Summary of 2006 NEEM Manufactured Homes: Field Data and Billing Analysis

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Northwest Energy Efficient Manufactured Homes
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Prepared by:

David Baylon, Ecotope, Inc.

Bob Davis, Ecotope, Inc.

Kevin Geraghty, Ecotope, Inc.

Thomas Hewes, Oregon Department of Energy

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1. Introduction

Over the last twenty two years the manufactured housing industry and the region's utilities have maintained a partnership aimed at developing and marketing energy efficient manufactured homes throughout the Pacific Northwest. The Northwest Energy Efficient Manufactured Home (NEEM) program is a consortium of state agencies, utilities and manufacturers. The USDOE Building America Industrialized Housing Partnership program also provides technical support to the NEEM consortium. Quality control processes have been developed and are an integral part of the program, to ensure that the homes meet NEEM, BAIHP and EnergyStar guidelines.

Quality control standards are primarily aimed at in-plant practices and inspections. The efficiency of the homes manufactured under this program also depends on the quality of the installation of the home conducted on-site. Over the last twenty years, a series of field samples were drawn and reviewed both for compliance to the set-up specifications and to assess overall performance of ducts and heating systems, ventilation and infiltration—all items that must be evaluated after the home is sited to obtain a meaningful understanding of the home's performance. These past field samples and reviews assist in the quality control of the homes and assess the progress and impacts of changes in specification and manufacturing techniques on the performance of the homes.

The selection basis for this sample has been a simple random sample of homes in each state. The size of these samples is based on statistical significance criteria designed to represent the homes sited in each state as well as the entire region-wide.

This study is conducted periodically to establish performance levels of manufactured housing in the region built to the NEEM standard. Four previous field studies were conducted, in 1990, 1995, 1999, and 2003 each based on a particular cohort of manufactured homes. The focus of the studies was to establish the performance of components of the building that are not easily regulated as part of manufacturing standards, such as house and duct tightness, heating system performance, ventilation system operation and set-up, etc. These studies were based on a sample of homes constructed and sited in the Pacific Northwest region.

From January to August, 2008, a random sample of homes was drawn, recruited, and reviewed. These homes were manufactured over the period of one year (Calendar year 2006). The sample is meant to be representative of the homes built under the program. Since the efficiency standards are regional and the set-up standards are controlled by individual states, the sample was designed to be representative of both the region as a whole and of each state.

2. Sample Design

A simple random sample is drawn in each state. The sampling standard is designed around a sample size at a 10% significance level and a 90% confidence interval for each state. A representative sample of duct and building shell tightness is taken to represent the remainder of the set-up and installation practices and is not as easily quantified.

A second criterion was designed to provide a regional review with a 5% significance level and a 95% confidence interval. This sample is much larger. A minimum sample is assembled for each state and the remaining sample size is allocated roughly by percentages of the total homes in the NEEM state sample. As a result of this, the sample is stratified by state so that case weights can be assigned to each individual state and a regional summary can be prepared.

The overall sample goal for this study was approximately 89 cases. Given the past experience, a random sample of approximately 200 homes would be required in order to locate and test 89 homes. This sample was drawn at random from the NEEM database, which includes all homes constructed to the standards in 2006. A total of 4,824 homes were built to NEEM standards by factories in the Northwest and in California. For purposes of developing the initial sample frame only homes sited in Washington, Oregon, Montana, and Idaho were included in the final sample frame. A total of 3,981 homes met this criteria. This criteria resulted in homes built to the current standard that when surveyed would be old enough to collect at least a year of performance data and utility billing data. Furthermore, the impact of aging on seals, especially duct sealing, would be apparent when the fieldwork was conducted. The individual state energy offices were responsible for recruiting their particular sample. The Oregon team also tested two homes in Nevada and included them in their sample. We have included them in the study.

Unfortunately for this study, the NEEM database did not generally contain homeowner's names and addresses; there was only information from the dealers and manufacturers. The sample was drawn by state using only dealer locations. Since the name and address of the owner was not known, several stock homes were also included in the state sample. Stock homes typically occupy dealer lots and are not representative of either set-up standards or final infiltration and duct sealing control. As a result of stock homes and homes with incomplete addresses, a much larger sample of about 350 homes was needed (distributed across the individual states) for recruiting purposes.

Once the sample was drawn, serial numbers and NEEM numbers were assigned and a list was compiled and submitted to individual states to begin recruiting. Then the states used their own manufacturers' database and warranty information. In some cases, a visit to manufacturers' plants was required to review warranty files. This information was used to assemble a list of names, addresses and phone numbers as the basis for recruiting the final sample. Stock homes were dropped when they were identified in the recruiting process.

Of the original list submitted to the states for review, approximately 11% of the homes could not be identified in any of the database sources available. Scheduling and willingness to participate also had a significant impact on the recruiting. This sampling and review was conducted between February and July 2008.

2.1. Sample Design and Recruitment

Table 1 shows the distribution of the final recruiting sample delivered by the state energy offices. "Sitings" refers to the homes actually sited in the individual state. "Pool" refers to the initial sample drawn at random from the siting in each state. "Target" is the results of the initial sample design based on an assumed sampling criterion of a 90% confidence interval and a sample capable of discerning 10% significance criteria. 343 homes were drawn as the random sample stratified by state. This group was then reviewed using program records, manufacturers' records and dealer records to identify names and phone numbers of final occupants. Homes identified in this process as "stock" or "display" homes were dropped. This sample can be compared to the distribution shown in Table 2. Most of the apparent discrepancy is the result of the relatively large number of homes sold in Washington but sited in Oregon, and the homes sold in Idaho but sited in Montana. The rest of the discrepancy is the need to over sample Montana and Idaho to develop a representative sample for those states. Thus the distribution of the homes that are not stock homes is somewhat biased toward the smaller states. This bias was corrected by case weights in the final data analysis and summaries.

Table 1: Population and Final Sample Distribution

State	Sitings	Samples		
		Target	Pool	Final
Idaho	595	18	54	18
Montana	231	17	50	17
Oregon	1,435	24	109	26
Washington	1,720	27	130	26
Nevada	131	0	0	2
Total	4,112	86	343	89

The final recruitment sample was sent to the field technicians in order for them to recruit homes into the sample. In general, they were given targets that were based on the original random sample. In Idaho, Montana and Oregon, the targets were closely followed. There were some difficulties with recruitment and scheduling in Washington that resulted in a short fall of one home. In addition to the initial sample targets the Oregon field tem recruited an extra two sites. Data from these sites was used but the Oregon sample was reweighted to account for its slightly larger size relative to the Oregon population. Two Nevada homes were also reviewed. These homes were not used in the regional summaries.

The overall targets for each state were based on the assumption that the distribution of relevant variables such as envelope and duct tightness would have a coefficient of variation of approximately 25%. This assumption was made as a result of distributions observed in the previous studies. Using these criteria, a sample size was set at approximately 75 homes in the region distributed throughout the states. In individual states, the sample was enhanced to yield a statistically significant sample at a 90% confidence interval. This set the number of homes at about 18 sites per state. In Idaho and Montana the sample was enhanced to allow the sample in each state to be representative at a similar level to the regional sample.

Table 2: Regional Field Sample Distribution*

State	Freq.	Percent Sample	Percent Population
Idaho	18	20.7	15.0
Montana	17	19.5	5.8
Oregon	26	29.9	36.0
Washington	26	29.9	43.2
Total	87	100.0	100.0

*2 Nevada cases not included in regional sample

Case weights were used in summarizing the regional samples. They were based on the relative sampling of each of the states. In general, the case weights have an impact on the final averages as the relative sample sizes in each state differ from their proportion of the population.

3. Field Sample Overview

This report includes several summary tables and related text that present the field data gathered by the state NEEM programs between March and August 2008 for a random set of 89 NEEM homes. The data collection protocol is included in the appendix. Auditors made it to 18 sites in Idaho, 17 sites in Montana, 26 sites in Oregon, 26 sites in Washington and two sites in Nevada. At a few sites, the full protocol was not completed because of time or other constraints.

The summaries presented in the following tables correspond (in most cases) with the tables found in the previous report published in March 2004 (Davis & Baylon, 2004). That report looked at 105 homes in the region that were built in 2001-2002. The original MAP study was completed in 1995 and looked at about 170 homes built to the original MAP specifications in 1992-1993 (Baylon et al., 1995). The results of that survey are also noted here where possible. The impact of this long-term commitment by the region's utilities and the region's manufactured housing industry has resulted in a documentation of the overall improvement in performance over the 20 years this partnership has developed.

The field data collected for this study was of very high quality, but there are some cases where the summaries will not include all possible cases. Table 3 outlines the basic sample characteristics of the types of homes and the basic house size. Homes manufactured in 1992-93 in the original MAP survey increased in size about 15% compared to homes built in 1997-98. Since 1997, the size of homes and the proportion of larger multi-sections homes have remained fairly constant. The NEEM manufactured homes are consistently smaller than the single family homes built on site.

Table 3: Basic Sample Characteristics from 1992 - 2006

Sections	2006 Idaho (n=18) %†	2006 Montana (n=17) %	2006 Oregon (n=26) %	2006 Wash. (n=26) %	2006 All (n=87) %	2001-02 Homes (n=105) %	1997-98 Homes (n=49) %**	MAP Homes 1992-93 (n=178) %
Single Section	5.5	5.8	0.0	0.0	2.2	0	0	11.8
Double Section	88.9	76.5	69.2	88.5	79.8	74	73	81.5
Triple Section	5.5	17.7	30.8	11.5	18.0	24	27	6.7
Quad Section	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0
Home size (sq. ft)‡	1,928	1,659	1,893	1,726	1,739	1,769	1,750	1,433

*n shown is possible number of cases that could have been used. Actual numbers used in subsequent summaries are usually smaller for various reasons (not all tests apply, bad data, etc).
†Includes home installed on full heated basement.
‡The average house size is weighted by state case weights.
**This study included home sites in WA and ID only

The 2006 sample includes all Northwest manufacturers; some (Fleetwood, Champion, Valley) are much better represented than others (Liberty, Guerdon). Production of NEEM homes has fluctuated considerably by manufacturer since the end of the MAP in the mid-90s; some plants have continued to produce a majority of NEEM level homes and others have focused on other market segments. Table 4 lists the number of homes used in a sample corresponding with the manufacturer of the homes. This summary excludes the Nevada homes that were outside the sample frame.

