone survey. I'd like to ask a few questions about the presence of and use of energy using equipment and lighting in your home. The feedback provided through this survey will be used by PSE to improve their program and assess the value of offering this no-cost program to PSE customers. The information we are requesting from you today is treated as confidential and will not be used for any other purpose.

[ONLY IF NEEDED] We are not soliciting any products or services of any kind. Your responses will remain confidential and will not be associated with you directly.

[ONLY IF NEEDED (PHONE) Validation Concerns]: If customer expresses concern over the validity of the survey, they can call PSE Manager Bobette "Bobbi" Wilhelm to verify that DNV KEMA is conducting the evaluation at: 425-462-3432 or Mobile 425-223-1504

[ONLY IF NEEDED (PHONE) Validation Concerns]: If customer express concern about the questionnaire or have questions for DNV KEMA than can call Consultant, Amber Watkins at 866 439 8006 or 707 820 4400.

• *Identify Decision-Maker*

[THE PURPOSE OF THIS SECTION IS TO CONFIRM THAT WE ARE SPEAKING WITH AN ADULT, OVER 18 YEARS OF AGE, WHO IS A HOUSEHOLD DECSIONMAKER]. [*IF T&T, THEN THANK AND TERMINATE*.]

DM1 Are you a person in the home who pays the energy bills and makes decisions concerning energy usage? [CONFIRM ADULT AND OVER 18 YRS OF AGE]

Yes ..... [GO TO Q1] 1
No 2
[Refused] ..... [T&T] 99

DM2 Can I speak to the person who makes decisions concerning energy usage in your home?

Yes RECORD RESPONDENT NAME: 1
No ..... [T&T] 2
Call back to speak with: _____ 3
[Refused] ..... [T&T] 99

[ONCE THE CORRECT PERSON IS ON THE PHONE, RE-READ INTRO AND CONTINUE TO Q1]

• *Confirm Program Awareness*

PA1. Prior to this call were you aware of the insulation and air sealing improvements that were made to your apartment building and performed by a company named Arrow Insulation?

Yes ..... [SKIP TO PA2] 1
No ..... [Continue to PA1a. 2
Don't know 3

PA1a. Sometime during the last year Arrow Insulation performed testing on all the units in your building by attaching a large fan to a red frame that was installed in your front door. You should have received a noticed from your property manager requesting permission to enter your space and/or informing you of the activities occurring on the property. Our record show the improvements were performed during the month of <merge>Now do you recall the Insulation and Air Sealing program?

Yes 1
No ..... [T&T] 2

PA2. Do you recall Arrow Insulation installing a large fan and red frame to your front door for the purpose of performing a blower door test?

Yes 1
No 2
Don't know 3

• *Portable Heat Source*

I'd like to ask you a couple of questions about the presence of portable space heaters in your home. The purpose of these questions is to better understand if this energy conservation program is helping customer reduce their electricity usage. To do this we need to get an idea of the heating equipment in your home, and determine if there have been any changes since the building improvements occurred. The information gathered for all these questions will only be used to inform our energy models that predict electricity savings.

1. How many portable space heaters do you have, if any? [If needed, portable space heaters are not typically furnished by the building management company but rather something the tenant brings to the home].

Record Qty:.....[Continue to Q2] Qty
None.....[Skip to Primary Heat; Q5] 0
Don't know ..... [Skip to Primary Heat; Q5] -98

2. Did you purchase or receive the portable heater(s) since <*merged month improvement occurred*> ?

Yes .....[SKIP TO Q2a] 1
No .....[Continue to Q4] 2
Don't know .....[Continue to Q4] 3

2a. Were the heater(s) a replacement or an addition to your home?

Additional ..... [SKIP TO Q3] 1
Replacement.....[Continue to Q4] 2

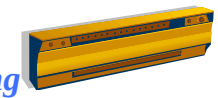
Don't know .....[Continue to Q4] 3

3. [If additional] Approximately what month did you start using the portable heater(s)?

Record.....[Month]

	Questions -Ask for each Portable Unit	Portable Heater1	Portable Heater2	Portable Heater3
Q4a	Which room in the house is/are the portable heater located: (Hallway/Kitchen/Brdm/Living Rm/Family Room/Bathroom)	[Room]	[Room]	[Room]
Q4b	From October through April how often would you say you use your heater(s)?	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly
Q4c	From May through September how often would you say you use your heater(s)?	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly
Q4d	Open Ended Comments			

- ***Primary Heat Source & Thermostat Setting***



5. Next I'd like to ask about the primary heat source in your apartment, to your knowledge do you have electric baseboard heat?

Yes .....[Skip to Q6]1
No.....[Continue to Q5a] 2
Don't know .....[Skip to Q6] 3

5a. What is your primary heat source?_____

Q6. For the next couple of questions I'd like to ask about thermostat usage, for these questions we would like you to think back on what you normally do during the colder months of October through April and from May through September.

Q6	Questions, For ALL thermostats in the apartment.	T-Stats1	T-Stats2	T-stat3
Q6a	How many thermostats do you have in your apartment?	[Qty]	[Qty]	[Qty]
Q6 b	Are/Is the thermostat(s) programmable? Programmable (Digital) /Non-Programmable (Dial)	Prgm/N-Prgm	Prgm/N-Prgm	Prgm/N-Prgm
Q6c	Q8. Which room in the house is/are the thermostat(s) located: (Hallway/Kitchen/Bedroom/Living room/Family Room/Bathroom)	[Room]	[Room]	[Room]
Q6 d	Q9. Do you typically use the set back or off feature? (If set back what is that temperature 50? Or 60 degrees?)	Yes/No	Yes/No	Yes/No
Q6e	Q10. [If Programmable] Do you use the programming feature?	Sometimes/Always/Rarely/Never	Sometimes/Always/Rarely/Never	Sometimes/Always/Rarely/Never

I'd like to know more about your room temperature preferences, again during the heating season of [October through April]. [If they have a programmable thermostat then read: "For these questions it may be helpful to be looking at your thermostat if you're able to do so". [Accept a range no more than two degrees; if needed READ: "Typically people will heat their home from temperatures ranging from 65 to 75 degrees Fahrenheit".]

Q6f	From October through April how often would you say you use your heater(s)?	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly
Q6g	From May through September how often would you say you use your heater(s)?	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly	Hourly/Daily/Weekly/Bi-Weekly/Monthly/or Bi-Monthly
Q6h	Q11. What is the approximate room temperature you prefer to heat your home during the day? [Sunrise to Sunset]	[Temp/Always Off]	[Temp/Always Off]	[Temp/Always Off]
Q6i	Q12. How about in the evening? [Sunset to Sunrise]	[Temp/Always Off]	[Temp/Always Off]	[Temp/Always Off]
Q6j	Q13. How about a when you are away from your home?	[Temp/Always Off]	[Temp/Always Off]	[Temp/Always Off]
Q6k	Q14. How about on the weekends or days when you're off work and at home most of the day?	[Temp/Always Off]	[Temp/Always Off]	[Temp/Always Off]
Q6l	Open Ended Comments			

10. Great is there anything else you would like to share regarding your heating preferences before we move on to the next topic? *[Interviewee: Record anything noteworthy from questions 9 here]*

Record ..... [Verbatim]

• *Lighting*

Next, I'd like to ask a few questions about you're lighting. We're interested in knowing about the type, quantity and approximate wattage of the light bulbs in your home.