Table 4: 2006 Sample Manufacturer Information

Manufacturer	NEEM*	Sample**	Manufacturer	NEEM	Sample
Champion- OR	220	8	Karsten	278	5
Champion-ID	453	6	Kit	188	6
Fleetwood-OR	427	9	Liberty	104	2
Fleetwood-WA	227	2	Marlette	562	5
Fleetwood-ID	92	3	Nashua	188	6
Fuqua	321	5	Palm Harbor	549	7
Golden West	473	6	Skyline	291	7
Guerdon-ID	12	1	Valley	233	9
			Total*	4,808	87

*Includes NEEM sitings in all states
**Excludes the two Nevada sites

3.1. Set-Up Summaries

An important part of the field review takes place mostly under the house, where the auditor looks at the structural and the related physical set-up of the house as noted in Table 5. The Oregon field audits did not include the set-up review done in the other states. The summaries include only the remaining states and the total is constructed using case weights for those states.

Table 5: 2006 Structural & Operational Set-Up Compliance

Compliance Issue	% Complying in Idaho	% Complying in Montana	% Complying in Washington	% Complying in all States
Percent Foundation	83	53	73	74
Skirting Installed (Where Applicable)	100	100	100	100
Ground Vapor Barrier Present	100	76	92	92
Pier Supports in Place Under I-Beam	94	67	100	96
Pier Supports in Place Under Ext. Doors	94	100	100	98
Pier Supports Capped and Shimmed	100	94	100	99
Footings Sized and Installed Correctly	100	100	96	97
Belly Penetrations Sealed	78	35	96	86
Marriage Line Sealed	88	93	95	93
No Visual Problems With Roofline	100	94	92	94
All Liquid Drains Exit Perimeter of Home	76	80	96	90
Exterior Doors Operate Smoothly	93	47	88	85
Windows Operate Smoothly	93	94	100	98

Generally set-up compliance is very good; the problem areas are belly penetrations (especially in Montana) and drain placement. Belly penetrations have been a problem in every field study, at least in terms of the visual inspection. Houses have gotten more airtight despite the persistence of this problem. There are some notable exceptions to the general success. Homes with serious problems have been referred to the state offices and then to manufacturers for corrective action.

Table 6 shows the review of the crossover ducts. Particularly in Montana the crossovers appear to be a problem that will certainly result in difficulties. Fortunately 30% of the Montana and Idaho homes have internal crossovers or are single-wides so the impact on the overall duct leakage is not as significant.

Table 6: 2006 Crossover Duct Set-Up Compliance

Compliance Issue	% Complying in Idaho	% Complying in Oregon	% Complying in Washington	% Complying in all States
Crossover Cut to Length	83	70	95	91
Crossover Connections Secure	84	78	90	88
Crossover Connected With Sheet Metal Elbows	83	22	95	87
Crossover Connections Insulated	90	50	100	94

It is unclear to the authors why such a high number of systems are installed without sheet metal elbows in Montana because they are required to be included in the ship loose materials when the homes are transported. A number of homes used a splitter box for one of the main crossover connections, but this alone cannot explain why almost three quarters of the Montana homes apparently did not use elbows. The purpose of this detail is to improve the connection and the seal between the crossover duct and the trunk ducts. Homes with interior crossovers are not included in this comparison. Apparently, there is still work to be done to improve the air tightness of the duct and crossover system. (See Section 3.5 for a full discussion of duct leakage.)

3.2. Lighting

The audits of the individual homes were asked to collect detailed information on lighting systems and lighting technologies used in these homes. The underlying goal of this review was to establish the current baseline for connected lighting load as a basis for estimating the impacts of future programs aimed at reducing this load.

The data collected included fixture type, lighting type and fixture location. In general, we were unable to establish a consistent relationship between home living areas described by the auditors. Thus the lighting data was aggregated by home and these summaries reflect that aggregation.

Because the sampling weights differed between states the summaries used case weights to correct the totals presented. Within each state the cases each have the same sampling weights since the sample was drawn as a simple random sample of each state. Thus, only the totals are affected by the weighting scheme.

3.2.1. Lighting Technologies

The lighting review was focused on the amount of efficient lighting that was part of the current practice in the NEEM housing stock. This was defined as linear florescent fixtures which have been common in kitchen and utility lighting in this sector for some time and compact florescent lamps (CFL) which are used as substitutes for standard lamps in A-line sockets. Table 7 shows the distribution of lamps in the sample. In this sample the distribution of fixtures and lamps is essentially identical. Thus, in virtually all (99.6%) fixtures once a CFL is used it is not mixed with an incandescent bulb. As can be seen the sector uses about 23% florescent lamps of both types. In Oregon there was a significant increase in the use of CFLs over the rest of the region probably due to various utility and state programs that support this technology. This trend was counter-balanced by a few cases with large wattage lamps especially in exterior applications.

Table 7: Percent Lamps by Technology

State	CFL	Incand.	Linear Florescent	Total
ID	11.3	86.0	2.7	100.0
MT	15.5	82.2	2.2	100.0
OR	23.2	73.8	3.0	100.0
WA	16.3	75.0	8.8	100.0
Total	18.5	76.5	5.0	100.0

The lamp count per home was extremely varied and subject to the particular interpretation of the auditors. In several cases the number of lamps was not described and thus was estimated in the data cleaning. Overall the average number of lamps per home was about 50 lamps of all types. This is consistent with findings of other lighting reviews in the region when the smaller size of these homes is taken into account.

Table 8 converts the observed lamps to a lighting power and summarizes the distribution of lamps by their contribution to the overall connected lighting load in the home. The process of generating this table used the results of the audits. The field staff was asked to record the fixture watts when that was observable. If the fixture characteristics made that difficult then the auditor was asked to estimate based on what could be observed. The data processing, in turn, used the auditor estimates to develop fixture wattage. Where this was ambiguous, estimates were made using the available data supplied by the auditor. In a few cases, large wattage lamps using HID or Mercury Vapor technology were observed. These lamps were included in the summary for incandescent lamps.

This process established lighting power for virtually every home in the sample. The estimates assumed that the standard CFL was 18 watts and that the standard incandescent lamp was 75 watts. About 10% of the fixtures were re-evaluated using these values to generate the final lighting power.

Table 8: Percent Total Lighting Power by Technology

State	CFL	Incand.	Linear Florescent	Total
ID	4.1	93.3	2.5	100.0
MT	4.9	94.0	1.1	100.0
OR	8.5	89.0	2.6	100.0
WA	5.4	87.7	6.9	100.0
Total	6.5	93.8	4.1	100.0

3.2.2. Lighting Power Density

Table 9 summarizes the results of the lighting review as a lighting power density across the entire NEEM sample. This summary uses the case weights developed to correct for sampling bias. In most cases, the summary of individual states is influenced by one or two exceptional homes. This occurs at both the low end (very low LPDs) where virtually all of the laps are high efficiency CFLs and at the high end where exceptionally large amounts of fixtures and especially exterior lighting drives up the overall average for individual states. This feature of the sample is largely balanced out in the overall population. Thus, for purposes of summarizing the potential for lighting efficiency in this sector the overall averages would be more reliable.

Table 9: Lighting Power Density (Watts/ft^2)

State	LPD	St.Dev.	N
ID	1.37	0.48	18
MT	1.50	0.48	17
OR	1.58	0.45	26
WA	1.24	0.39	26
Total	1.40	0.45	87

3.3. Appliances

Field auditors interviewed homeowners as part of the field visit. Among the topics of their interview was an effort to assess the saturation of EnergyStar appliances. These appliance packages are generally purchased through the retail dealers, but not all dealers offer an EnergyStar appliance package. The question specifically mentioned refrigerators, dish washers and clothes washers. The results of this survey are shown in Table 10. As the table shows, of the appliances that are generally part of the home purchase (refrigerators and dish washers) about half of the NEEM homes included the EnergyStar appliances. Since 2004, the industry agreed to include Energy Star dishwashers in every NEEM Energy Star home. For the clothes washers the number fell to a third, probably reflecting the independent nature of that purchasing decision.

Table 10: Percent EnergyStar Appliances

Appliance	ID	MT	OR	WA	Total
Refrigerator	44.4	47.1	50.0	38.5	44.0
Dish Washer	100	100	100	100	100
Clothes Washer	27.8	23.5	38.5	34.6	34.2

3.4. House Tightness and Ventilation

Northwest manufactured homes have become tighter over the past 10 years as can be seen in the blower door results summarized in Table 11. Production techniques have standardized and intentional air inlet vents are no longer required for NEEM. This has made the performance of the whole house ventilation system even more important. Note that Montana and Oregon did not participate in the 1997-8 studies. The blower door results are expressed as the number of house air changes that are measures when the house is pressurized to 50 Pa. This measure is a standard value for characterizing the results of blower door tests and has been part of the manufactured home field testing in all of the previous studies. Thus, the comparison between studies documents the increase in home tightness over the last 15 years.

Table 11: Blower Door Results (ACH_{50})

Group	2006-07 Sample			2000-01	1997-98	1992-93 (MAP)
	n*	ACH_{50} average	Std. Dev.	ACH_{50} Average	ACH_{50} Average	ACH_{50} Average
All	74	3.87	0.98	4.16	4.76	5.50
Double Wide	60	3.80	0.85	4.30	4.90	5.50
Triple Wide	14	4.01	1.05	3.84	4.40	4.92
Idaho	10	3.80	1.44	4.59	4.63	6.12
Montana	15	4.00	1.03	—	—	5.63
Oregon	25	4.40	0.92	4.36	—	5.43
Washington	24	3.74	1.01	3.89	4.90	5.36

*13 cases thrown out for having unacceptable flow exponents, case weights applied, Nevada homes not included.

In the current 2006 study, the minimum ACH_{50} is 1.65, and maximum ACH_{50} is 6.70. Only 14 cases have ACH_{50} over 5.0 and none are over 7.0 ACH_{50},. The nominal program standard is 5.0 ACH50. The standard deviations in most categories are very similar to the previous studies, but show less scatter than the original MAP results, which should be viewed as an indicator of successful quality control. Overall the results of this review are fairly similar to the 2000-2001 sample. Nevertheless, this sample shows a continued tendency for the manufactured homes to be very tight and often approach the level where ventilation levels could be a concern.

Results are also expressed in equivalent leakage area (ELA) in Table 12. As one would expect, the numbers scale along with the ACH results. Even though houses are much larger than in the original MAP study, the ELA has decreased in most comparisons. (ACH results are normalized by house size, while ELA is not.) When reviewed in this context the increase in envelope tightness is more noticeable. This is probably due to the increase in duct tightness as discussed in the Section 3.5. Note the ELA has decreased by almost 30% for double-section homes since the original MAP sample. Single wide units and bad blower door tests are excluded in the summaries.

Table 12: Blower Door Results (ELA, in^2)

Group	2006-07			2000-01	1997-98	1992-93
	n	Mean ELA	Median ELA	Mean ELA	Mean ELA	Mean ELA
All*	74	50.8	45.8	62.1	73.2	67.4
Double Wide	60	46.9	44.4	59.0	68.0	65.7
Triple Wide	14	73.0	70.0	73.4	87.5	83.4
Idaho	10	46.6	45.4	66.1	67.6	74.9
Montana	15	52.4	50.3	—	—	—
Oregon	25	54.6	45.8	64.8	—	69.3
Washington	24	48.3	46.5	58.7	79.0	62.7

*Case weights applied to overall summary figures in current and MAP 1992-93 studies, very few cases also thrown out because of bad test exponents.

3.4.1. Whole House Ventilation System Performance

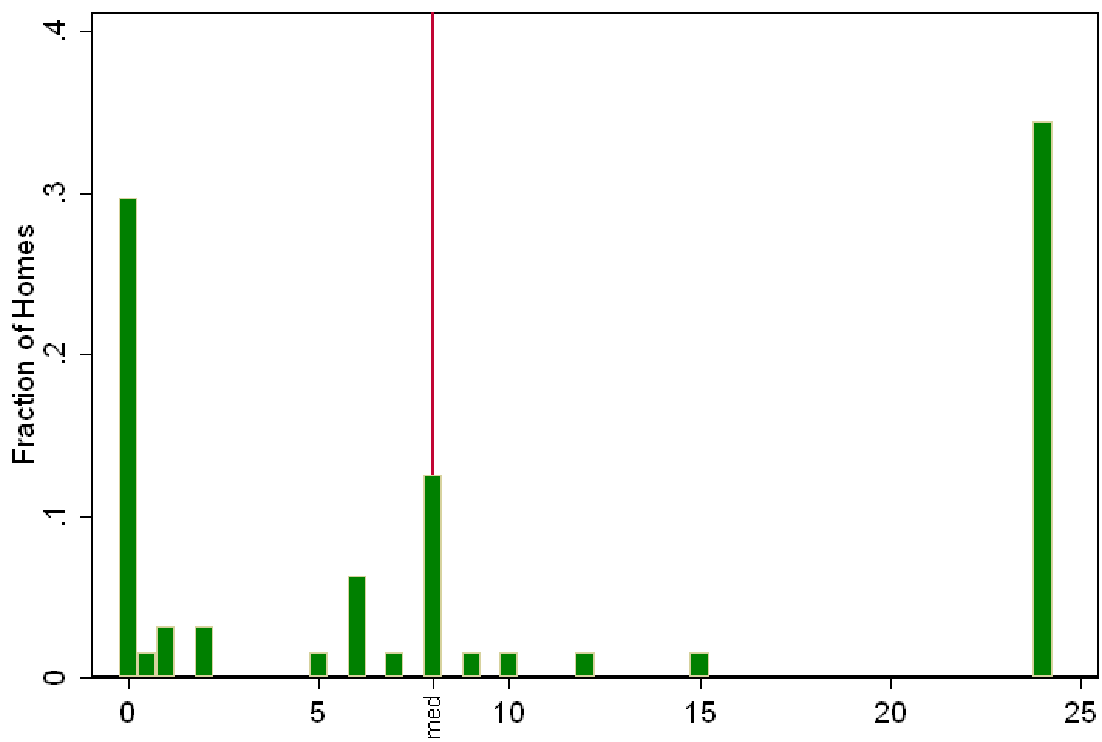
Several data on whole house fans are worth noting. The two most common locations for the whole house fan are the main hallway (45% of cases) and the utility/laundry room (43% of cases). About 60% of sites use a manual switch for control; the other 40% are wired directly to the breaker box or to a timer.

The median flow rate measured is 52 CFM, which is 8 CFM less than that found in the 2003 study. There were 14 cases with measured flow rate of less than 30 CFM, and there were three cases with a zero reading.

The median fan flow rate (0.029 CFM/ft^2) is less than that needed to meet the HUD requirement of 0.035 CFM/ft^2 of floor area. The average flow rate (about 0.033 CFM/ft^2) is closer. In several cases, the delivered flow was clearly inadequate, either due to the fan being undersized based on the formula or due to poor fan performance.

Assuming the fan is sized correctly, it must be run enough hours in the day to provide long-term effective ventilation. The runtime of the whole house fan is highly variable. About 29% of the homes reviewed had disabled the whole house fan or set fan controls to zero run time. In about a third of the cases, the whole house fan ran continuously. The median run time for all valid cases was eight hours. These three settings, zero hours per day, eight hours per day, and 24 hours per day, accounted for almost 80% of all the observations. Figure 1 shows the distribution of observed fan runtime.

Figure 1: Whole House Fan Runtime (Hrs per Day)



3.5. HVAC and Ducts

A major focus of this survey is evaluating the efficiency of the HVAC system. Auditors inventoried the central heating/cooling system and measured duct leakage, air handler flow, and operating static pressure. Table 13 shows the results of the audit.

Table 13: Central Heating & Cooling System Survey

System	2000-01	2006-07
An Electric Furnace (Elements + Fan Only)	54	49
A Heat Pump (HP)	24	36
A Furnace Fired by Natural Gas or LPG	22	15
Central Air Conditioning (Not Including Heat Pumps)	19	19
Overall Cases With Central Air Conditioning	43	55
Gas/Propane Furnace With Central AC	7	9

The percentage of homes with central electric forced air has decreased. At this point the total fraction of homes with either electric heat or electric heat pumps has actually increased as the fraction of homes with gas or LPG has decreased. The amount of cooling in this population now is over half of the sample largely as a result of the move toward heat pump systems.

As shown in Table 14, when the distribution of HVAC system selection is reviewed by state it is quite clear that Oregon and Washington are more likely to choose heat pumps or central cooling than Idaho and Montana. The move toward central cooling in the Oregon market is most of the reason for the nearly 30% increase in cooling saturation in this sample over the sample from six years ago. This sample showed an excess of 30% drop in the saturation of gas and propane. This drop seems to be the result of the Idaho sample, where gas was much lower than earlier surveys. One wood heat system and two of the gas systems had heat pumps installed but were counted as gas only systems.

Table 14: Distribution of HVAC system type by State (% of all surveys)

HVAC System	ID	MT	OR	WA	Total*
Electric Furnace	77.8	35.3	26.9	57.7	49.0
Heat Pump	11.1	5.9	53.9	34.6	35.7
Gas/Propane	11.1	58.8	19.2	7.7	15.2
Cooling (No Heat Pump)	22.2	11.7	19.2	19.2	19.3
All Central Cooling	33.3	17.6	73.1	53.8	55.0

*Summarized with case weights

A review of system sizing for the heat pump and air conditioning reveals a very limited sizing range used throughout the region without regard to climate. Both AC and heat pump installations average three tons compressor capacity with more than 80% of the cases between 2.5 and 3.5 tons. This distribution does not seem to be dependent on any particular characteristics such as home size, climate, or state.

3.5.1. Duct Leakage Results

A number of important summaries are included in this section, including raw duct leakage, air handler flow, and supply leakage fraction. The most important comparisons and explanations occur in the supply leakage fraction table (Table 15), where the duct leakage is normalized both by air handler flow and by house size as can be seen in the following Table 15.

Results are presented as the means of previous studies and both means and medians to allow the illustration of the leakage data without the influence of large outliers. In general, there looks to be about a 50% decrease in exterior duct leakage for the overall group when compared to the last study. This is important since it reflects the immediate result of introducing duct mastic in 2003 and requiring duct testing of each home in the factories in 2005. All the homes in this sample include duct systems sealed with mastic in the factory. It is quite clear from the available data that this in-factory duct sealing/testing succeeded in a dramatic improvement in overall duct leakage. Table 15 compares the results of the exterior (net) duct leakage test to previous studies. To expedite this table compares the results at 50 Pa duct pressure. The improvement over the 2000-2001 survey is striking. Almost all these differences can be attributed to revised duct installation practice in the factories.

Table 15: Comparison of Exterior Duct Leakage (CFM at 50 Pa)

Group	2006-07			2000-01	1997-98	1992-93
	n	Median	Mean	Mean	Mean	Mean
All*	72	77	95	209	231	157
Double Wide	59	64	85	199	240	155
Triple Wide	11	149	151	265	210	169
Idaho	11	76	88	229	254	—
Montana	13	88	149	—	—	—
Oregon	23	86	107	198	—	—
Washington	25	61	82	202	208	—

*Case weights applied

Table 16 details the results of the exterior duct leakage for this sample at both the 50 Pa and the 25 Pa exterior leakage test. Even with the reduced overall leakage rate, the distribution is still very skewed as evidenced by the spread between the mean and the median of this data. When the outliers and large leakage cases were reviewed it was apparent that the main cause of the higher leakage was attributable to the cross-over duct (which is installed and sealed during the set-up, not in the plant).

Table 17 summarizes the impact of the cross-over duct and set-up when the crews could not or did not secure the duct adequately. Indeed for those cases where set-up review was completed (about 65% of the duct tests), the leakage rates in homes with auditor identified problems in the installation of the cross-over duct had a 50% higher leakage rate than the remaining sample. Moreover, when only homes that did not use the sheet metal elbow in connecting the cross-over duct the same relationship applied. In general, the cause of virtually all the high duct leakage cases in this sample was the duct sealing issues brought on by the connection of the cross-over duct.