11. Since <month 2012> have you replaced, removed or stopped using, added or purchased, and/or replaced any light fixtures such as a desk, table or floor lamp?

[REMOVED]..... [Tables/Floor/Desk/Other]
[ADDED] ..... [Tables/Floor/Desk/Other]
[REPLACED]..... [Tables/Floor/Desk/Other]
None .....[Skip to 14] 0
Don't know.....[Skip to 14] -98

[If Q11 = Added] 11a. Was this new fixture a replacement or an addition to what you currently have? Did this fixture replace another fixture or is it an additional fixture before.
[Replacement].....[Yes/No]
[Addition] .....[Yes/No]

Removed (ask for each)
You mentioned you removed a <fixture type(s) cited> I'd like to ask a few questions about that.

12. How many light bulbs did the fixture require? [Count of light sockets in fixture]
[Record for Each] .....[Count/DK]

13. What kind of light bulb did the fixture have in it?
[Record for Each] ..... [Incandescent/Halogen/CFL/LED/None/DK]

14. Approximately what month and year did the fixture(s) change (removal) occur? [Or when did they stop using it]
[Record for Each] .....[Month/Year/DK]

Added (ask for each)
You mentioned you added a new <fixture type(s) cited> I'd like to ask a few questions about that.

15. How many light bulbs does the fixture use?

[Record for each]..... [Count]

16. What kind of light bulb do you use?
    [Record for Each]..... [Incandescent/Halogen/CFL/LED/None/DK]

17. Approximately what month did you add the fixture to your home? [Or when did they start using it]
    [Record for Each].....[Month/Year/DK]

Those are all the questions I have regarding fixtures, next I would like to ask a few questions about the light bulbs that you have screwed into light sockets.

18. Who is responsible for replacing light bulbs in your home, yourself or your building manager?
    [Record].....[Tenant/Bldg. Mgr.]

19. Since <month/year> have you replaced any incandescent or halogen light bulbs with the more efficiency compact fluorescent or LED type?
    [Record]..... [Yes/No/DK]
    19a. If yes, what did you replace? .....[Record <removed> to a <installed>]
    19b. If yes, how many did you replace? .....[Record <removed> to a <installed>]

20. I'm going to read off a short list of light bulb types I would like to know how many of these you have in your home. If you are able or willing to walk around your home while we ask these questions that would help improve the accuracy of our survey.

[DO NOT READ: Did respondent agreed or decline to walk around the house? Agreed/Decline/]

	Light Bulbs In Home			
Q20a	How many Incandescent light bulbs do you have?	[Total/None/DK]		
Q20b	What are the wattages?	[Average watts]	[Specific Wattages]	[Specific Wattages]
Q20c	How many CFL light bulbs do you have?	[Total]		
Q20d	What are the wattages?	[Average watts]	[Specific Wattages]	[Specific Wattages]
Q20e	How many LED light bulbs do you have?	[Total/None/DK]		
Q20f	What are the wattages?	[Average watts]	[Specific Wattages]	[Specific Wattages]
Q20g	How many Halogen slight bulbs do you have?	[Total/None/DK]		
Q20h	What are the wattages?	[Average watts]	[Specific Wattages]	[Specific Wattages]
Q20i	Do you have any ceiling mounted linear fluorescent 4' or 8' light bulbs in your kitchen or perhaps elsewhere in the house?	[Yes]	[No]	
Q20j	[If yes] How many 4 foot and 8 foot fixtures do you have?	[Total 4' Fixtures] /None]	[Total 8'Fixtures] /None]	
Q20k	[If yes] How many light bulbs are in each fixture?	[4' or 8'] Qty	[4' or 8'] Qty	[4' or 8'] Qty

21. Great is there anything else you could tell me about how your lighting has changed <since month> before we move on to the next topic?

[Record].....[Qty/Wattage]
[Record].....[None]

• *Appliances & External Electric Loads*

Next I would like to ask you about the presents of appliances.

22. Which of the following appliances do you have inside your apartment?

Washing Machine & Dryer 1
Dishwasher 2
Freezer 3
Water Cooler 4
[None] 5

23. Since <month> have you had any large appliances, such those that I previous mentioned and/or a refrigerator, replaced or added to your home?

[Replacement /Added] ..... [Appliance Type1]
[Replacement /Added] ..... [Appliance Type2]
No Changes ..... [Skip to Q25] 2

24. What month and year did this occur?

[Record appliance type] ..... [Record Month/YR]
Don't know ..... DK

25. Since <month> have you had any small appliances, such as a microwave, coffee machine, toaster/ toaster oven, or garbage disposal, replaced or added to your home?

[Replacement /Added] ..... [Appliance Type1]
[Replacement /Added] ..... [Appliance Type2]
No Changes ..... [Skip to Q27] 2

26. What month and year did this occur?

[Record small appliance type] ..... [Record Month/YR]
Don't know ..... DK

Washing Machine

Next I would like to ask you about the use of your clothes washer.

27. [If Q22 = Yes/Washing Machine] Approximately how many loads of laundry a week would you estimate you wash in a given week?

[Record Laundry] ..... [Loads of Wash]/ NA /DK

28.  [If Q22 = Yes/Dishwasher] How often do you run your dishwasher on a weekly basis?

[Record Dishwasher] .....[Loads of Dishes]/ NA /DK

29. [If Q22 = No/Washing Machine] Is there a laundry facility at your apartment complex or do you wash your laundry off site?

At complex.....[Continue to Q28]1
Offsite .....[Skip to Q29] 2

30. [If Q22 = No/Washing Machine] Is the laundry facility located in the same building or structure as your apartment or is it in a different building at the complex?

Same Building 1
Separate Building..... 2

Electronics

31. Since <month> have you added or removed any electronic equipment such as a televisions, cable set-top boxes, computer, handheld devices, or gaming equipment?

[Added/Removed] .....[Note all Electronics]
No Changes .....[Skip to Q31] 2

32. [If Q31 = Added] Was this <cited equipment> a replacement or an addition to what you currently have?

[Record for Each] .....[Replacement [Skip Q33]/ Addition]

33. [If Q3a = Addition] What month did you start using it/them?

[Record] .....[Month/YR]
Don't know ..... DK

34. Since <month> have you purchased and installed any smart power strips?

Yes ..... [Continue to Q35] 1
No .....[Skip to Q36] 2
Don't know.....[Skip to Q36] 3

35. [If Q31 = Added] Was this <cited equipment> a replacement or an addition to what you currently have?

[Record for Each] .....[Replacement [Skip Q36]/ Addition]

36. What month did you start using them?

[Record] .....[Month]
Don't know 2

- *Program Satisfaction*

Thanks for all the detailed information about your homes lighting and appliances we're just about done. I would like ask just a few questions about your satisfaction with the program contractors and with PSE.