Table 16: Exterior Duct Leakage* (CFM at 25 Pa and 50 Pa)

Group	n	CFM@25 Pa			CFM@50 Pa		
		Median	Mean	St.Dev.	Median	Mean	St.Dev
All*	72	48	61	46.4	77	95	72.4
Double Wide	59	41	56	42.8	64	85	64.7
Triple Wide	11	94	93	54.9	149	151	90.3
Idaho	11	46	58	28.8	72	88	44.2
Montana	13	58	97	99.4	88	149	153.9
Oregon	23	55	69	48.4	87	107	78.2
Washington	25	37	53	37.9	61	83	57.3

*Case weights applied

Table 17: Exterior Duct Leakage by Cross-Over Duct Installation

Cross-Over Status	n	CFM Leakage @ 50 Pa	
		Mean	SD
Not Secured	17	135.2	139.5
Secured	32	83.8	51.7
Total	49	101.6	94

3.5.2. Airflow and Supply Leakage Fraction

Furnace airflow and static pressure were measured with the TrueFlow® plate. Since the last survey this measurement procedure has been established as the most reliable method of measuring air handler flow. Corrections were made to the raw TrueFlow® numbers to account for test conditions. The results of the airflow measurements are shown in Table 18. In reviewing heat pump installations it is apparent that air flows are near the requirements of the regional heat pump programs, although these units may not have generally used local utility incentives programs for the heat pump installations.

Table 18: Furnace Airflow and System Static Pressure*

Air Handler Type	Mean	Median
Air Handler Flow (Trueflow®); N=77	1,044 CFM	1,007 CFM
System Static Pressure; N=83	19.0 Pa	19.4
Air Handler Flow Heat Pump Installations, N=24	1,051 CFM	1,040 CFM
Air Handler Flow per Ton of Compressor Capacity (HP), N=24	332 CFM/tn	351 CFM/tn
Air Handler Flow per Ton of Compressor Capacity (HP), N=24	310 CFM/tn	333 CFM/tn

*No case weights applied

Supply leakage fraction (SLF) summarized in Table 19 is found by determining the flow equation for exterior duct leakage and then applying it using the average system static pressure at normal operating conditions at each site. Static pressure was measured with a long Pitot tube in several registers at each site and averaged. The supply leakage fraction is the percentage of conditioned air that is not delivered to the home's interior during normal heating or cooling operation. It is difficult to scale the SLF directly from the air handler flow and duct leakage measured with the Duct Blaster™ test since the operating pressure can vary quite a bit from home to home. Therefore, the leakage at operating conditions also varies quite a bit for homes that might have very similar air handler flows and Duct Blaster™ results.

The SLF was calculated somewhat differently in the 2000 study; a weighting procedure between plenum and register pressure was used (rather than taking an average of all register static pressures). (Typically, static pressure was measured in more than half of the registers in this study.) In all cases, readings which had an unreliable leakage flow exponent were excluded from summaries.

Table 19: Supply Leakage Fraction

Flow Characteristics	Mean%	Median%
Based on True Flow AH Flow (N=69)*	4.8	3.9
Exterior Duct Leak at 25 Pa Per Ft^2 of House Area (N=73)	3.9	3.1
Based on True Flow AH Flow (2000-01 Sample N=76)*	13.4	11.4
Exterior Duct Leak at 25 Pa per Ft^2 of House Area (2000-01)**	7.9	7.5
Exterior Duct Leak at 25 Pa per Ft^2 of House Area ('97-98 Homes; 49 Cases))	—	5.9
Exterior Duct Leak at 25 Pa per Ft^2 of House Area ('92-93 MAP Homes, 150 Cases)	7.2	—

Table 20 presents the detailed SLF results for this study. As can be seen the SLF has fallen to the level used to develop the performance requirements (6%). Thus, in spite of the variations in set-up and home characteristics, the current manufacturing standard is generally delivering homes that meet or exceed the EnergyStar specification for SLF of 5%.

Table 20: HVAC Air Handler SLF

Group	n	Supply Leakage Fraction % Total Flow*		
		Median	Mean	St. Dev.
All*	69	3.9	4.9	3.35
Double Wide	57	3.6	4.9	3.56
Triple Wide	11	5.5	5.0	2.29
Idaho	10	5.7	6.1	2.89
Montana	11	3.9	4.8	2.00
Oregon	23	3.8	4.8	3.22
Washington	25	2.8	4.6	3.69

* Case weights applied

3.6. Customer Satisfaction Survey

Customers were asked several questions about how they felt about the performance and value of their NEEM home. Results are encouraging, as Table 21 shows. An overwhelming majority (92%) were at least "somewhat satisfied" with the efficiency and comfort of their home, and 70% would recommend to others that they buy a NEEM home. These responses have been fairly consistent with the results of previous surveys.

Table 21: Customer Satisfaction

Customer response	% of surveys
Very Satisfied with Home	64
Somewhat Satisfied with Home	28
Would Recommend to Another Buyer	68
Would Recommend with Reservations	29

Customers generally were purchasing homes that were part of the NEEM program, which was largely made clear to them at the dealership. Only 32% had heard of NEEM at all before reviewing their option at the dealership. Almost 90% of the respondents said the dealer recommended or highly recommended the NEEM package. This compares to 25% that reported the dealer highly recommended the NEEM package in the 2002 sample. Table 22 describes the main areas mentioned by the dealers in explaining the benefits of the NEEM package.

Table 22: Dealer Approach to NEEM Sales

Dealer Comments	% of surveys
Highly Recommended	69
Recommended	20
Features Mentioned	
Extra Insulation	68
Extra Air Sealing	46
Better Indoor Air Quality	41
Utility Incentives or Tax Credits	40
Loan or Purchase Package	11

The most important elements influencing the purchase of a NEEM home were cost of the home followed by low energy bills and environmental benefits. In general, homeowners thought they were getting a good value, but some still complained their utility bills were higher than expected. In some cases, this had to do with moving into a larger home and keeping the thermostat set higher than before, but in other cases, there were some isolated installation and set-up problems that were contributing to the higher bills. All of these problems have been brought to the attention of state agencies concerned; detailed comments are available for all homes. All deficiencies in the NEEM specification were sent to the appropriate plant general manager for remediation. In general, complaints from homeowners were typically related to perceived deficits in customer service and deficiencies in the home set-up rather than problems with the energy efficiency characteristics of the home. In those few cases where the quality of the home was cited as less than satisfactory, the primary complaints centered on poor set-up or higher-than-expected heating bills.

4. Characteristics Results

This study presents some unique opportunities to track the development of energy efficient manufactured homes over the last decade. There are several key trends that arise from this review:

- Average house size is 1,739 ft^2. The house size is very comparable to the homes built in the other surveys since 1997 but 20% larger than the homes in the early MAP program (1992-1993). Apparently the demand for ever larger houses has leveled off in the NEEM program
- Houses are getting tighter, according to the blower door results. The average air leakage rate at 50 Pa is 3.8, which represents a tightening of almost 30% over the original MAP home average. The median equivalent leakage area (ELA) for double-section homes has decreased by about 25% despite a substantial increase in house size.
- 96% of homes in the study reported dedicated whole house fans and a substantial fraction of homeowners are using their whole house fans. However, a significant minority (30%) do not turn them on.
- 55% of homes in the study use central cooling, about 70% of these homes have a heat pump.
- Duct systems are much tighter than any previous study; the median value in this study is more than twice as tight as the 2000-01 study median. The duct tightness meets the NEEM standard.
- The median supply leakage fraction is about 4% for the homes in this sample (that is, about 4% of heated or cooled air is not delivered through the registers).
- The lighting system review developed an LPD that was consistent with the connected lighting loads of the single family homes reviewed in this region. The presence of linear florescent lamps and CFL lamps causes an apparent reduction of about 20% in the connected lighting power resulting from florescent technologies covering about 25% of the lamps in the NEEM homes.
- No utility involvement with the installed heat pumps was mentioned, but at least air flow seems to meet the regional utility standards.

The impact of the revised duct sealing specifications and factory test of each floor cannot be overstated. The factories are delivering very tight ducts and this shows up in all states regardless of set-up practice. It should be noted, however, that the fraction of homes that did not meet the duck leakage targets were largely linked to deficiencies in set-up practice, usually involving the securing and coupling of the crossover duct. Although Oregon has a very good installation and inspection program, Oregon's sample homes leaky ducts were the result of relocating registers after the homes were installed and inspected and issues with complicated duct systems and multiple heating systems in three and four section homes. These problems were almost totally absent in Washington where strong inspection and set-up specification were present.

Overall shell tightness has increased steadily since the early 1990s. The results of this study show that current homes are 40% tighter than homes built in 1992 and 8% tighter than the homes built in the 2000-01 sample. It is likely that homes of this tightness should have some level of central fan-forced ventilation. While all these homes have ventilation systems as required by the NEEM specifications, many of the occupants do not use their system. While the progress made in occupant understanding is significant, more progress is needed as the homes become tighter.

Homeowners report overall high levels of satisfaction with their homes, in terms of value, utility costs, and other factors. As in the previous studies, these added energy efficiency features are well received by the homeowners. The sample did, however, find a few "problem homes," which were reported to the state agencies and to the manufacturer for repair. Owners in these homes had a less positive attitude on most of these issues.

5. Billing Analysis

The homes built and sited in 2006 that were included in this study were recruited and field tested for this study using a similar methodology to most previous field reviews conducted over the last 20 years. One of these reviews, the MAP program evaluation of homes built in the 1992-93 time frame, (Baylon, et al, 1995) focused on a billing analysis to determine the performance of the manufactured homes in that program.

In this analysis of the 2006 homes, a similar effort was done to use the energy bills collected for each house to estimate the heating energy requirement and subsequently use a simulation tool to assess the degree to which these estimates corresponded to the performance predicted for the NEEM program. At the present time the simulation tool used for this purpose (SEEM) has been refined over the techniques used in 1995. As a result, more direct accounting of comparison of thermal, duct sealing, and air tightness could be done. This process provides better confidence in the savings and quality of the NEEM homes.

The goals of the analysis described in the comparison sections below were:

- To assess insofar as possible the heating energy savings achieved by the NEEM homes. This was compared to the predicted heating savings.
- To assess the predictive value of the current SEEM thermal simulation tool in establishing the performance requirements of a NEEM home. This analysis presents the heating system performance estimates and compares these results to the SEEM simulations.

5.1. Billing Data

Ecotope attempted to collect energy bills for all 89 audited sites. We succeeded in collecting complete energy bill streams for 78 of 89 sites. Of the eleven lost sites, roughly half were due to the occupant not signing the billing release, and roughly half were issues on the utility end, such as the signature not matching with the account holder, or the requested account not matching any known active account. In one case the house was unoccupied. Within the 78 sites for which we collected complete bill streams, the length of collected bill streams, in total billing period days, varied from a low of 337 to a high of 1,368, with a median length of 696 billing days.

To conduct HDD regressions, a further pairing down of the 78 was needed to exclude sites with highly irregular billing intervals, or with insufficient bills. The effective criteria were:

- **All-electric heat (resistance or heat pump).** Minimum of 12 consecutive bills, minimum of 365 days in the aggregated billing period.
- **All metered natural gas heat.** Minimum of 12 consecutive bills, minimum of 365 days in the aggregated billing period. Complete (non-space heat) electric billing history for the same interval.
- **Propane heat.** Excluded from the regression-based analysis, because fill-up intervals are highly irregular and long, and the time displacement between purchases and consumption can be large. The median number of propane bills available in propane-heated sites was 6; the maximum was 10.

These screens resulted in a loss of a further eight sites: all five propane sites, two gas heat sites, and one all-electric site. Thus, for the final sample used in this analysis a total of 70 sites were included.

5.2. Weather Data

Ecotope used the National Weather Service's Cooperative Station Network as our source for daily weather data. In comparison with the relatively sparse network of highly automated stations run by the Weather Service itself, this is a dense network of sites, with hundreds of stations in the state of Washington alone. However, not all the data are of high quality and not all stations had data records over the intervals of interest. Each house site was mapped to a geographically close cooperative station with recorded daily minimum and maximum temperature available over the house's aggregated billing interval, avoiding large disparities in elevation or displacement along steep climate gradients (e.g. the Columbia River Gorge). The distance between the house site and the chosen weather recording station was typically less than ten miles, and the elevation difference was typically small. In three cases where there were no good alternative stations we had to splice temperature data from a second station into data gaps in a primary station, and there were also a couple of cases where missing single-day data were filled in with the simple expedient of averaging the available values from the immediately preceding and immediately following day. But otherwise the daily temperature records from the chosen stations were complete. For a chosen degree-day base temperature, each series of daily minimum and maximum temperatures can be used to calculate daily degree days to that base using the standard approximation formula:

Equation 1: $$Max(0, t_{base} - (t_{\min} + t_{\max})/2)$$

Where t_{base} is the chosen degree-day base temperature, and t_{min} and t_{max} are the day's recorded minimum and maximum temperatures, respectively.

5.3. Heating Degree Day (HDD) Regressions

For each of the 70 screened sites, we regressed billing period consumption on billing period degree-days using a slight modification of the standard variable-base degree day method pioneered by Fels (1986). Under the Fels method, the degree day base and the regression response coefficient of energy consumption to degree-days are jointly estimated by finding the heating degree-day base which maximizes "goodness of fit," as measured by R^2, the coefficient of determination. Using R^2 as a criterion effectively maximizes the proportion of total variation in consumption explained by a linear response to heating degree-days. The "Ecotope modification" involves excluding data points from a regression estimation where the billing interval's heating degree-days to that base are zero. Empirically, this serves to insulate the estimated HDD slope coefficient and constant from the influence of summertime cooling loads, which certainly exist for some of our sites.

After estimating such best-fit HDD regressions for our 70 sites, we scrutinized slope coefficients, R^2, and scatter plots for acceptable fit. Quality of the regression results, measured in this way, varied significantly according to heating system. None of the gas regressions are deemed unusable; 6 % of the electric furnace regressions are; but a full 20% of the heat pump regressions cannot be used.

In a single zone structure (like a manufactured house), the linear coefficient has the interpretation of house UA, and the intercept has the interpretation as a constant base load not dependent on space heating demand. Varying solar gains and thermostat set point changes have the effect of changing the balance point, so that the actual heating input data (the bills) in fact reflect some random mix of effects of heating degree days to different bases.

Effective thermal output for natural gas and for electric resistance is a direct and linear function of energy input. But whereas natural gas in these structures is used almost exclusively for space heating (occasionally hot water heat), electricity in houses with electric resistance furnaces is used for many other things, including appliances, lighting, seasonal cooling and hot water heat). Some of these loads vary seasonally, whereas some do not; but all have the effect of muddying the linear relationship between heating loads and heating degree days. In gas heated homes there is good reason to suspect that a linear relationship between energy consumption and heating degree days is less noisy than in houses heated with electric resistance (kWh).

Electric heat pump sites can be expected to do significantly worse than either electric resistance or gas sites. They share the problem that the fuel has a number of other residential end-uses which may or may not vary seasonally; but there are additional problems unique to heat pumps. One of these is that heat pumps operate in both heating and cooling mode. A second problem is that the heat pump efficiency itself varies with temperature. Finally, detailed reviews of heat pumps in the Pacific Northwest have shown a substantial reduction in overall efficiency due to set-up and control decisions made by typical heat pump installers. This resulted in specifications for heat pump installation under the PTCS specification which were not employed in this sample. These and other factors make the degree-day fit much more error prone in homes with heat pumps and introduce the chance of substantial bias in the estimation of the heating load.

5.4. Estimating Annual Heating Consumption

Given a variable-base heating degree day (VBHDD) fitted regression coefficient a straightforward estimate of heating load is the product of the regression coefficient and HDD to that base for that month. An accompanying estimate of annual non-heating related base load is simply the fitted regression constant times 12 months. A problem with this simplest of approaches is that it is well established from sub-metered data that non-space-heat load components do have seasonal variation, notably electric light (with length of day) and hot water heat (with seasonally varying intake water temperature), and without adjustment these seasonally varying base load components are imputed to heating load. An adjustment method first proposed by Fels et al (1986) is to fit a cosine function using the regression constant. Following the Fels approach, we adjust our heating estimate using a trigonometric function of the estimated regression "base load" constant α as follows:

Equation 2: Heat for month $m = Max(\beta \cdot HDD - \alpha \cdot (.1 + .1 \cdot \cos(2\pi m / 12)), 0)$

Where β is the estimated regression slope coefficient, *HDD* is calculated heating degree days for month *m* to the chosen base, and α is the estimated regression constant. In effect, some of the seasonally varying load is taken away from the heating estimate $\beta \cdot HDD$ and given to the base load estimate α.

5.4.1. Comparisons of Estimates across Time, Climates, Heating Types, and Methodologies

Only 63 sites survived the several screens imposed for usable billing records and plausible VBHDD slope coefficients explaining a reasonable proportion of variation in consumption. These 63 sites are spread across three climate zones, from mild coastal climates of Oregon and Washington, to cold continental sites in northern Montana.

Results of this analysis are divided into the same three climate zones used in most regional analysis (NPCC, 2005). In general the three climate zones are defined as:

- **Climate Zone 1:** The western parts of Oregon and Washington (with a few warmer sites in the Columbia Basin)
- **Climate Zone 2:** The Intermountain area, including most of North Idaho and most of South Idaho.
- **Climate Zone 3:** The Rock Mountain areas of Montana and Idaho

The sample is also spread unevenly across three heating types (gas, electric resistance, and electric heat pumps) and climate zones. For example, heat pumps are confined largely to the milder zones 1 and 2, whereas gas is predominantly a zone 3 heat type. In this sample only electric resistance, the largest heating type (N=38), has something approaching an even distribution across climate zones. Given the very limited samples we have limited the comparisons to three main areas:

1. The valid cases are separated into individual climate zones and heating fuel types. This strategy allowed comparison across the various climate zones. In all cases the results of the VBHDD analysis have been normalized by the square feet of the individual home so that billing data from large and smaller homes can be compared.
2. The aggregated results of this study are compared to the values predicted by the SEEM simulations. The SEEM simulations used the characteristics of the homes in the sample to calibrate the simulation results to the observed billing analysis results. This allowed the billing analysis to estimate energy savings in spite of the fact that there was no comparison group developed for this sample. Section 5.4.3 details this process.
3. For the homes with electric resistance heat a comparison was made with the results of the last billing analysis done for this program (Baylon, et al, 1995). This sample was compared to sample taken during the MAP program which operated from 1992-1995. The 1995 MAP homes program included comparable specifications and quality control to the 2006 sample.

5.4.2. Comparison of Sample Points

The locations of the 2006 sample NEEM homes have been divided into the three climates zones used in the Pacific Northwest. The second major distinction between the 1995 and the 2006 sample is heating fuel. The 2006 sample has been divided into three categories: gas furnace, electric resistance furnace, and heat pumps. Two of the gas systems were gas furnaces with AC installed. All these heating systems types use the same ducting and distribution system and have the same thermal requirements under the NEEM specifications.

In otherwise equivalent houses, regression coefficients for gas sites should be larger than those for electric resistance sites, to reflect the AFUE of gas used as a heating fuel. The regression coefficient in VBHDD regressions is generally interpreted as the house UA, or heat-loss coefficient. In the case of electric resistance, where the effective conversion efficiency is 1 this is a reasonable assumption. In the case of gas heating where the combustion efficiency is less than 1 the UA is divided by the AFUE of the furnace (~0.80) to reflect the greater input energy to achieve a given level of plenum output energy. This would result in about a 25% increase in the apparent UA derived from the regression. With heat pumps, the situation is reversed. The ratio is precisely the average COP for that heat pump. With a heat pump COP of 2, we would intuit that the "UA" coefficient would be roughly half the magnitude of the coefficient for the otherwise identical electric resistance site. These differences in degree day response coefficients would be reflected in overall energy use. Table 23 below shows the total energy use of each cell in our sample normalized by building area (Energy Use Index, EUI). The energy use recorded in the bills has been converted to kBtu's to allow comparability between electric and gas usage

Table 23: Annualized Energy (kBtu/Yr/Sq. Ft.) Use by Climate Zone and Heating Type

Heating System		Zone 1	Zone 2	Zone 3	Total
Heat Pump	Mean	30.4	35.68	26.31	32.04
	Std. Dev.	8.62	11.03	–	9.47
	N	12	7	1	20
Electric Resistance	Mean	30.58	37.94	44.27	36.13
	Std. Dev.	12.51	7.85	9.33	11.7
	N	15	10	8	33
Gas	Mean	41.01	49.76	51.83	49.46
	Std. Dev.	5.07	–	7.92	8.06
	N	2	1	7	10
Total	Mean	31.22	37.71	46.46	36.95
	Std. Dev.	10.76	9.26	10.43	11.87
	N	29	18	16	63

In Table 23 above, the annualized EUI relationship between climates is generally as expected. Similarly, the relationship between the electric furnace and the gas furnace is approximately as expected. For the heat pump cases, however, the apparent similarity between electric resistance and heat pump systems suggest minimal savings for the more efficient heat pump option. Some form of behavioral "takeback", poor heat pump installations or increased summer cooling load for heat pumps vis-à-vis resistance houses seem the likeliest explanations. Given that a number of the zone 1 sites (e.g.: Medford, Oregon; Yakima, Washington; and The Dalles, Oregon), have cooling climates, the cooling loads seem to be plausible explanation. An equally plausible explanation is that these heat pump units do not in fact achieve an average COP of as much as 2 under actual operating conditions. Field notes from heat pump cases in the Oregon sample (high percentage of heat pumps) mentioned occupants who complained about a lack of comfort to their heating contractor and were told by their heating contractors to switch the heat pumps to run in electric resistance heating mode –field technicians found the thermostats set to emergency heat setting.