37. Since these improvements were made in <month> would you say your electric bills have increased, decreased or are they unchanged?

[Record] ..... [Increased/Decreased/Unchanged]

38. Did you have any interaction at all with the installation crew Arrow Insulation?

Yes 1
No .....[Skip to Q] 2

39. How would you rate the attitude of the crew in terms of being courteous and professional on 0-5 scale were five is the most satisfied and zero is the least?

Record .....[0-5]

39a. [If <2] Why do you give this rating? .....[Record]

40. Did you have any interaction at all with the PSE regarding this project?

Record ..... [Yes/No/DK]

41. Using that same 0 to 5 scale, how would you rate your satisfaction with PSE?

Record .....[0-5]

42a. If <2then ask why do you give this rating? .....[Record]

42. Again, using that same 0 to 5 scale, how would you rate your experience with this program as a whole?

Record .....[0-5]

42a. If <2then ask why do you give this rating? .....[Comment]

43. I'd like to know how strongly do you agree with this statement: "Program's such as these demonstrate PSE's commitment to providing their customers with high quality products and services". Would you say you? Strongly Agree/Agree/Disagree/or Strongly Disagree

[Level of Agreement] .....[Strongly Agree/Agree/Disagree/or Strongly Disagree]

44. Compared to how you felt about PSE before this project, would you say overall your satisfaction with PSE is better, worse, or about the same?

Record.....[Better, Worse, the Same]

43a. If better or worse why do you give this rating? .....[Comments]

45. Is there anything regarding this specific program that you would like to share with PSE or Arrow Insulation before we move on to our last topic?

Record .....[Comments]

- *Demographics*

We're almost done. I just have a few more questions about your household. The information used will help us estimate your energy usage and will be kept confidential.

46. Including yourself, how many people live in your home year-around?

[Record] ..... [Count:__]
Refused .....-99

47. Have there been any occupant changes since <month>? [If needed has anyone moved in or moved out?]

[Record Occupant Changes] ..... [# of Occupants:__/None]
Refused ..... -99

48. To help us better understand day-time energy usage we would like to know is there any occupants who are home most or all of the day? Such as a perhaps who work from home, or stay at home individual, or childcare provider, or an elderly-retired individual?

[Record].....[# Occupants:__/ None]
Refused..... -99

49. Have there been any changes since <month improvements were made> in the last year 12 months regarding year regarding the number of people who stay at home? and if so what month did this occur?

Changes .....[# Occupants:__ /None]

48a. If yes, what month did this occur? Month changed ..... [Month/Yr]

- 

- *Gift Card & Close*

On behalf of PSE I would like to thank you for your feedback on this survey. As promised we would like to offer you a gift card for you input.

Would like to know would you like a gift card from Safeway or Starbucks?

Record ..... Safeway
Record .....[Ask Gift Card Email Q] Starbucks
[Neither] .....[None the T&T]

IF STARBUCKS:

Starbucks had a feature that allows us to email you the gift card that way you won't have to wait for it in the mail. You will most likely need a printer too. If you have an email account I can take that down now and send it to you today. Would you be interested in this option or do you prefer to receive it in the mail?

Record .....[Email]//Mail]

Email Address:_____

Could you slowly state address where you would like to gift card to be sent?

Mailing Address:_____

IF SAFEWAY

Could you slowly state address where you would like to gift card to be sent?
Mailing Address:_____

Great, thank you. Unless you have any questions for me we are finished? Thank you. END

11. Appendix E: Building Energy Simulation and TECLOG analysis

TREAT is building energy simulation software originally used by the implementation team to predict energy savings on the multifamily buildings in the pilot program. In the ex post evaluation we wanted to model the buildings again, calibrated using billing data, to see how the actual savings compare to the predicted

savings. The TREAT software automatically normalizes billing data, allowing for accurate projections of savings many years into the future regardless of whether the time of testing was a mild or severe temperature year. However, TREAT doesn't use actual and normal weather from the same weather station – there are more actual weather stations than stations with normal weather. This creates a bias caused by the difference between the weather conditions at the two stations used to normalize a particular building. We attempted to fix this problem by importing our own actual and normal files so we could keep the weather station consistent. This would yield more accurate results based on actual HDD and CDD for that location and specific year. Unfortunately, importing weather files into TREAT was not a straightforward process and we were not able to correct the weather file problem.

Note that the TREAT limitation was the same for ex ante and ex post, so the realization rates should be unaffected by this issue. The absolute results are likely biased by 2-3% but it appears that is in both positive and negative directions since there are some sites in slightly hotter and some in slightly colder locations. Ultimately, we could not quantify this bias since we only reviewed some projects in Phase 1, but we know it is present and not accounted for. Ideally, we recommend using real weather and TMY3 from the same station. If the models are used to make ex ante predictions without calibration (using software other than TREAT) then there will be no inherent spatial bias since billing data is not being normalized. In Phase 2 we will summarize the difference in daily temperatures between the program population sites and modeled weather stations.

11.1 Teclog Data Analysis

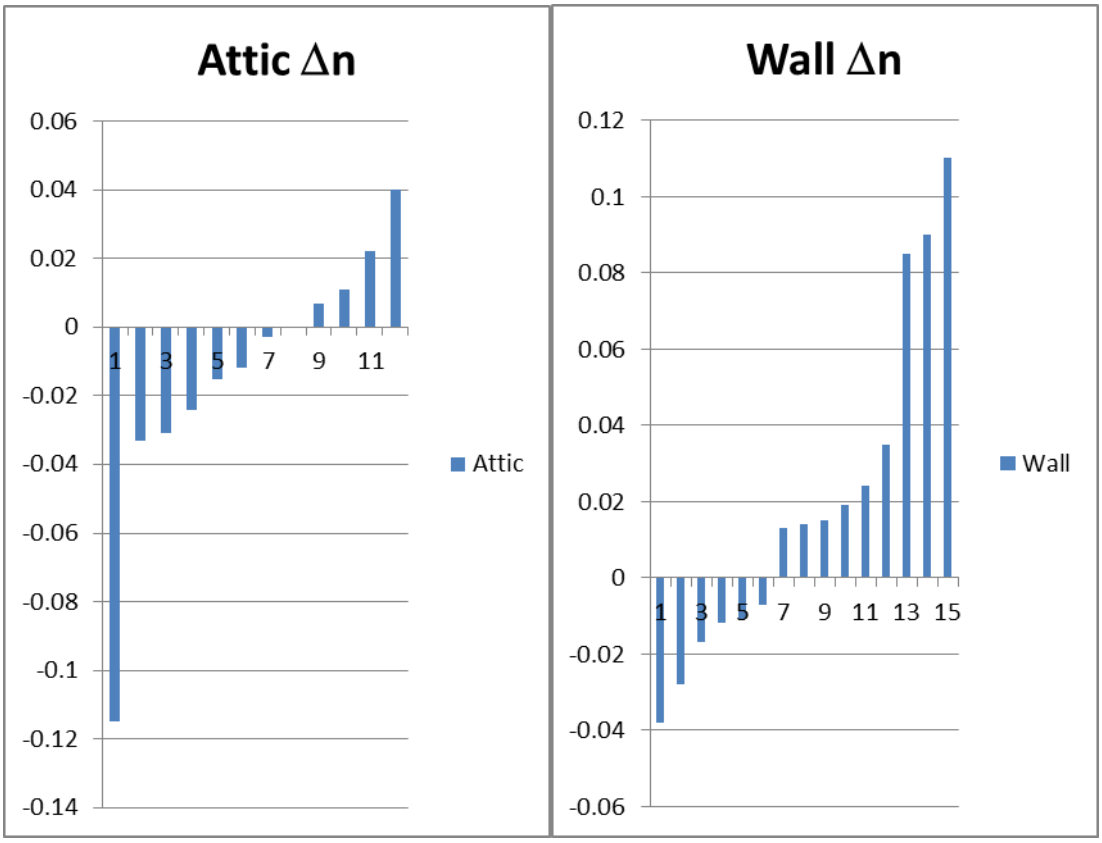
We explored the Tec log data for 38 buildings and determined that there were no extremely windy conditions or large changes in the leakage exponent, n, from pre to post, which validates the CFM results showing they are not biased.