Table 24 summarizes the regression results from the three heating system categories. Unlike the previous Table 23, this table is the result of separating the apparent heating energy from the remaining energy bills. This table excludes sites where there were known outbuildings that would add to the space conditioning load and sites where there was strong evidence of extensive wood heating. These results are a summary of the slope of the regression line from the VBHDD regression. For comparison purposes the UA of the NEEM home calculated from the specifications and an assumed infiltration rate (based on the field results of the blower door test summarized previously) would be 0.0046 kBtu/dd/sq. ft. This estimate would not include the distribution efficiency of the duct leakage or the efficiency of the furnace or heat pump. In general this would increase the base UA by about 6% for the electric resistance furnace and about 25% for the gas furnace. In the heat pump cases the apparent UA would decrease by 45%.

Table 24: Area-Normalized Estimated UA's (kBtu/Degree-Day/Sq. Ft.) with Outbuilding Sites Excluded

Heating System		UA	UA Ratio*
Heat Pump	Mean	.00358	1.28
	Std. Dev.	.0015	–
	N	19	–
Electric Resistance	Mean	.00513	.90
	Std. Dev.	.0020	–
	N	30	–
Gas	Mean	.00556	.83
	Std. Dev.	.0019	–
	N	7	–

*Assume an apparent UA of .0046 kBtu/dd/sq.ft.

Note that these results are not disaggregated by climate zone, since there's no compelling reason to think these coefficients vary by climate. At conventional significance levels the "null hypothesis" that there is no significance difference between the heat pump and electric resistance systems can be rejected. However, a 38% point estimate gap between heat pump and electric resistance heating degree-day consumption responses is substantially lower than the anticipated difference between heat pump with a COP of about 2.0 and the electric resistance furnace.

Table 25 below shows the space heating estimates derived from the VBHDD billing analysis of these sites using Equation 2, as can be seen there is an expected relationship between the heating estimates for each heating system type and each climate zone. Indeed the ratio between electric resistance and heat pump estimates approaches a ratio that would be expected with an average COP of about 2.0.

Table 25: Estimated Heating Energy Use Index (kBtu/Yr/Sq. Ft.) by Climate Zone and Heating Type

Heating System		Zone 1	Zone 2	Zone 3	Total
Heat Pump	Mean	8.86	11.64	11.57	**9.97**
	Std. Dev.	4.61	8.45	–	**6.06**
	N	12	7	1	**20**
Electric Resistance	Mean	14.3	21.3	24.14	**18.8**
	Std. Dev.	5.11	10.38	6.35	**8.31**
	N	15	10	8	**33**
Gas	Mean	18.09	29.17	32.62	**29.37**
	Std. Dev.	4.03	–	4.86	**7.35**
	N	2	1	7	**10**
Total	**Mean**	**12.31**	**17.98**	**27.06**	**17.68**
	Std. Dev.	**5.62**	**10.61**	**7.95**	**9.83**
	N	**29**	**18**	**16**	**63**

Table 26 shows the EUI distribution of the loads that are not space heat. The trigonometric adjustment discussed before in Equation 2 in the context of space heating loads is also applied here, but with opposite sign. In the case of gas heating sites, all electric load is included here. For these non-space heat loads the size of each cell should be similar in the absence of estimation issues or of hidden cooling loads. Looking at zone totals, and aggregating across heating types, this appears so; however, looking at differences between heating types, but aggregating across zones, differences emerge: the point estimate for heat pump sites is roughly 30% larger than for electric resistance sites.

Caution is called for, however: there is substantial variability across different sites. No difference between row totals or column totals approaches statistical significance. Nonetheless, the differences in point estimates across heating types do at least help to explain some apparent discrepancies between prior tables. Electric resistance sites and heat pump sites have very similar total EUI's but the estimated UAs differ by roughly 40%. The heat pump numbers suggest that "take back" relative to resistance sites, in the form of cooling, poor heat pump installation, heat pump control issues or other conditioning in the non-heating months. Indeed, as expected from the overall summaries the estimate of space heating particularly in the heat pump cases are probably influenced by the nature of this heating system and the difficulties of estimating heat load from a system where cooling cannot be easily separated from base load estimates. While Table 26 suggests a reasonable prediction we are left with the near certainty that the estimate of non-space heat includes a substantial amount of heating energy disguised as cooling take-back or mis-estimation of the heating season resulting from the uncertainty introduced by even a modest cooling load.

Table 26: Estimated Non-Space Heat Loads (kBtu/Yr/Sq. Ft.), by Climate Zone and Heating Type

Heating System		Zone 1	Zone 2	Zone 3	Total
Heat Pump	Mean	20.55	23.17	13.75	21.13
	Std. Dev.	8.63	8.71	–	8.47
	N	12	7	1	20
Electric Resistance	Mean	14.46	16.44	18.77	16.11
	Std. Dev.	10.22	9.41	7.08	9.2
	N	15	10	8	33
Gas	Mean	22.75	15.47	18.89	19.32
	Std. Dev.	8.9	–	8.13	7.57
	N	2	1	7	10
Total	**Mean**	17.55	19	18.51	18.21
	Std. Dev.	9.76	9.24	7.17	8.9
	N	29	18	16	63

5.4.3. Calibration and Savings

The study design for this field sample emphasized the review of the NEEM homes and their compliance to the overall NEEM specifications. The billing analysis was done only on those homes. The sample and scope was not sufficient to develop a comparison group that would represent manufactured homes that were not built to the NEEM standards. Thus, the billing analysis was focused on the degree to which these homes met the performance goals of the program in comparison with a baseline manufacturing standard that would be used in the absence of NEEM program participation. Table 27 summarizes the comparison between these baseline homes and the homes manufactured under the NEEM program. The values in this table were derived from direct conversations with plant managers or plant QC managers in late 2008.

Table 27: NEEM/Baseline Comparison

Component	NEEM	Baseline
Ceiling	R-38	R-28
Floor	R-33	R-22
Wall	R-21	R-13
Window	U=0.35	U=0.35
Door	R-5	R-5
Duct Leakage	As Found	SLF=0.15
Infiltration	As Found	.35 ACH
Ventilation	Vent Fan Operation	None

The evaluation of the NEEM homes was conducted using the SEEM simulation program:

1. The first step was to develop SEEM inputs for each house that corresponded to the values in Table 27. The component areas were derived from the building size as collected in the field audit. Values for duck leakage, envelope tightness, ventilation system operation were taken from the values observed in the field.
2. The next step was to compare the values generated for the space heat using the SEEM simulation to the billing analysis results. To do this the billing analysis was re-normalized to the TMY3 climates used by the SEEM analysis. This was accomplished using the parameters derived from the VBHDD analysis and applying these parameters to the temperature data in the TMY3 files. This resulted in an adjustment to every home to account for the temperature differences between the particular climate and year and the "typical weather used to represent that site over the long term. Ultimately, heat pump homes were not included because of difficulties in developing a reliable weather normalization parameters for homes with heat pumps. Similarly, gas heated homes were dropped because the sample size was so small in Zones 1 and 2 that the comparison to a more generalize analysis would be misleading. A few of the remaining electrically heated homes were removed where the available information on duct leakage or house leakage was insufficient to make definitive estimates. As a result, only 29 electrically heated homes were used in this analysis.
3. Once these two calculations were complete they were compared. In general, the SEEM runs with these specifications matched within 10% of the heating estimates derived from the billing analysis.
4. A comparison SEEM run was then developed using the Baseline assumption from Table 27. This run was taken as the base case and savings were calculated from the difference between the SEEM runs in step 1 and the Baseline runs.

These savings estimates were then compared to the predicted values from the previous estimates made for the NEEM program. The comparison included an adjustment to account for the size difference in the homes in this sample compared to the prototype analysis used for the initial NEEM energy savings estimates. Table 28 summarizes the results of this analysis. As can be seen the predicted values of the NEEM prototype analysis are about 20% larger than the realized savings derived from this analysis.

Table 28: SEEM Calibration and Energy Savings

	Units	Zone 1 (n=14)	Zone 2 (n=8)	Zone 3 (n=7)	All (n=29)
Billing Analysis	kWh/sf	14.3	21.3	24.14	18.8
Normalized (TMY3)	kWh/sf	14.7	22.5	24.5	19.2
Heat Estimate	kWh	6419	9715	13901	9134
SEEM (NEEM Sample)	kWh	5960	8754	13706	8601
SEEM (Comparison)	kWh	9544	14161	21321	13660
Estimate Savings	kWh	3584	5406	7615	5060
Predicted Savings	kWh	4659	6087	8634	
Realization		0.77	0.89	0.88	0.83

5.4.4. Comparison to Previous Studies and Simulations

The 1995 MAP study focused entirely on electric resistance houses, and screened out heat pump houses, not only because of the modeling issues already alluded to, but also because in 1995 they represented a far smaller fraction, approximately 13%, of the heat type installations. Square footage normalization is also mandatory to make meaningful comparisons with the 1995 MAP results, since average house size has increased—in the 1995 sample it was roughly 1,400 square feet for electric resistance manufactured houses, and in the current analysis data set it is approximately 1,700 for all heat types.

The following Table 29 compares average estimated normalized annual energy consumption for electric resistance heat for each of our three climate zones from the current study, with those of the 1995 MAP study and with SEEM modeling results. The NEEM program specification has not changed greatly since 1995. Improved duct sealing is the sole exception to that, and this might be expected to change the normalized heating consumption numbers by less than 10% relative to the 1995 standard. Given the relatively small size of our current analysis data set (N=38 for electric resistance houses), and the relative uncertainty of the VBHDD methodology it is not possible to reject the contention that the current numbers are pretty much exactly the same as the 1995 numbers. The same can be said of the comparison with SEEM modeling results, which use the current NEEM specification and TMY data, that is, at no reasonable level of significance can current VBDD estimates be distinguished from the SEEM modeling point estimates for the same climate zone.

These results suggest that the SEEM analysis is reasonably accurate in predicting the performance of the NEEM homes. Furthermore, the results suggest a reasonably consistent heating performance compared to the MAP homes.

Table 29: Estimated Average Energy Use Index (kBtu/Yr/Sq. Ft.) for Electric Resistance Houses: Comparison of Current Study, 1995 MAP Data, and SEEM Modeling Results

Climate Zone		Current Billing Data (Ecotope VBHDD Methodology)	1995 MAP Study Billing Data (Ecotope VBHDD Methodology)
1	Mean	14.3	14.5
	Std. Dev.	4.9	5.5
	N	16	53
2	Mean	22.1	18.3
	Std. Dev.	10.7	5.0
	N	9	44
3	Mean	24.1	25.9
	Std. Dev.	6.3	8.6
	N	8	18

5.5. Billing Analysis Results

The results of this analysis show the potential for a billing analysis in this sector. Even in small sample sizes the consistency of the size and components of the homes result in few outliers and much more predictable regression results. The exception here is the heat pump systems. While the explanation of cooling “takeback” and poor heat pump installations is credible, there is the alternative problem that the technology itself varies in efficiency with temperature. Thus, the underlying assumption of the regression analysis (a consistent relationship between temperature and heating energy requirements) is actually compromised. The size of the sample precludes detailed evaluation of these matters as well as other potential determinants of consumption such as duct leakage, envelope tightness, and the impact of outbuildings.

Future efforts of this sort would benefit from sample sizes that were somewhat larger. More importantly such a review would benefit from a control group selected from homes not built to the NEEM specifications but subject to the same audit and building characteristics developed for the NEEM sample. The overall impression based on this analysis is that the NEEM homes are behaving as predicted by simulations and is comparable to the previous billing analysis in 1995. It would be useful to compare the NEEM homes to another sample of new manufactured homes sited in the region.

The lack of a data for a non-NEEM sample makes the utility of this analysis more limited although the results do suggest that the efforts to calibrate the SEEM simulation to the performance of these homes is, at least, defensible.

6. References

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Fels, M., J. Rachlin, and R. Socolow. 1986. Seasonality of Non-Heating Consumption and Its Effect on PRISM Results. Energy and Buildings, Volume 9 (1986), pp. 139-148.

HUD. 1994. *Manufactured Home Construction and Safety Standards*. Revised Part 3280 of Title 24. United States Department of Housing and Urban Development.

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7. Appendix: Field Protocol

NEEM FIELD SURVEY 2008

Site ID#_________ Date_______________

Occupant Name__________________________Address_________________________________

City, State _____________________________ Zip__________

Phone_________________________________

Utility_________________________________

Dealer/location___________________________

Set-up crew/number (if known; check metal plate next to HUD sticker)______________________________

Person filling out this report_____________________________________

Record Serial # of the Dent datalogger used (if appropriate) ______________________________

Basic Information

Manufacturer _____________________ Model ________________________

HUD #:__________________________ NEEM#_______________________

____Single Wide
____Double Wide
____Triple Wide

____Other (two story, four-section, etc)
Describe: _______________________________________
____

Attach a sketch of the floor plan with accurate exterior dimensions. Use back page of protocol if desired. Sketch in interior rooms and ***number*** heating registers. Calculate house volume and write on the sketch. Take picture of home facing toward and away from front door; take pictures of any notable details.

Perform a quick visual inspection of the home interior and ducts. Use a mirror. Note problems on sketch. If you use the full set-up checkout procedure, use the form on page 8.

Does homeowner report problems germane to testing (moisture, high bills, air flow, roof/siding, plumbing failures, and comfort issues)? If so, note here:

Ask homeowner to respond to the questions on the next page and also ask for a signature to release billing records. Name of homeowner responding to consumer questionnaire:____________________________

Consumer Questionnaire

1. How long have you lived in the home? ______________
2. How satisfied are you with the energy efficiency/comfort levels of your home? Separate into 2 separate questions; energy efficiency (utility bills) and comfort.

Energy Efficiency: Very satisfied ______ Somewhat satisfied______ Somewhat dissatisfied_____ Very dissatisfied _______

Comfort: Very satisfied ______ Somewhat satisfied______ Somewhat dissatisfied_____

Very dissatisfied _______

3. Would you recommend that a friend, neighbor or relative buy a NEEM home?

Yes, enthusiastically______ Yes, with some reservations_______ Definitely not_____

Comments:

4. What influenced you to buy a NEEM home? Rank from 1 to 5, with 5 being most influential:

Comfort	_____
Lower energy bills	_____
Good for the environment	_____
Affordable option vs site built	_____
Quiet inside	_____
Increased resale value	_____
Utility or tax incentive	_____
Other:	

____

____

5. Were you told about the home's ventilation system and showed how it works? ____yes ____no

   Have you made any changes to the home's ventilation operating time? ____yes ____no
6. Was the NEEM upgrade mentioned by your dealer? _____yes ____no

   If yes, was it Highly recommended _____ moderately recommended______

   Dealer recommended <u>against</u> the NEEM upgrade ______
7. Did the dealer mention any of the following when explaining the NEEM upgrade? (circle all that apply):

Added insulation Extra air sealing Better indoor air quality with upgraded ventilation

Utility incentive Tax credit Special SEO service with energy/comfort related problems

Other________________________________

8. How did you learn about the NEEM upgrade (circle one): at dealership brochure read about heard an advertisement Other____

9. Did you receive an incentive from your utility or other entity such as a tax credit that influenced your decision to get the NEEM option? ____yes _____no

Describe: ____

10. How often do you change your furnace filter?________________

11. Typical occupied thermostat setting in winter ____ summer____.

12. Do you practice thermostat setback ___ yes ___ no

Describe:____

13. Has anyone inspected the set-up and energy features of your home? Describe:

____

14. Did your lender take the NEEM upgrade into account when you obtained your loan? Yes no was not discussed

Describe ____

15. Before your purchase do you recall reading or hearing any NEEM/SGC/ESTAR advertising material? Yes no. If yes, what was source (circle)?

Brochure radio or TV commercial other __________________________________.

Did it affect your purchase? ________________________

16. Do you have any ENERGY STAR appliances (circle all that apply)? Refrig, dishwasher clothes washer lights other__________________

17. Were ENERGY STAR appliances, lighting, furnace offered to you as an option when you purchased the home? Yes no Describe:

____

Note any additional loads that would affect a billing analysis (well pump, outbuildings, etc.):

Billing Release

[Ask the homeowner to release his/her energy bills for future billing analysis. Be sure to explain that the bills will be held in strict confidence by OOE and used only for the evaluation of the overall NEEM manufactured home program.]

I _____________________________ (homeowner name) hereby grant permission for the Oregon Office of Energy to receive a copy of my electrical and/or gas utility bills. I understand that these will be used for statistical purposes and be held in confidence by Oregon Office of energy and its assigned contractor.

____ ________________________

Signature *Date*

Electric utility name/account#_______________________/_____________________________

Gas utility name/account#_________________________/______________________________

Air Quality/Ventilation

Technician's observations of odors or moisture

____None ____Odors ____Moisture _____Mold/Mildew

Location and Description:____

____

Note any conditions which may significantly affect air quality or ventilation (e.g. smokers, solvents, aquarium):____

____

Number of full-time _______ adult occupants ______children (under 12)

Ventilation Systems

Make and Model	Type: whole house, spot, combined, AAHX	Location (bath, hall, etc.)	Flow (cfm)	Daily run time (hrs)	Noisy ?	Control type*

*manual switch, timer *(note flow measurement device used)*___________________________

Is whole house fan operating as designed? Yes No

Location of whole house fan switch __________________ Is switch labeled? Yes No

Note any problems with vent terminations (no exhaust stack, suspected disconnect between exhaust fan and termination point, etc.):

____

____

____

Classify the **make-up air** system installed in the home.

None	
Passive duct (POS or VentilAire™ I)	
Dampered duct	
Dampered duct with interlock (NW Timer Kit)	
Blendaire System	

Make-up duct diameter _______inches. Note if the make-up damper is jammed or otherwise inoperable: ____.

Do all bedrooms have pass-through vents or door undercuts? Yes ____ No_____

Note deficiencies:

Central Heating Source

Is there an electric furnace? ______yes ______no Size (kW) @ ___________
Is there a gas furnace? ______yes ______no 208/240V (circle one)
Make and capacity (000 of Btu) ____
Confirm unit is sealed combustion: ______yes ______no (check house dataplate first)

Is there central AC/heat pump*? ______yes ______no
(*confirm HP by turning on heat and seeing if compressor comes on. T
his doesn't rule out either a 5 minute lockout or controls problem. Can also look for reversing valve in outdoor unit.)

If AC/heat pump, note make and model of outdoor unit _________________________________

Register Static Pressures

Set-up: Turn on air handler (best to just turn on the heat). Measure static pressure in at least 4 registers (at least 2 on each side of the home; best to do one at midpoint and one at end). Use long Pitot tube or static pressure tap. Make sure end of tap is at the bottom of the boot (part way into trunk duct) when taking reading. Point hook of probe into airflow; tape into place and put grille back into place (upside down is okay).

Reg. loc or #	Static P (Pa)

Air Handler Flow Measurement Using TrueFlow Plate

.