We looked at leakage reduction as a percent of pre retrofit leakage to see how much of the potential was achieved. We found that the average leakage reduction was 27% with a standard deviation of 17%. Several buildings achieved leakage reduction as high as 50%; others achieved reductions as low as 0%, with several buildings coming in lower than 10%. This shows a wide variation in leakage reduction within the program. In our limited sample, standalone attic sealing was the most effective, achieving 20% leakage reduction; wall sealing was next most effective achieving 16% leakage reduction with floor sealing achieving only 11% reduction in total leakage. We furthermore concluded that in our sample the order of measures does not matter, i.e. wall sealing achieves the same savings independent of the whether it was done before or after attic and floor sealing. We believe, however, that interactive effects are worthy of more investigation.

We are also considering in future analysis, drafting simple diagrams for leakage by unit and then looking at the measures to see if leakage reduction is distributed as expected with wall insulation impacting mainly the side units, floor sealing impacting lower level units, and roof sealing impacting upper level units.

We investigated the change in leakage exponent, n, between the pre and post leakage tests to see if we could tell anything about the nature of the holes that were sealed. The coefficient n tells whether the holes in the building shell are shaped more like a circle or a slit (0.5 = perfect circle, 1.0 = perfect slit). A slit or crack would be a long narrow hole in the building shell such as spaces between top plates, loose fitting windows and doors, or an unsealed sill plate where it meets the foundation, all potentially indicated by a high n. A circular hole is one that is roughly as wide as it is tall such as holes around wiring and plumbing penetrations or round holes in can light housing potentially indicated by a low n (near 0.5, the lower theoretical limit). We found that in general attic sealing looked like sealing of cracks in many buildings, and that wall sealing look more like filling of holes in most buildings, see the distributions shown in the charts below. Our hypothesis is that plumbing and electric penetrations in walls are circular hole shaped and leaks at attic hatches or seams where walls meet ceilings are why attic leakage appears as linear cracks.

Figure 22: Leakage Exponent for Attic and Wall Sealing



12. APPENDIX F – SITE SUMMARIES FOR CALIBRATED PHASE 1 MODELS

	SITE 1							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	9,240	$795	7,625	$656	9,487	$816	8,895	$765
February	8,067	$694	7,160	$616	8,241	$709	6,936	$596
March	7,175	$617	7,125	$613	7,791	$670	7,906	$680
April	4,086	$351	5,524	$475	5,265	$453	6,172	$531
May	3,117	$268	5,247	$451	4,321	$372	5,697	$490
June	3,017	$259	4,017	$345	4,182	$360	4,050	$348
July	3,117	$268	3,811	$328	4,321	$372	3,507	$302
August	3,117	$268	3,715	$319	4,321	$372	3,245	$279
September	3,399	$292	4,089	$352	4,663	$401	3,332	$287
October	6,058	$521	5,876	$505	7,103	$611	5,162	$444
November	7,177	$617	6,113	$526	7,941	$683	6,352	$546
December	9,827	$845	7,706	$663	9,979	$858	7,660	$659
Total	67,397	$5,796	68,008	$5,849	77,616	$6,675	68,913	$5,927
Daily Base Load	100.55	$9	101.36	$9	139.40	$12		
Virtual Rate	$0.09							
Date of Retrofit	Feb-12				BPC Projected Savings		13,273	$1,141

Notes:	
	Negative savings on this one
	Infiltration lowered from 3747 to 3727, very little CFM improvement
	Walls improved from 342 to 2, walls previously uninsulated
	Raised occupied heating temp from 65.6 to 68.5
	Thermostat's changed to non-programmable
	Raised DHW demand multiplier from 0.33 to 0.75

	SITE 2 (101-204)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	11,249	$967	8,762	$754	8,717	$750	7,472	$643
February	9,828	$845	8,090	$696	7,562	$650	6,618	$569
March	9,405	$809	8,440	$726	7,148	$615	7,061	$607
April	6,308	$542	7,303	$628	4,906	$422	6,079	$523
May	3,907	$336	7,243	$623	4,371	$376	4,583	$394
June	3,781	$325	6,236	$536	4,230	$364	4,155	$357
July	3,907	$336	6,123	$527	4,371	$376	3,717	$320
August	3,907	$336	6,087	$523	4,371	$376	3,722	$320
September	5,534	$476	6,314	$543	4,461	$384	4,011	$345
October	8,663	$745	7,643	$657	6,550	$563	4,600	$396
November	9,539	$820	7,662	$659	7,304	$628	6,030	$519
December	11,702	$1,006	8,815	$758	9,131	$785	7,180	$617
Total	87,729	$7,545	88,719	$7,630	73,122	$6,288	65,227	$5,610
Daily Base Load	126.03	$11	126.84	$11				
Virtual Rate	$0.09							
Date of Retrofit	Feb-12				BPC Projected Savings		4,236	$364

Notes:	
	Lowered CFM from 5238 to 3669
	It appears that the existing wall type was not input correctly as it remained the same in both cases (2) even though a wall blow was done
	Walls changed from 2 (cellulose only) to 291 (cellulose plus fiberglass)
	Lowered the occupied heating temp from 76 to 72
	Thermostat's changed to non-programmable
	Changed light fixture wattage from 18 to 40 to raise baseline
	DHW multiplier raised from 0.65 to 0.72

	SITE 3 (101-204)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	10,764	$926	8,661	$745	8,666	$745	7,725	$664
February	9,083	$781	7,987	$687	7,211	$620	6,459	$555
March	9,065	$780	8,359	$719	8,507	$732	7,103	$611
April	6,598	$567	7,281	$626	5,264	$453	5,554	$478
May	4,272	$367	7,240	$623	4,239	$365	4,942	$425
June	4,135	$356	6,274	$540	4,102	$353	3,940	$339
July	4,272	$367	6,188	$532	4,239	$365	3,538	$304
August	4,272	$367	6,159	$530	4,239	$365	3,329	$286
September	5,516	$474	6,356	$547	4,540	$390	2,892	$249
October	8,460	$728	7,614	$655	6,468	$556	3,946	$339
November	9,427	$811	7,617	$655	8,708	$749	5,845	$503
December	11,497	$989	8,709	$749	8,944	$769	7,327	$630
Total	87,362	$7,513	88,445	$7,606	75,127	$6,461	62,600	$5,384
Daily Base Load	137.82	$12	138.56	$12				
Virtual Rate	$0.09							
Date of Retrofit	Feb-12				BPC Projected Savings		6,208	$534

Notes:	
	TREAT weather file only goes through June 2013.
	Calibration: Lowered cfm from 5990 to 3635
	Walls changed from 343 to 291
	Lowered the occupied heating temperature from 76 to 69.5 degrees
	Thermostat's changed to non-programmable
	Changed light fixture count from 48 to 38 to lower baseline
	TREAT normalizes for weather
	Move to closest TMY3 weather file

	SITE 4							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	13,651	$1,174	11,483	$988	11,384	$979	10,467	$900
February	11,554	$994	10,807	$929	9,554	$822	8,417	$724
March	10,165	$874	10,670	$918	8,657	$745	9,711	$835
April	5,966	$513	8,159	$702	5,616	$483	7,402	$637
May	5,079	$437	7,679	$660	5,360	$461	7,106	$611
June	4,915	$423	6,006	$516	5,187	$446	5,274	$454
July	5,079	$437	5,784	$497	5,360	$461	4,060	$349
August	5,079	$437	5,113	$440	5,360	$461	3,521	$303
September	5,124	$441	6,070	$522	5,235	$450	3,303	$284
October	8,499	$731	8,672	$746	7,494	$644	5,597	$481
November	10,373	$892	9,087	$781	8,714	$749	7,154	$615
December	14,795	$1,272	11,612	$999	12,325	$1,060	9,368	$806
Total	100,279	$8,624	101,141	$8,698	90,244	$7,761	81,381	$6,999
Daily Base Load	163.85	$14	164.94	$14				
Virtual Rate	$0.09							
Date of Retrofit	Feb-12				BPC Projected Savings		12,497	$1,075

Notes:	
	Lowered CFM from 7613 to 6890
	Floor changed from 49 (no insulation) to 54
	Walls changed from 282 to 2
	Thermostat's changed to non-programmable
	Decreased the occupied heating temp from 63.7 to 62
	Increased DHW multiplier for 0.62 to 0.67

	SITE 5 (1-14)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	14,926	$1,284	13,476	$1,159	13,270	$1,141	13,495	$1,161
February	13,281	$1,142	12,830	$1,103	11,814	$1,016	11,822	$1,017
March	14,657	$1,260	13,821	$1,189	13,051	$1,122	7,254	$624
April	10,779	$927	11,815	$1,016	9,782	$841	10,243	$881
May	8,645	$743	12,003	$1,032	8,405	$723	9,723	$836
June	8,366	$719	9,652	$830	8,134	$699	7,821	$673
July	8,645	$743	9,412	$809	8,405	$723	7,271	$625
August	8,645	$743	9,122	$784	8,405	$723	9,359	$805
September	8,722	$750	9,442	$812	8,295	$713	7,231	$622
October	11,241	$967	11,621	$999	10,052	$864	8,802	$757
November	14,931	$1,284	13,260	$1,140	13,226	$1,137	10,433	$897
December	16,833	$1,448	14,148	$1,217	14,955	$1,286	12,198	$1,049
Total	139,669	$12,012	140,602	$12,092	127,792	$10,990	115,652	$9,946
Daily Base Load	278.86	$24	279.00	$24	271.12	$23		
Virtual Rate	$0.09							
Date of Retrofit	Feb-12				BPC Projected Savings		6,891	$593

Notes:	
	Infiltration lowered from 9929 to 7308
	Attic improved from 73 to 66
	lowered the occupied heating temp from 68 to 65
	Thermostat's changed to non-programmable
	Number of light bulbs lowered from 72 to 40
	Average light bulb wattage lowered to 30

	SITE 6 (1-8)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	8,801	$757	7,217	$621	7,363	$633	7,289	$627
February	7,941	$683	6,781	$583	6,654	$572	6,354	$546
March	8,437	$726	7,355	$633	7,068	$608	5,408	$465
April	6,096	$524	6,506	$559	5,231	$450	5,873	$505
May	3,907	$336	6,647	$572	4,407	$379	4,854	$417
June	3,781	$325	5,522	$475	4,264	$367	4,607	$396
July	3,907	$336	5,377	$462	4,407	$379	3,380	$291
August	3,907	$336	5,105	$439	4,407	$379	3,075	$264
September	4,663	$401	5,493	$472	4,369	$376	3,750	$322
October	6,827	$587	6,491	$558	5,671	$488	5,062	$435
November	8,738	$751	7,072	$608	7,322	$630	6,096	$524
December	9,641	$829	7,486	$644	8,141	$700	7,224	$621
Total	76,648	$6,592	77,052	$6,626	69,303	$5,960	62,972	$5,416
Daily Base Load	126.04	$11	127.09	$11	142.15	$12		
Virtual Rate	$0.09							
Date of Retrofit	Mar-12				BPC Projected Savings		760	$65

Notes:	
	Infiltration lowered from 4972 to 4700
	Walls improved from 284 to 292
	lowered the occupied heating temp from 77.9 to 72.5
	Thermostat's changed to non-programmable
	Added two dishwashers
	Increased number of light bulbs to 70, hours on to 6.0 and average wattage to 40

	SITE 7							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	13,067	$1,124	11,343	$976	6,800	$585	7,463	$642
February	11,536	$992	10,725	$922	6,270	$539	5,559	$478
March	12,965	$1,115	11,595	$997	6,657	$572	6,099	$525
April	9,588	$825	10,090	$868	4,970	$427	5,299	$456
May	7,368	$634	10,290	$885	4,275	$368	4,449	$383
June	7,130	$613	8,368	$720	4,137	$356	4,211	$362
July	7,368	$634	8,143	$700	4,275	$368	4,460	$384
August	7,368	$634	7,839	$674	4,275	$368	4,322	$372
September	7,576	$652	8,249	$709	4,184	$360	4,305	$370
October	10,110	$869	10,012	$861	5,108	$439	4,980	$428
November	13,127	$1,129	11,137	$958	6,803	$585	5,613	$483
December	14,713	$1,265	11,833	$1,018	7,691	$661	6,731	$579
Total	121,915	$10,485	119,624	$10,288	65,446	$5,628	63,490	$5,460
Daily Base Load	237.68	$20	232.55	$20	137.91	$12		
Virtual Rate	$0.09							
Date of Retrofit	Mar-12				BPC Projected Savings		2,761	$237

Notes:	
	Infiltration lowered from 5843 to 4602
	Lowered the occupied heating temp from 72 to 66
	Ventilation total cfm increased from 1120 to 1500
	DWH multiplier increased from 1.0 to 1.15
	Lights hours on per day increased from 3.0 to 6.0

	SITE 8							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	22,674	$1,950	19,031	$1,637	13,067	$1,124	13,132	$1,129
February	20,047	$1,724	17,759	$1,527	11,536	$992	11,122	$957
March	22,502	$1,935	19,330	$1,662	12,965	$1,115	11,750	$1,011
April	17,864	$1,536	17,378	$1,495	9,588	$825	9,849	$847
May	9,495	$817	17,794	$1,530	7,368	$634	7,921	$681
June	9,189	$790	15,268	$1,313	7,130	$613	7,456	$641
July	9,495	$817	15,069	$1,296	7,368	$634	6,995	$602
August	9,495	$817	14,486	$1,246	7,368	$634	6,330	$544
September	14,891	$1,281	15,181	$1,306	7,576	$652	6,265	$539
October	19,121	$1,644	17,456	$1,501	10,110	$869	7,969	$685
November	22,513	$1,936	18,607	$1,600	13,127	$1,129	9,650	$830
December	24,539	$2,110	19,614	$1,687	14,713	$1,265	12,396	$1,066
Total	201,827	$17,357	206,975	$17,800	121,915	$10,485	110,836	$9,532
Daily Base Load	306.30	$26	313.59	$27	237.68	$20		
Virtual Rate	$0.09							
Date of Retrofit	Mar-12				BPC Projected Savings		5,800	$499

Notes:	
	Infiltration lowered from 8600 to 8564
	Walls improved from 283 to 291
	lowered the occupied heating temp from 89 to 70
	Average light bulb wattage lowered to 20
	Number of light bulbs lowered from 75 to 40
	Refrigerator type changed to more efficient
	Oven/Range kWh lowered to 1000 kwh/y
	Ventilation total cfm lowered from 1755 to 1365
	Original model may have used all units, not 1-13

	SITE 9 (1-6)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	5,983	$515	5,242	$451	6,303	$542	6,678	$574
February	5,562	$478	4,981	$428	5,833	$502	5,582	$480
March	5,852	$503	5,371	$462	6,179	$531	5,511	$474
April	4,323	$372	4,622	$398	4,740	$408	4,639	$399
May	2,809	$242	4,702	$404	3,299	$284	3,909	$336
June	2,718	$234	3,704	$319	3,192	$275	3,274	$282
July	2,809	$242	3,545	$305	3,299	$284	2,825	$243
August	2,809	$242	3,357	$289	3,299	$284	2,652	$228
September	3,172	$273	3,656	$314	3,658	$315	2,955	$254
October	4,527	$389	4,559	$392	4,957	$426	3,738	$321
November	5,989	$515	5,155	$443	6,282	$540	5,027	$432
December	6,667	$573	5,494	$473	6,948	$598	5,970	$513
Total	53,220	$4,577	54,388	$4,677	57,989	$4,987	52,759	$4,537
Daily Base Load	90.61	$8	93.53	$8	106.42	$9		
Virtual Rate	$0.09							
Date of Retrofit	Mar-12				BPC Projected Savings		1,393	$120

Notes:	
	Infiltration lowered from 3833 to 3220
	Walls improved from 343 to 291
	Refrigerator moved to more inefficient model
	Number of light bulbs increased from 36 to 60
	lowered the occupied heating temp from 73 to 75
	Thermostat's changed to non-programmable
	Results show negative savings

	SITE 10 (1-6)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	5,282	$454	4,758	$409	6,678	$574	6,882	$592
February	4,765	$410	4,525	$389	6,013	$517	5,785	$498
March	5,323	$458	4,878	$419	6,721	$578	6,246	$537
April	3,925	$338	4,181	$360	5,118	$440	4,985	$429
May	2,986	$257	4,253	$366	3,551	$305	4,823	$415
June	2,890	$249	3,405	$293	3,437	$296	3,356	$289
July	2,986	$257	3,310	$285	3,551	$305	2,979	$256
August	2,986	$257	3,197	$275	3,551	$305	2,592	$223
September	3,025	$260	3,339	$287	3,934	$338	2,772	$238
October	4,003	$344	4,121	$354	5,280	$454	3,855	$332
November	5,330	$458	4,681	$403	6,705	$577	5,276	$454
December	6,020	$518	4,991	$429	7,466	$642	6,309	$543
Total	49,519	$4,259	49,639	$4,269	62,006	$5,333	55,859	$4,804
Daily Base Load	96.32	$8	96.54	$8	114.56	$10		
Virtual Rate	$0.09							
Date of Retrofit	Mar-12				BPC Projected Savings		-20	($2)

Notes:	
	Negative savings
	Infiltration raised! from 4473 to 4484. increase in cfm???
	Raised occupied heating temp from 69 to 74
	decreased number of dishwashers from 6 to 0
	Raised DHW demand multiplier from 0.87 to 1.2
	Moved dishes hand washed from no to yes
	Number of lights increased from 36 to 60
	"Other electrical" category added to appliances
	Fan hours per day increase from 0.2 to 0.8

	SITE 11 (7-12)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	5,692	$490	4,962	$427	4,558	$392	4,722	$406
February	5,193	$447	4,741	$408	4,173	$359	3,920	$337
March	5,591	$481	5,098	$438	4,486	$386	3,887	$334
April	4,034	$347	4,322	$372	3,196	$275	3,136	$270
May	2,713	$233	4,392	$378	2,441	$210	2,761	$237
June	2,626	$226	3,391	$292	2,362	$203	2,195	$189
July	2,713	$233	3,231	$278	2,441	$210	1,702	$146
August	2,713	$233	3,067	$264	2,441	$210	1,842	$158
September	2,937	$253	3,326	$286	2,439	$210	2,420	$208
October	4,212	$362	4,242	$365	3,297	$284	2,108	$181
November	5,733	$493	4,888	$420	4,603	$396	3,510	$302
December	6,469	$556	5,227	$450	5,251	$452	4,360	$375
Total	50,627	$4,354	50,889	$4,376	41,687	$3,585	36,562	$3,144
Daily Base Load	87.52	$8	87.94	$8	78.75	$7		
Virtual Rate	$0.09							
Date of Retrofit	Mar-12				BPC Projected Savings		2,039	$175

Notes:	
	Infiltration lowered from 3623 to 3128
	Attic improved from 104 to 216
	lowered the occupied heating temp from 71 to 68
	Removed dishwashers

	SITE 12 (1-8)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	6,003	$516	5,172	$445	5,871	$505	5,726	$492
February	5,106	$439	4,678	$402	4,989	$429	4,563	$392
March	6,049	$520	5,334	$459	5,847	$503	4,157	$358
April	3,308	$285	3,842	$330	3,604	$310	3,411	$293
May	2,194	$189	3,598	$309	2,521	$217	2,695	$232
June	2,123	$183	2,949	$254	2,440	$210	2,414	$208
July	2,194	$189	2,731	$235	2,521	$217	2,246	$193
August	2,194	$189	2,648	$228	2,521	$217	2,149	$185
September	2,534	$218	3,153	$271	3,008	$259	2,112	$182
October	4,070	$350	4,151	$357	4,374	$376	2,861	$246
November	5,848	$503	4,863	$418	5,786	$498	3,815	$328
December	6,004	$516	4,988	$429	5,960	$513	5,288	$455
Total	47,627	$4,096	48,108	$4,137	49,444	$4,252	41,438	$3,564
Daily Base Load	70.78	$6	71.70	$6	81.34	$7		
Virtual Rate	$0.09							
Date of Retrofit	Apr-12				BPC Projected Savings		9,485	$816

Notes:	
	Infiltration lowered from 5032 to 2300
	Walls improved from 283 to 3
	Raised the occupied heating temp from 69 to 77
	Increase light wattages from 18 to 30 and hours per day from 1 to 5
	Normalized billing data shows negative savings

	SITE 13 (13-20)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	12,199	$1,049	10,354	$890	7,916	$681	6,966	$599
February	10,157	$873	8,998	$774	6,505	$559	6,573	$565
March	8,972	$772	8,961	$771	5,631	$484	6,343	$545
April	7,475	$643	8,248	$709	4,813	$414	6,619	$569
May	4,929	$424	7,904	$680	4,111	$354	9,755	$839
June	4,770	$410	6,464	$556	3,979	$342	4,498	$387
July	4,929	$424	6,078	$523	4,111	$354	6,575	$565
August	4,929	$424	6,035	$519	4,111	$354	3,921	$337
September	5,898	$507	6,941	$597	4,155	$357	3,440	$296
October	8,888	$764	8,497	$731	5,767	$496	4,506	$388
November	11,047	$950	9,348	$804	7,244	$623	4,677	$402
December	12,050	$1,036	9,890	$851	7,962	$685	5,367	$462
Total	96,242	$8,277	97,717	$8,404	66,308	$5,702	69,242	$5,955
Daily Base Load	158.99	$14	162.94	$14	132.63	$11		
Virtual Rate	$0.09				0	0		
Date of Retrofit	May-12				BPC Projected Savings		14,904	$1,282

Notes:	
	Infiltration lowered from 5293 to 2830
	Walls improved from 283 to 2
	attic improved from 145 to 216
	floor improved from 328 to 54
	lowered occupied heating temp from 71 to 69
	removed dishwashers
	reduced number of washers from 1 to 0 and dryers from 8 to 1
	raised lights on per day from 5 to 6
	lowered "other electrical" from 1000 kwh/y to 500
	Only used 11 months of billing data
	HSE Account, was it included in original?

	SITE 14 (12-23)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	15,304	$1,316	12,477	$1,073	8,675	$746	6,362	$547
February	12,610	$1,084	10,852	$933	6,776	$583	5,413	$465
March	10,875	$935	10,835	$932	5,214	$448	6,293	$541
April	8,899	$765	9,994	$859	4,308	$370	4,707	$405
May	5,769	$496	9,597	$825	3,720	$320	4,409	$379
June	5,583	$480	7,820	$673	3,600	$310	4,025	$346
July	5,769	$496	7,301	$628	3,720	$320	7,133	$613
August	5,769	$496	7,229	$622	3,720	$320	4,460	$384
September	6,986	$601	8,425	$725	3,712	$319	4,240	$365
October	11,148	$959	10,288	$885	5,531	$476	5,233	$450
November	13,931	$1,198	11,282	$970	7,701	$662	6,184	$532
December	15,185	$1,306	11,930	$1,026	8,653	$744	6,344	$546
Total	117,828	$10,133	118,030	$10,151	65,332	$5,619	64,803	$5,573
Daily Base Load	186.10	$16	186.51	$16	120.01	$10		
Virtual Rate	$0.09							
Date of Retrofit	Jun-12				BPC Projected Savings		11,069	$952

Notes:	
	Infiltration lowered from 6576 to 3250
	Walls improved from 283 to 2 (is this correct? Shouldn't it be 291 which has fiberglass + cellulose?)
	lowered occupied heating temp from 73.5 to 65
	lowered lights on per day from 5 to 2
	decreased number of lights from 60 to 36
	decreased number of dryers from 8 to 2
	decreased number of clothes washers from 8 to 4
	decreased ventilation rate from 480 cfm to 400
	Hot water usage multiplier lowered from .88 to .55
	Only used 10 months of billing data

	SITE 15 (24-35)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	14,414	$1,240	11,823	$1,017	8,737	$751	7,720	$664
February	11,816	$1,016	10,272	$883	6,917	$595	6,096	$524
March	10,049	$864	10,223	$879	5,816	$500	6,970	$599
April	8,204	$706	9,406	$809	5,150	$443	5,193	$447
May	5,439	$468	9,015	$775	5,067	$436	7,619	$655
June	5,263	$453	7,321	$630	4,903	$422	187	$16
July	5,439	$468	6,832	$588	5,067	$436	6,544	$563
August	5,439	$468	6,776	$583	5,067	$436	4,705	$405
September	6,359	$547	7,890	$678	4,935	$424	3,681	$317
October	10,313	$887	9,689	$833	6,101	$525	4,852	$417
November	13,077	$1,125	10,670	$918	7,830	$673	5,947	$511
December	14,298	$1,230	11,290	$971	8,740	$752	6,883	$592
Total	110,109	$9,469	111,205	$9,564	74,329	$6,392	66,399	$5,710
Daily Base Load	175.44	$15	177.80	$15	163.45	$14		
Virtual Rate	$0.09							
Date of Retrofit	Jun-12				BPC Projected Savings		4,777	$411

Notes:	
	Infiltration lowered from 6380 to 3240
	Walls improved from 283 to 291
	lowered occupied heating temp from 72.5 to 63.25
	lowered DHW demand multiplier from 0.8 to 0.71
	Only used 10 months of billing data

	SITE 16 (13-24)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	17,430	$1,499	14,301	$1,230	12,330	$1,060	10,487	$902
February	14,336	$1,233	12,455	$1,071	9,929	$854	11,092	$954
March	12,482	$1,073	12,487	$1,074	8,271	$711	10,848	$933
April	10,223	$879	11,540	$992	6,737	$579	6,318	$543
May	6,870	$591	11,119	$956	5,421	$466	8,326	$716
June	6,649	$572	9,138	$786	5,246	$451	0	$0
July	6,870	$591	8,581	$738	5,421	$466	7,390	$636
August	6,870	$591	8,502	$731	5,421	$466	4,734	$407
September	8,289	$713	9,806	$843	5,587	$481	4,833	$416
October	12,778	$1,099	11,882	$1,022	8,659	$745	5,451	$469
November	15,802	$1,359	12,964	$1,115	11,148	$959	7,044	$606
December	17,166	$1,476	13,696	$1,178	12,242	$1,053	8,789	$756
Total	135,765	$11,676	136,473	$11,737	96,415	$8,292	85,313	$7,337
Daily Base Load	221.62	$19	222.67	$19	174.88	$15		
Virtual Rate	$0.09				0	0		
Date of Retrofit	Jun-12				BPC Projected Savings		6,455	$555

Notes:	
	Infiltration lowered from 8062 to 4401
	Walls improved from 283 to 291
	lowered occupied heating temp from 73.4 to 71
	lowered DHW demand multiplier from 0.93 to 0.61
	Only used 10 months of billing data
	Analysis period 12 months or 10 months?

	SITE 17 (25-36)							
	BPC Pre Retrofit				Post Retrofit			
	Original Model		Billing Data		Calibrated Model		Billing Data (Averaged)	
	kWh	Cost	kWh	Cost	kWh	Cost	kWh	Cost
January	15,381	$1,323	13,191	$1,134	11,069	$952	9,516	$818
February	12,807	$1,101	11,461	$986	9,109	$783	7,628	$656
March	11,405	$981	11,407	$981	7,950	$684	7,307	$628
April	10,049	$864	10,497	$903	7,161	$616	7,773	$669
May	6,129	$527	10,062	$865	5,585	$480	12,007	$1,033
June	5,931	$510	8,174	$703	5,405	$465	0	$0
July	6,129	$527	7,630	$656	5,585	$480	7,503	$645
August	6,129	$527	7,567	$651	5,585	$480	5,508	$474
September	7,606	$654	8,808	$757	5,744	$494	6,584	$566
October	11,619	$999	10,813	$930	8,321	$716	7,339	$631
November	14,455	$1,243	11,905	$1,024	10,528	$905	8,042	$692
December	15,745	$1,354	12,596	$1,083	11,575	$995	9,586	$824
Total	123,384	$10,611	124,112	$10,674	93,620	$8,051	88,793	$7,636
Daily Base Load	197.70	$17	198.70	$17	180.17	$15		
Virtual Rate	$0.09							
Date of Retrofit	Jun-12				BPC Projected Savings		11,947	$1,027

Notes:	
	Infiltration lowered from 7771 to 4174
	Walls improved from 283 to 291
	lowered occupied heating temp from 73.5 to 70.5
	lowered DHW demand multiplier from 0.8 to 0.68
	Only used 10 months of billing data
	Analysis period 12 months or 10 months?

About DNV GL

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Evaluation Report Response

Program: Multifamily Retrofit
Program Manager: Clint Stewart
Study Report Name: Impact Evaluation of Air Sealing and Insulation in Multifamily Buildings Pilot Program
Report Date: October 16, 2015
Date ERR to Program Manager: October 19, 2015
Evaluation Analyst: Jim Perich-Anderson
Date of ERR: October 30, 2015

Evaluation Overview, Methodology and Key Findings

Overview:
This is the impact evaluation report for the rolling evaluation of the Puget Sound Energy (PSE) Air Sealing and Insulation in Multifamily Buildings Pilot Program. Whole building air sealing for multifamily is a new measure for PSE and the region and there are no available PSE or Regional Technical Forum (RTF) approved savings estimates. The pilot impact evaluation developed impact results and looked into the options for savings estimates going forward such that the measure can be offered to the mass market. Note that the pilot was limited to multifamily buildings with electric resistance heating and built prior to 1991 Washington State Energy Code.
The impact results from the pilot were promising. Table 3 summarizes the total savings for all evaluated sites and the total savings for different categories of sites. There are two categories for measures as earlier in the program some projects received limited insulation measures and later in the program all measures were included at all sites. The category "All Measures" best represents the pilot and future program. The program also tracks whether buildings were previously insulated by the PSE multifamily retrofit program and only air sealing was performed. Overall the pilot realized 87% of the expected energy savings (87% realization rate). Two interesting findings were that the energy savings realization rate for previously insulated buildings was 97% and for 2-8 Unit buildings was 100%. We feel that the results from previously insulated buildings show that the program simulation models may have been better built where the only measure was air sealing. When measures included insulation as well there may have been more errors in the program models, but there was no systematic inputs that were changed. The 100% realization rate result for smaller buildings may stem from the fact that tenant turnover appeared to be random and easier to identify and address in the calibration for smaller buildings. In the larger buildings there were larger swings in overall occupancy.

Key Findings/Analysis:
The primary evaluation activities were to collect additional data from surveys and post retrofit billing data to refine or "true-up" the original site specific savings estimates. The surveys focused on collecting data on changes to tenant behavior or internal loads that would affect energy consumption, especially those changes that fall outside of program rules for preventing other energy efficiency upgrades after the air sealing treatment.
The final results are summarized in two tables below: Table 3 summarizes the total savings for all evaluated sites and the total savings for different categories of sites and Table 2 provides site specific results. There are two categories for measures as earlier in the program some projects received limited insulation measures and later in the program all measures were included at all sites and the category "All Measures" best represents the pilot and future program. The program also tracks whether buildings were previously insulated by the PSE multifamily retrofit program and only air sealing was performed. Overall results are promising that the overall realization rate is 87%. This is lower than initial results that were greater than 100% when the sample size was about half in Phase 1. More interesting are the results that realization rates for previously insulated are 97% and for 2-8 Units is 100%. We feel that the results from previously insulated show that the program models may have been better built where the only measure was air sealing. When measures included insulation as well there may have been more errors in the program models, but there was no systematic inputs that were changed. The result for smaller buildings may stem from the fact that tenant turnover is easier to identify and address for smaller buildings.

Table 12: Summary of Ex Ante and Ex Post Savings

Category	Sample Size	Ex Ante Savings	Ex Post Savings	Realiz-ation Rate	Total CFM-Pre	Total CFM-Post	Total CFM Reduc-tion	% CFM Reduc-tion
Total	36	319,562	277,875	87%	245,049	156,213	88,836	36%
Total All Measures	22	237,343	201,920	85%	150,881	84,329	66,552	44%
Total Single Measures	14	82,219	75,955	92%	94,168	71,884	22,284	24%
Total Previously Insulated	21	128,803	124,543	97%	139,476	94,269	45,207	32%
Total Not-Previously Insulated	15	190,759	153,331	80%	105,573	61,944	43,629	41%
2-8 Units	17	136,462	137,086	100%	91,012	59,858	31,154	34%
9-20 Units	19	183,099	140,788	77%	154,037	96,355	57,682	37%

PSE Program Response to Evaluation Findings

Action Plan:
Effective immediately, PSE will follow the evaluation report recommendations and continue established program delivery through utilizing the calculator to determine estimated ex ante savings. The program will also continue with claiming the current RTF deemed savings values for bundled insulation and air sealing projects in addition to calculated air sealing savings.
The program will explore random blower door testing on like buildings on a multifamily campus to help improve the measure's cost effectiveness and reduce the burden placed on multifamily residents and owners/managers. Further evaluation will need to be conducted on buildings larger buildings with 21+ units, which the program will also explore through a prototype model and pre/post blower door testing. As the program acquires a sufficient sample size for each of the building categories (2-8 units, 9-20 units, 21-50 units, and 51+ units), a deemed savings approach will be pursued upon achieving a 90/10 relative precision. The program may currently have the ability to establish deemed savings for the two smaller building categories with sample data through 2015, while the two larger building categories will require additional sample points and analysis.