1. Open interior doors.
2. Place Pitot tube or static pressure tap into closest register to furnace (in furnace section of home), tip pointing into airflow.
3. **Leave filter in place**, unless it is very dirty and **furnace doors & grilles in place**. Turn furnace on (use heating speed.)
4. Connect hose from Pitot tube/static tap to Channel A Input tap.
5. (DG-3) Turn to Channel A.
6. (DG-3) Turn to Pressure. Read pressure & ***record below as NSOP***. Leave hose connected to manometer.
7. Shut **system off**. **Remove filter**.
8. Put plate into filter slot or onto best opening in furnace cabinet and block off any bypasses, so all airflow goes through plate (Keep cardboard on hand). (Common situation is Coleman with 16 x 20 filter on top and 20 x 20 in door. If adequate air supply to top of furnace, block door grille with cardboard, use filter slot for plate. *Plate goes in with metal tubing side toward fan*.
9. Connect Red hose from plate to Channel B Input, Green hose to Channel B Reference. Fan select to PL (14 or 20), depending upon which plate is used. ***Record plate size***.
10. Turn system on so fan goes to same speed as above.
11. (DG-3) Select Channel B. Turn to Flow. Read flow, ***record as Raw Flow***.
12. (DG-3) Turn to Pressure. Read and ***record as Plate pressure drop***.
13. (DG-3) Turn to Channel A. Read pressure & ***record as TFSOP***.
14. Use correction table to find Correction Factor and ***record***.
15. Multiply raw flow by Correction Factor to get Corrected Flow. ***Record.***
16. Turn system off.
17. Remove plate from furnace. Remove any cardboard. Remove plate's hoses from manometer. Replace filter(s).

Plate used (14 or 20) ________________

Normal System Operating Pressure (NSOP) _______Pa   Plate pressure drop ________Pa

True Flow System Operating Pressure (TFSOP) _____Pa   Raw Flow (CFM)________

Correction Factor √(NSOP/TFSOP) __________   Corrected Flow ________CFM

If you cannot use the TrueFlow, use Duct Blaster matching (form in PTCS set-up guide).

Notes (difficult set-up, etc.):

As-Found Blower Door Test

Set-up: Close all windows and doors to the outside (except door which will receive blower door). Open all interior doors, close all dampers and doors on wood stoves and fireplaces. Make sure blower door is set to depressurize the house. Ensure that furnace and (gas-fired) water heater can not come on during test. Make sure all fans are off (including make-up air fan).

1. Set-up frame (fit it snugly), fan.
2. Run hose from Outside to manometer; connect to channel A Ref.
3. Run hose from fan to Channel B Input.
4. Use smallest ring on fan that still lets you get the pressure—depressurizing home (door skin in)—check and re-check fireplace before getting to test pressure(s)!
5. (DG-3) Turn Manometer to Channel A Turn to Pressure
6. Cap blower door and ***record*** pressure of house WRT outside (Channel A) _____ Pa (pre baseline)
7. (If using DG-700, can do test with automatic baseline correction if desired.)
8. Take house to -25/-50 Pa. ***Record Ring and House P***.
9. (DG-3) Turn to channel B.
10. Read fan pressure and ***Record***.
11. (DG-3) Turn to Fan Select. Select Up to 3 – Down to (0,1,2).
12. (DG-3) Turn to Flow. ***Record Flow***.
13. Cap blower door and ***record*** pressure of house WRT outside (Channel A) _____ Pa (post baseline)
14. Check flow exponent using procedure detailed below. Repeat test as needed.
15. After readings, turn off fan. Make note of windy conditions, etc. Leave door set-up, fan open. Proceed to next test.

House P near-25 pa ______ Ring ____ FAN PRESSURE _____ CFM ________

House P near -50 pa _____ Ring _____ FAN PRESSURE ______ CFM ________

Sq Ft of home _______ X Average Ceiling Height ________ = Volume of Home __________
Blower Door, CFM50-- ______ x 60 = Cfm/Hr _______ / Home Volume _________ =
ACH-50 – _______ / 20 = ACH NATURAL_______

Air changes at 50 requirement for NEEM homes is 5.5 ACH 50,
Windy?
If so, highest gust estimate:

Other notes:

Record outdoor temperature__________ Record indoor temperature _____________

To check test, calculate the flow exponent, n. Use the following formula, $n = \ln(Q_{50}/Q_{25})/\ln(P_{50}/P_{25})$. *Note* Q_{50} *and* Q_{25} *are the flows through the blower door at the testing pressures (which are denoted* P_{50} *and* P_{25}*). Depending on the test, you may not get the house to exactly –50 or –25 Pa WRT outside.*

Use the exact ΔP you measure when checking the flow exponent. For example, if the house gets to –48 Pa for the high ΔP, use this as the P_{50} *in the equation. If the flow exponent is not between 0.50 and 0.75, repeat the test.* ***The quick way to do this (as long as test pressures are very close to 2:1 ratio, such as 50:25), is to see if the flow near 25 is about 0.6x the flow near 50. So if the flow at 50 Pa is 1000 CFM, the flow at 25 should be about 600 CFM.***

Exterior Duct Leakage Test

Note type of crossover (if known): external_____ internal _____

If available, record factory tests of the ducts:

	CFM_{50}
A side	
B side	
Pod, etc	
Total	

Duct Leakage To Outside

1. Set blower door to pressurize home. With mfd homes, you probably only need to flick the flow direction switch on the blower door. (If home is very leaky you may need to turn the blower door around.) If using DG-700, it is advisable to use automatic baseline correction mode.
2. Remove all rings.
3. (DG-3) Turn to channel A.
4. (DG-3) Turn to pressure.
5. Pressurize home to +25/+50 WRT outside.
6. Put Ring 3 in duct blaster. (use smallest ring that allows pressure to be reached
7. (DG-3) Turn to channel A.
8. (DG-3) Turn to pressure.
9. Take ducts to zero WRT house. (House is the REF tap on Channel A.)
10. Hook up hose going to outside tap to REF on A and check duct pressure WRT outside. ***Record below.***
11. (DG-3) Turn to channel B. Read & ***record ring and DB fan pressure***.
12. (DG-3) Turn to fan select.
13. (DG-3) Select Up to 8- Down to (1,2,3).
14. (DG-3) Turn to flow. Read and ***record flow***. (Note flashing number means below measurable range).
15. Leave fan running.
16. Go to blower door. Take house to +50. Go to Duct Blaster.
17. (DG-3) Turn to Channel A.
18. (DG-3) Turn to Pressure.
19. Take ducts to zero WRT house.
20. Hook up hose going to outside tap to REF on A and check duct pressure WRT outside. ***Record below***
21. (DG-3) Turn to Channel B. ***Record ring and DB fan pressure***.
22. (DG-3) Turn to fan select. Select combination.
23. (DG-3) Turn to Flow. Read flow and ***record***.
24. Check flow exponent using procedure detailed below. Repeat test as needed.
25. Shut down all fans.
26. Remove Blower door. Remove duct blaster. Return furnace and thermostat to original condition. Remove register plugs. Leave all register grills in open position. Pack up equipment and move to load out position by front door.

Ducts WRT out near 25 pa _____ Ring ___ FAN PRESSURE ______ CFM ______

Ducts WRT out near 50 pa _____ Ring ___ FAN PRESSURE _______ CFM ______

Flow exponent check (as for BD test):

Interior/exterior Lighting review

List each fixture type observed in the house. Include exterior lights attached to the house. Describe these fixtures as they appear when developing the lighting power for the house each of these fixtures should be represented in the fixture counts in the next section. If two fixtures are essentially identical but have different lamps then enter them as separate fixtures with separate wattage.

Where fixture descriptions beyond the generic types would be helpful the auditor can add them with the appropriate lamp and ballast information. Use the notes field to expand on the description as needed.

Fixture Schedule:

Fixture Type ID	Fixture/lamp Type[1]	# of Lamps	Ballast Type[2]	Watts/ Fixture	Field Verif	Estimated? Y/N	Notes
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

[1] Use generic fixture descriptions:
- Incandescent
- CFL
- Linear fluorescent
- Track light (MR16)
- Other

[2] Magnetic or electronic from instrument

The "Space ID can be arbitrary and is for the convenient of the fixture count. We suggest that a count for the bedroom area, the living/dining area, the kitchen/utility rooms and the bathrooms would be a reasonable breakdown. In general, try to break the house up into at least three spaces and treat the exterior lighting as a separate space.

Fixture count

SpaceID[1],	Area (ft^2)[2]	Fixture Type ID	Total Count

[1] The auditor can decide how to group the spaces. Generally this should separate the main living space from the bedroom areas and the utility, bathroom and kitchen from the other spaces. Include exterior lights as a separate "Space"

Set-Up Review

Crawlspace/Exterior:

Yes	No		
		Is skirting in place? or foundation system?	
		Are pier supports in place under I-beam with at most 8' O. C. spacing?	
		Are pier supports in place under exterior doors, windows over 4', recessed entries or bay windows?	
		Are pier supports properly shimmed (not overdriven)?	
		Are footings proper size and smooth (min 256 in^2 or 18" wide runner)?	
		Note type of crossover (internal/external)	
		Is crossover duct cut to length?	
		Are crossover duct connections secure? Sealed ?	
		Are crossover ducts connected with sheet metal elbows? Seams sealed?	
		Are crossover connections insulated to R-8?	
		Are belly penetrations sealed?	
		Are patches and repairs holding in plans? Pictures if possible	
		Is marriage line sealed? (indicate where inspected)	
		Evidence of problems from looking at exterior marriage line or roofline?	
		Do water heater, AC/HP, and clothes dryer drains/vents exit the home properly?	
		Is there a ground vapor barrier? Is it properly lapped? Is it damaged	
		Is there standing water under the VB?	
		Is there any sign of moisture on top of ground vapor barrier?	??

Number, size and location of crawlspace vents – list on floor plan sketch. Are Vents open or closed?

Does ground slope away from house?

Crossover duct size__________ Describe any unusual T's, Y's, or junction boxes. Are these features insulated to at least R-8? How is crossover supported? ____________________
Take pictures if possible.
Other comments:

Operations:

Yes	No	
		Do exterior doors operate smoothly and seal against weather-stripping?
		Do windows operate smoothly?

Any other comments: