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Northwest ENERGY STAR Homes Energy Analysis: 2006 - 2007

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Northwest ENERGY STAR® Homes Energy Analysis: 2006 - 2007

Final Report

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1. Executive Summary

1.1 Introduction

This report presents the results of an evaluation of energy use of homes in the Northwest Energy Star Homes Program of the Northwest Energy Efficiency Alliance (NEEA) and operated by utilities throughout the Pacific Northwest. It is likely that in the near future the Program will be known as the Certified Home Programs Initiative. The evaluation is based on a comparison of a sample of the homes that qualified for Northwest ENERGY STAR certification during the period 2006 – 2007 (referred to as "Participant sample or homes") to a sample of houses that were built during the period 2004 – 2005 without initiative support (referred to as "Baseline sample or homes").

The evaluation consists of the following four components:

- New Home Characterization Study
- Lighting Logger Study
- Estimation of Energy Savings through Billing Analysis
- Comparison of Energy Savings Estimates from Billing Analysis to Modeled Results from Algorithms of the Regional Technical Forum (RTF)[1]

1.2 Summary of Findings and Conclusions

1.2.1 Key Differences between Participant and Baseline Homes

The differences between the Participant and Baseline homes are most pronounced in the energy efficiency of manufactured equipment installed. For example:

- Virtually all gas furnaces in Participant homes met the program standard efficiency level of AFUE 90, and 38.5 percent exceeded that efficiency level. By contrast, only 25.3 percent of the furnaces in Baseline homes met the AFUE 90 standard.

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[1] The results of this component will be presented in a separate document.

- Nearly three-fourths of the central air conditioners installed in Participant homes exceeded the efficiency levels required in the program standards. Only 5.1 percent of the units in the Baseline homes met those standards.
- Over 69 percent of the lighting sockets in the permanent fixtures in the Participant sample contained ENERGY STAR compliant lamps, versus 22.6 percent in Baseline homes.

Some of the observed differences between the samples in saturation of efficient equipment are so closely linked to program requirements that it is reasonable to attribute them to the influence of the Northwest ENERGY STAR initiative. These would include the differences in saturations of ENERGY STAR compliant lamps, the high saturation of efficient furnaces and hot water heaters, the large share of central air conditioners with SEER ratings between 13 and 14 and ENERGY STAR dishwashers. Other differences, such as higher saturation of ENERGY STAR appliances (except for dishwashers) likely reflect general trends in these markets toward higher efficiency levels, as well as changes in federal product standards and ENERGY STAR product criteria.

1.2.2 Energy Savings Associated with Northwest ENERGY STAR Certification: Billing Analysis versus Planning Assumptions

KEMA conducted an analysis of billing data from both the participant and baseline samples to estimate electricity and natural gas savings associated with Northwest ENERGY STAR Homes program certification. We estimated weather-normalized annual consumption of electricity and gas for the homes in both samples, controlling for differences between homes in size, heating and cooling system configuration, and household characteristics. The difference in average annual consumption represents the effects of participation in the program. We were also able to disaggregate average annual use to heating, cooling, and baseload end uses.

To assess the plausibility of the billing analysis results, we compared them to estimates of energy savings that the Alliance developed for program planning. These are based on building simulation models incorporated in the Alliance Cost Effectiveness (ACE) model. The savings estimates generated by the billing analysis were consistent with those produced by the ACE simulations. Where discrepancies occurred they were clearly traceable to differences between observed conditions in the baseline and/or participant samples and assumptions incorporated into the ACE model. The following paragraphs summarize the findings of the billing analysis and their comparison to the corresponding results of the ACE models. Table 1-1 summarizes this comparison.

Table 1-1. Comparison of Estimates of Annual Energy Savings per Home: Billing Analysis and ACE Model Energy Savings Results

FUEL/End Uses	Saturation in NW ESH	Billing Analysis Savings Results	ACE Model Savings Results
ELECTRICITY		KWH/YEAR PER HOME	KWH/YEAR PER HOME
Heating	7%	203	392
Cooling (Central AC)	60%	229*	47
Hot Water	10%	793*	21
Dishwasher	100%		3
Lighting & Other Base Load	100%		924**
Electric Total		1,224*	1,449***
NATURAL GAS		THERMS/YEAR PER HOME	THERMS/YEAR PER HOME
Heating	90%	58.7*	116.3
Hot Water	88%	13.2	14.9
Natural Gas Total		71.9*	131.9

* Billing analysis result statistically significant at the 90 percent confidence level. Column does not add due to rounding.
** Does not include savings from "Plus" package lighting and appliance measures.
*** End use consumption estimates do not sum to total consumption in the ACE modeling framework.

Electricity Savings. The billing analysis produced an estimate of average electricity savings per home associated with Northwest ENERGY STAR certification of 1,224 +/- 528 kWh per year. This is 13 percent of baseline annual usage of 9,417 kWh per year. Annual savings estimated through the billing analysis were 225 kWh per year less than the ACE model results after accounting for differences between the participant sample and ACE model input assumptions in terms of space and water heating fuel saturation. The key components of this difference were as follows.

- **Baseload use reductions.** The ACE model yielded average baseload electricity savings of 948 kWh per year, of which 924 kWh per year was due to lighting energy reductions. The billing analysis estimated average baseline savings of 793 kWh kWh per year – 131 kWh per year less than the ACE model. This difference was largely due to differences in assumed versus observed reductions in baseline lighting power density (LPD) associated with Northwest ENERGY STAR program certification. The home characteristics survey found that LPDs in the baseline sample averaged 30 percent higher than those in the participant homes. The ACE model assumed a 50 percent difference. The fact that the participant homes were somewhat smaller than the baseline sample and contained slightly fewer lighting fixtures may also have contributed to this result.

- **Heating use reductions.** Average reductions in heating use were estimated at 392 kWh per year by the ACE models versus 203 kWh per year by the billing analysis. The billing analysis estimate was not statistically significant.
- **Cooling use reductions.** The billing analysis produced estimates of average savings in cooling energy of 229 kWh per year versus ACE model estimates of 47 kWh per year. This difference is largely explained by differences in baseline. The average SEER of central air conditioners observed in the baseline sample was 10.45 whereas ACE incorporates an assumption that central air conditioners will meet the current 13 SEER federal standard.

Natural Gas Savings. The billing analysis produced an estimate of natural gas savings per home associated with Northwest ENERGY STAR certification of 71.9 +/- 32.2 Therms per year. This is 10 percent of baseline use and 60.0 therms per year less than the ACE model results. Nearly all of this difference is attributable to the disparity in the estimates of heating use reductions. These differences are most likely related to differences in observed versus assumed levels of insulation and in the baseline homes and in observed versus assumed levels of duct leakage in the baseline sample.

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2. Introduction and Summary of Key Findings

This report presents the results of an energy analysis of the Northwest ENERGY STAR Homes Program operated by utilities throughout the Pacific Northwest with the support of the Northwest Energy Efficiency Alliance (NEEA). The evaluation is based on a comparison of a sample of the homes that qualified for Northwest ENERGY STAR certification during the period 2006 – 2007 (referred to as “Participant sample or homes”) to a sample of houses that were built during the period 2004 – 2005 without initiative support (referred to as “Baseline sample or homes”). The evaluation consists of the following four components.

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- **New Home Characteristics Study.** This component of the study compares the structural features, thermal performance, HVAC equipment, domestic hot water, lighting, appliances, and plug loads of the Participant and Baseline homes, based on the results of on-site surveys. KEMA conducted on-site surveys of a representative random sample of 345 homes certified by the Northwest ENERGY STAR Homes program in 2006 and 2007. The Baseline Study is based on a 2006 survey of 604 new homes completed during the period 2004 - 2005.
- **Lighting Logger Study.** KEMA installed lighting loggers on selected fixtures fitted compact fluorescent bulbs in a subsample of 68 Northwest ENERGY STAR homes. Through these devices we collected hours of use information for 467 fixtures for an average of 6.5 months. We used these hours of use data along with statistical models of lighting use in response to hours of darkness to annualize the observations. We then used this annualized data set to estimate annual hours of use and lighting load shapes.
- **Estimation of Energy Savings through Billing Analysis.** KEMA collected gas and electric billing records for 310 Participant homes and 225 Baseline homes. We used these records to conduct an analysis of billed electric and gas consumption to estimate energy savings associated with certification through the Northwest ENERGY STAR Homes program.
- **Estimation of Energy Savings through Building Simulation Models.** The Regional Technical Forum (RTF) developed a set of algorithms based on building simulation models to support program planning. The inputs for the model consist of data on home size, configuration, and equipment. The outputs of the model consist of estimates of energy savings versus construction practices and equipment required by building codes. KEMA developed a method to run the RTF algorithms in batch mode. We used this process to along with input data sets created from the on-site new home characterization

surveys, to develop a second estimate savings associated Northwest ENERGY STAR Homes certification. The findings from this component of the project will be made available later in 2010.

In this document we report the methods and results of three of the four components of the study and assess the degree to which they convey a consistent profile of the effect of Northwest ENERGY STAR certification on efficiency-related home construction features and equipment on the one hand and on energy consumption and savings versus baseline gas and electricity use on the other.

In the remainder of this section, we summarize the methods and findings from the four components for quick reference and provide a guide to the contents of the larger report.

2.1 New Home Characterization: Approach

This study presents and compares the results of two on-site surveys that characterized the energy efficiency characteristics of new homes in the Pacific Northwest. The earlier "Baseline" survey was conducted by RLW Analytics under the supervision of NEEA and other stakeholders. It collected information from 604 single family homes constructed during the study period 2004 – 2005, including duct leakage, duct airflow, and infiltration testing on a subsample of 264 homes. The current Participant survey collected information from a sample of 345 homes that received Northwest ENERGY STAR Home certification during the period from January 1, 2006 through September 30, 2007. All of the Participant surveys included the duct and infiltration tests.

Sampling. RLW used Census Bureau data on building permits to estimate the distribution by county of new homes built during the study period across the four-state region. The sample design for the survey was driven largely by the spatial distribution of permits issued during the study period.[2]

The Participant survey conducted for this study used as its sample frame the database of all homes that were certified by local program sponsors during the period January 1, 2006 through September 30, 2007. Three hundred thirty qualified homes were deleted from the sample frame because they were located on a military reservation with limited access. An additional 97

[2] The RLW study also collected information on a sample of multi-family buildings. The results of that effort are not discussed here.

served by small rural utilities were eliminated due to costs of access. After these adjustments, 3,981 certified homes remained in the sample frame.

Working closely with NEEA and other stakeholders, KEMA developed a sample design that would produce estimates of means and proportions with a 90 percent confidence interval of +/-10 percent, while providing a sufficient number of observations to characterize key market segments accurately. Market segments were defined by sub-region and heating equipment type. KEMA was able to complete 345 of the targeted 350 surveys, all of which included HVAC equipment and infiltration tests. We were able to realize most of the intended sample design, with the exception of falling short on the quota for homes with heat pumps.

These sampling procedures produced a Participant sample that was nearly identical to the Baseline sample in terms of its distribution on most key household and housing characteristics that could affect energy consumption. The one difference between the samples that may affect comparisons of energy consumption is that the attached single-family homes represented 13 percent of the Participant Sample versus 1.1 percent of the Baseline sample. Some portion of the differences observed between the two samples in average duct leakage, window-to-floor area, and level and type of floor insulation may be attributable to the higher representation of attached homes in the Participant sample.

Data Collection. KEMA designed the Participant on-site data collection protocol to correspond as closely as possible to the Baseline protocol in order to maximize comparability between the results of the two surveys. Figure 2-1 displays the kinds of data collected on site for both surveys.

Figure 2-1. Data Collected on Site in Baseline and Participant Surveys

Collection Means	Categories	Information
On-site Interview	Single Family Demographics	Number/Ages of Occupants Household Income Owner/Renter
	General Building Information	Type Year of Construction Conditioned/Unconditioned Floor Areas
Onsite Inspection Construction Practices, Materials, and Equipment Installed	Building Envelope	Windows Walls Roof/Attic Basement
	HVAC Systems	System & Fuel Types Thermostat(s) and Usage
	Domestic Hot Water	System & Fuel Types
	Lighting	Fixture Types Lamp Types/Wattages/Quantity Control Types
	Large Appliances	Refrigerators/Freezers Dishwashers Clothes Washers Clothes Dryers
	Other	Pool and Spa Small Appliances Contributing to Plug Load
On-Site Measured Performance Test Results	Duct System	Leakage Rate: using Minneapolis Duct Blaster equipment. n = 239 Airflow Rate: Using TrueFlow Air Handler Flow meter equipment. n = 226
	Building Envelope	Infiltration Rate: using Minneapolis Blower Door equipment

2.2 New Home Characterization: Key Findings

2.2.1 Overview

Figure 2-2 summarizes key comparisons between the Participant and Baseline samples on construction and equipment features that are addressed directly by the Northwest ENERGY STAR Homes program standards. The differences between the Participant and Baseline homes are most pronounced in the energy efficiency of manufactured equipment installed. For example:

- Virtually all gas furnaces in Participant homes met the program standard efficiency level of AFUE 90, and 38.5 percent exceeded that efficiency level. By contrast, only 25.3 percent of the furnaces in Baseline homes met the AFUE 90 standard.
- Nearly three-fourths of the central air conditioners installed in Participant homes *exceeded* the efficiency levels required in the program standards. Only 5.1 percent of the units in the Baseline homes *met* those standards.
- Over 69 percent of the lighting sockets in the permanent fixtures in the Participant sample contained ENERGY STAR compliant lamps, versus 22.6 percent in the Baseline homes.

Some of the observed differences between the samples in saturation of efficient equipment are so closely linked to program requirements that it is reasonable to attribute them to the influence of the Northwest ENERGY STAR program. These would include the differences in the saturation of ENERGY STAR compliant lamps, the high saturation of efficient furnaces and hot water heaters, the large share of SEER 14 central air conditioners and ENERGY STAR dishwashers. Other differences, such as higher saturation of ENERGY STAR appliances other than dishwashers likely reflect general trends in these markets towards higher efficiency levels, as well as changes in federal product standards and ENERGY STAR product criteria.

In most cases, the differences between the two samples on site-built components are not so pronounced. Levels of attic and wall insulation were only slightly higher in the Participant sample than in the Baseline sample, as was saturation of efficient windows. However, the samples did differ significantly in thermal performance and measured by functional tests. The average rate of air infiltration in the Baseline homes was 19 percent higher than in the Participant homes. Average duct leakage exceeded the program standard in both samples. However, average leakage to the outdoors was twice as high in the Baseline homes as in the Participant homes. An earlier study of duct leakage based on measurements taken at the point of certification found that nearly all certified homes met the duct leakage standard. These findings suggest that duct integrity may begin to deteriorate fairly soon after installation, even when initial installations meet the program standards.

Figure 2-2. Key Comparisons of the Participant and Baseline Samples

* = Difference between Participant and Baseline Samples is statistically significant at p = 0.1

Element	Efficiency Indicator (Program Standards where Applicable)	Participant	Baseline
		n = 345	N = 604
Home Configuration	Average size	2,276 sf	2,355 sf
	% of sample single family detached	86.7%	98.9%
Air Infiltration	% of sample meeting Program air infiltration standard	88%	71%
	Average Air Changes/Hour at 50 Pa (7.00)	4.92	5.87*
Insulation	% of homes with 2x6 framing to accommodate insulation	89.6%	78.9%
	Average level of attic insulation (R-38)	R-40.7	R-38.1
	Average level of floor insulation (R-30)	R-27.0	R-25.2
Windows	Window/Floor Area Ratio (Maximum 21%)	9.4%	15.3%
	% of window area with non-compliant U-values (U-0.35)	0.0%	16.7%
	Average U-values (U-0.35)	U-0.340	U-0.371
	Saturation of low-e windows as % of total glazed area	96.6%	86.3%
Heating Equipment	% of Furnaces that meet program standards (AFUE 90)	96.4%	25.3%*
	% of Furnaces that exceed program standards (AFUE 90)	38.5%	11.4%*
Cooling Equipment	% of Central AC systems that meet standards (13 SEER)	76.0%	5.1%*
	% of Central AC systems that exceed standards	73.4%	2.4%*
Duct Leakage	% of homes meeting duct leakage standards (0.06 CFM per square foot of enclosed space)	56%	7%*
	Average duct leakage rate (0.06 CFM per square foot of enclosed space)	0.07	0.14*
Water Heating	% of storage water heaters meeting standards	~ 95%	~13%*
Lighting	Interior lighting sockets per 100 square feet	3.28	3.34
	% of permanent interior sockets with ENERGY STAR compliant lighting, primarily fluorescent (50%)	69.3%	22.6%*
	% of exterior lighting that is ENERGY STAR compliant	57.1%	13.3%*
	Lighting Power Density (watts of lighting installed/sf)	0.51	0.73
Appliances	% homes with dishwashers that meet standards (EF 75)	100%	30.7%*

2.2.2 Building Envelope Characteristics

The following highlights key points of comparison between the Participant and Baseline samples in terms of building envelope characteristics and performance.

Air Infiltration

- **Compliance with program standards.** Twelve percent of Participant homes and 29 percent of the Baseline sample did not meet the BOP-1 standard of 7.0 Air Changes per Hour (ACH) at 50 Pa.
- **Average infiltration rates.** Average infiltration rates for the two samples were 4.92 for the Participant and 5.87 for the Baseline.

Shell Construction and Insulation

- **Use of deep cavity construction.** Almost 90 percent of Participant homes used 2”x6” studs in wall framing to accommodate required levels of insulation, versus 78.9 percent for the Baseline survey. The few Participant homes with 4-inch studs likely made use of a Technical Compliance Option and compensated the reduced depth of wall insulation with other measures.
- **Attic insulation.** On average, Participating homes had higher levels of attic insulation than the Baseline homes: R-40.7 v. R-38.1. This difference is small but statistically significant and present in all states. The BOP-1 standard is R-38.
- **Floor insulation.** Fifty-four percent of the Participant homes had crawlspaces below their ground floors, as did 69 percent of the Baseline homes. The average level of crawlspace insulation among the Participant homes was R-27; R-25.2 among the Baseline homes. BOP-1 requires R-30 insulation in crawlspaces.

Fenestration and Windows

- **Window-to-floor area ratio.** The average ratio of window to floor area was higher in the Baseline than in the Participant sample: 15.3 percent v. 9.4 percent. Only 3 percent of the Baseline homes exceeded the maximum 21 percent permitted under BOP-1.
- **Compliance with U-value standards.** Windows accounting for 16.7 percent of the total glazed area in the Baseline sample homes failed to meet U-values required by BOP-1. In contrast, all of the windows in the Participant sample met the BOP-1 standard and windows accounting for 22.0 percent of the glazed area exceeded BOP-1 standards.

- **Prevalence of low-e coating.** Windows accounting for 96.6 percent of glazed area in the Participant sample had low-e coating versus 86.3 percent in the Baseline sample.

2.2.3 Heating and Cooling Systems

- **Efficiency ratings of installed heating equipment.** BOP-1 requires that gas-fired forced air furnaces have an Annual Fuel Utilization Efficiency (AFUE) rating of 90 percent or higher. All but 3.6 percent of the forced air furnaces installed in Participant homes met this standard, and 38.5 percent of them exceeded the standard. By contrast, 74.1 percent of the furnaces in the Baseline sample were rated from 80.0 to 82.5 AFUE. AFUE 78 was the minimum federal standard in force during the study period.
- **Saturation of central air conditioning.** According to the program tracking database, 35.6 percent of the homes in the Participant sample had central air conditioning systems installed at the time of certification. However, KEMA field engineers found that 60.8 percent of the Participant homes had central air conditioning installed at the time of the survey. If both the tracking system and the survey results are accurate, this finding suggests that over one-fourth of participating homeowners added central air conditioning systems after their homes received certification. Fifty-eight percent of the homes in the Baseline sample had central air conditioning installed, which suggests that the observed saturation in the Participant sample is a plausible estimate.
- **Efficiency ratings of installed central air conditioning equipment.** Interpretation of data on the efficiency of central air conditioning equipment installed is complicated by the promulgation in January 2006 of new Federal standards that raised the minimum efficiency of such systems from 10 SEER to 13 SEER, which is the minimum efficiency level in BOP-1. Among Baseline homes, which were built in 2004 – 2005, 82.5 percent of the installed systems were rated at 10 to 11 SEER. Only 5.3 percent of the systems installed in the Baseline homes were rated at 13 SEER or above. Roughly 14 percent of the systems installed in the Participant sample had SEER ratings below 13. However, 69.0 percent were rated at 14 SEER, and an additional 14.4 percent were rated at 14 – 15 SEER. Thus, nearly three-fourths of the central air conditioning systems installed in Participant homes exceeded minimum standards for the program.
- **HVAC Duct Leakage.** HVAC ducts in the Participant sample were substantially tighter than those in the Baseline sample. However, average duct leakage to the outdoors, as measured by the Minneapolis Duct Blaster system, exceeded the program standard of 0.06 cubic feet per minute (CFM) per square foot of enclosed area at 50 Pascals (Pa) of pressure in both samples. Average measured leakage among homes in the Participant sample was 0.07CFM per square foot; 0.14 CFM per square foot for the Baseline

sample. A review of duct leakage tests performed as part of the Northwest ENERGY STAR Homes certification process during program years prior to November 2006 found that 95 percent of the tested homes complied with the duct leakage standard and that the average measured leakage to the exterior was 0.05 CFM per square foot. This finding suggests that duct integrity begins to decrease soon after installation, even when those installations initially meet program criteria.

- **Thermostats.** The prevalence of electronic digital thermostats was identical in the Participant and Baseline samples at 90 percent. However, in the Participant sample the remaining units nearly all used hybrid digital/mechanical technology whereas the remaining units in the Baseline sample were all mechanical.

2.2.4 Domestic Hot Water Systems

- **Continued dominance of standard storage hot water heaters.** Nearly 97 percent of homes in the Baseline sample had storage hot water heaters, as did 89.1 percent of homes in the Participant sample. Roughly two-thirds of both samples had storage heaters with capacities of 60 gallons or more.
- **Prevalence of instantaneous hot water systems.** We found that 9.5 percent of homes in the Participant sample had instantaneous hot water systems, reflecting the recent emergence of that technology in the U. S. residential market. Only 3.2 percent of the Baseline homes had instantaneous hot water heaters.
- **Efficiency of water heaters installed.** Domestic water heaters installed in virtually all Participant homes met program standards for efficiency. By contrast, the vast majority of water heaters in the Baseline sample did not.

2.2.5 Lighting

- **Saturation of Lighting Fixtures and Sockets.** The Participant and Baseline samples were nearly identical on most indicators of interior lighting equipment saturation and the level of lighting delivered to the home. The average Participant home contained 47.4 lighting fixtures compared to 48.9 in the Baseline sample, and 73.1 light sockets v. 77.1 in the Baseline sample. The average number of sockets per 100 square feet was 3.28 in the Participant sample and 3.34 in the Baseline sample.
- **Saturation of fluorescent technologies.** Over 52 percent of all? the sockets in Participant homes were filled with some type of fluorescent lamp: linear, screw-in compact fluorescent, and pin-based. Forty-three percent were fitted with compact

fluorescent lamps (CFLs). Only 22 percent of the sockets in the Baseline homes used fluorescent technologies. Thirteen percent of sockets in the Baseline homes were fitted with CFLs. The large difference between the Participant and Baseline homes in saturation of fluorescent lighting and of CFLs in particular likely reflects the effects of the program, which require that 50 percent of all lighting sockets use ENERGY STAR fixtures, bulbs, or both.

- **Lighting Power Densities.** The average Lighting Power Density (LPD = watts of lighting equipment installed/interior square feet of floor space) in the Participant homes was 30 percent lower than in the Baseline sample: 0.51 v. 0.73.
- **Compliance with program lighting requirements.** The Northwest ENERGY STAR Builder Option Packages require that 50 percent of installed lighting sockets either be in ENERGY STAR compliant fixtures or fitted with ENERGY STAR-compliant bulbs (CFLs). Over 69 percent of the permanent fixtures installed in the Participant homes potentially qualified for compliance, versus 22.6 percent of the permanent fixtures in the Baseline homes.[3]
- **Exterior lighting.** Exterior lighting can qualify for ENERGY STAR certification either by using pin-based CFL technology or, if using screw-in sockets, by integrating daylight shut-off control and motion sensors to reduce daytime use. By these criteria, 57.1 percent of exterior fixtures qualified in the Participant homes, versus 13.3 percent in the Baseline homes.

2.2.6 Appliances and Plug Loads

- **Saturation of major appliances.** The Participant and Baseline samples are nearly identical in terms of the saturation of major appliances and their distribution by size and configuration.
- **Share of ENERGY STAR appliances compared to Baseline sample.** The saturation of ENERGY STAR appliances was generally higher in the Participant sample than in the Baseline sample, although direct comparison is complicated by the rapid evolution of ENERGY STAR product criteria over the study period. The most dramatic difference occurred in dishwashers: over 97 percent of the dishwashers in Participant homes met ENERGY STAR criteria versus only 30.7 percent in the Baseline sample. This difference

[3] In many cases the fixtures and lamps observed met technical criteria for ENERGY STAR qualification but the ENERGY STAR decal was not visible.

very likely represents a program effect since the program required ENERGY STAR dishwashers for certification. Dishwashers are the only major appliance that builders frequently build in, and, according to program staff, they tend to use "builder special" models that do not comply with ENERGY STAR standards. Fifty-four percent of the refrigerators installed in the Participant sample met the ENERGY STAR criteria in effect beginning in 2004, versus 39 percent in the Baseline sample. For the latter, however, the relevant criteria had only recently come into effect, and the supply chain was still in the process of responding to that change.

- **Share of ENERGY STAR appliances compared to contemporaneous general market share.** The share of ENERGY STAR appliances in the Participant homes was in most cases higher than that in the general market, as measured by sales data from ENERGY STAR Retail Partners in the Northwest compiled by the U. S. Department of Energy and the Environmental Protection Agency. For example, the share of primary refrigerators that bore the ENERGY STAR label was 54.0 percent, versus a 2007 market share of 30.5 percent. Similarly, all of the dishwashers in the Participant sample met ENERGY STAR criteria versus 83.3 percent in the general market. The saturation of ENERGY STAR clothes washers was very close to the market share of 50 percent. With the exception of dishwashers, the homeowners selected appliances, not the builder. Thus, these results reflect the owners' motivations and buying practices in the appliance market more than the results of the program.
- **Consumer electronics.** The Participant and Baseline samples are nearly identical in terms of the saturation of consumer electronic devices such as computers, televisions, telecommunications, and audio equipment.

2.3 Lighting Hours of Use Study Results

The average daily hours of use for the logged fixtures was 1.21 hours per day, ± 0.126 hours or 10.4 percent of the average. Usage varied by room, with kitchen, office, and "other" locations having the highest hours of use. There were significant differences associated with other attributes such as fixture type, size of home or lamp count per home.

The average daily hours of use for the Participant sample is low relative to findings from other studies. For example, the most recent residential lighting logger study in California registered average hours of use of 1.8 hours per day. However, comparisons to other logger studies are complicated because all of these have sampled existing homes as opposed to new construction. New homes differ systematically from existing homes in ways that may affect lighting hours of use. Specifically, new homes tend to:

- Enclose more area than average existing homes in most geographic areas.
- Contain larger numbers of permanent lighting fixtures and sockets.
- House somewhat larger numbers of occupants.

The trend towards lower hours is likely associated with the increased saturation in CFLs and lighting fixtures more generally. The logic behind this hypothesis is that lighting requirements are fairly uniform for households of a given configuration and that average hours of use per fixture will decline as the number of fixtures or lamps increases. The clearest empirical support for this hypothesis comes from the lighting logger study carried out in support of the evaluation of the California statewide residential lighting program. This study monitored hours of use for over 8,000 CFLs installed in 1,200 homes. Based on these data, the study team developed an Analysis of Covariance (ANCOVA) model of hours of use. Room location of the bulb had the strongest relationship to hours of use, as measured by the t-statistic of the coefficients. The saturation of CFLs had a large negative impact on hours of use (-0.423 hours on average) although the statistical strength of this relationship was only moderate ($p = 0.062$). The number of sockets also had a small negative coefficient (-0.004) which was nonetheless statistically significant ($p = 0.042$).

2.4 Billing Analysis Results

KEMA conducted an analysis of billing data from both the participant and baseline samples to estimate electricity and natural gas savings associated with Northwest ENERGY STAR Homes program certification. We estimated weather-normalized annual consumption of electricity and gas for the homes in both samples, controlling for differences between homes in size, heating and cooling system configuration, and household characteristics. The difference in average annual consumption represents the effects of participation in the program. We were also able to disaggregate average annual use to heating, cooling, and baseload end uses.

To assess the plausibility of the billing analysis results, we compared them to estimates of energy savings that the Alliance developed for program planning. These are based on building simulation models incorporated in the Alliance Cost Effectiveness (ACE) model. The savings estimates generated by the billing analysis were consistent with those produced by the ACE simulations. Where discrepancies occurred they were clearly traceable to differences between observed conditions in the baseline and/or participant samples on the one hand and assumptions incorporated into the ACE model on the other. The following paragraphs summarize the findings of the billing analysis and their comparison to the corresponding results of the ACE models.

Electricity Savings. The billing analysis produced an estimate of average electricity savings per home associated with Northwest ENERGY STAR certification of 1,224 +/- 528 kWh per year. This is 13 percent of baseline annual usage of 9,417 kWh per year. Annual savings estimated through the billing analysis were 225 kWh per year less than the ACE model results after accounting for differences between the participant sample and ACE model input assumptions in terms of space and water heating fuel saturation. The key components of this difference were as follows.

- **Baseload use reductions.** The ACE model yielded average baseload electricity savings of 948 kWh per year, of which 924 kWh per year was due to lighting energy reductions. The billing analysis estimated average baseline savings of 793 kWh kWh per year – 131 kWh per year less than the ACE model. This difference was largely due to differences in assumed versus observed reductions in baseline lighting power density associated with Northwest ENERGY STAR certification. The home characteristics survey found a that LPDs in the baseline sample averaged 30 percent higher than those in the participant homes. The ACE model assumed a 50 percent difference. The fact that the participant homes were somewhat smaller than the baseline sample and contained slightly fewer lighting fixtures may also have contributed to this result.
- **Heating use reductions.** Average reductions in heating use were estimated at 392 kWh per year by the ACE models versus 203 kWh per year by the billing analysis. The billing analysis estimate was not statistically significant. The lower result for the billing analysis is likely related to one or more of the following factors:
  - The assumed saturation of electric heat in the ACE model is over 14 percent, versus 7 percent in the participant sample.
  - The ACE model assumes that duct leakage in participating homes complies with the program standards, whereas it was found to be considerably higher.
  - The ACE model assumes the presence of “code” levels of insulation in the baseline whereas actual levels were observed to be higher.
- **Cooling use reductions.** The billing analysis produced estimates of average savings in cooling energy of 229 kWh per year versus ACE model estimates of 47 kWh per year. This difference is largely explained by differences in baseline. The average SEER of central air conditioners observed in the baseline sample was 10.45 whereas ACE

incorporates an assumption that central air conditioners will meet the current 13 SEER federal standard.

Natural Gas Savings. The billing analysis produced an estimate of natural gas savings per home associated with Northwest ENERGY STAR certification of 71.9 +/- 32.2 Therms per year. This is 10 percent of baseline use and 60.0 therms per year less than the ACE model results. Nearly all of this difference is attributable to the disparity in the estimates of heating use reductions. These differences are most likely related to differences in observed versus assumed levels of insulation and in the baseline homes and in observed versus assumed levels of duct leakage in the baseline sample.

2.5 Overview of this Report

We have organized the remainder of this report as follows.

- **Section 3: Characterization Study: Methods and Objectives** describes the key methodological aspects of the study including sample design, sample plan realization, data collection procedures, and analysis approach. We also review the sampling and data collection methods used in the 2005 – 2006 Baseline Study to facilitate comparison of results between the two studies.
- **Section 4: Housing and Demographic Characteristics** summarizes the key characteristics of the homes and households in both the Baseline and Participant (Program) samples. We focus particularly on attributes such as home size and configuration and household size and structure which may influence the comparison of energy efficiency features between the Baseline and Participant samples, as well as the outcome of the billing analysis.
- **Section 5: Building Envelope** presents comparisons between the Baseline and Participant samples on building envelope features, including: infiltration rates, insulation types and levels, window efficiency ratings, and efficiency-related construction features.
- **Section 6: HVAC and Domestic Hot Water Equipment** presents comparisons between the Baseline and Participant samples on heating and cooling systems, HVAC system airflow and duct leakage, HVAC controls, and domestic hot water systems.
- **Section 7: Lighting** presents comparisons between the Baseline and Participant samples on saturation of lighting fixtures and sockets, share of lighting technologies installed (incandescent, linear fluorescent, compact fluorescent), distribution of lighting fixtures and sockets by room, ENERGY STAR qualification of installed lighting, and lighting power density.

- **Section 8: Appliances and Plug Loads** presents comparisons between the Baseline and Participant samples on saturation of major appliances and consumer electronics, focusing primarily on the share of ENERGY STAR equipment in various appliance categories.
- **Section 9: Lighting Hours of Use Study** presents the results of the lighting logger study, focusing on estimates of average hours of use and load shape for fixtures with compact fluorescent lamps installed.
- **Section 10: Impact Assessment using Billing Analysis** presents the methods and results of the billing analysis, which yields estimates of the differences in electricity and gas use per house associated Northwest ENERGY STAR Homes certification.
- **Appendix A: New Home Characterization Tables** provide detail from the Baseline and Participant on-site surveys. Most tables compare the results of the two efforts directly and provide an indication of the statistical significance of observed differences.
- **Appendix B: Details of Billing Analysis** provides a more in-depth account of the methods and results of the billing analysis than appears in the body of the report.

3. New Home Characterization Study: Objectives & Methods

3.1 Objectives

This report presents the results of a survey to characterize the energy efficiency of homes built with the support of the NEEA Northwest ENERGY STAR Homes Program during the period 2006 – 2007 and to compare those houses to a sample of houses that were built during the period 2004 – 2005 without program support.[4]

3.2 Program Description

The Northwest ENERGY STAR Homes program promotes the construction and sale of new homes built to the Northwest ENERGY STAR Homes specification, which was designed specifically to take into account climate, baseline building practices, and energy supply patterns in Washington, Oregon, Idaho, and Montana. Homebuilders are offered training on the specification and marketing assistance, technical support and financial incentives provided by local utilities. During the period covered by this study (January 1, 2006, through September 30, 2007), a total of 4,078 homes were certified under the program.

The U. S. Environmental Protection Agency promotes ENERGY STAR Homes and the ENERGY STAR brand on a national level. On a regional level, NEEA has long promoted ENERGY STAR consumer products through a variety of programs. According to the latest ENERGY STAR awareness survey, 80 percent of respondents in areas with significant ENERGY STAR program activity recognize the brand and 68 percent display a high level of understanding of the brand content.[5]

Homes built to the Northwest ENERGY STAR Homes specification are at least 15 percent more energy efficient than the prevailing building code requirements. To achieve this level of

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[4] RLW Analytics, Inc. "Single-Family Residential New Construction Characteristics and Practices Study, Final Report Prepared for NEEA." March 27, 2007.

[5] EPA Office of Air and Radiation, Climate Protection Partnerships Division. *National Awareness of ENERGY STAR® for 2008: Analysis of 2008 CEE Household Survey*. U.S. EPA, 2009.

efficiency, ESNHs include high efficiency lighting, windows, appliances, water heaters, insulation, and heating and cooling equipment. Homes built to the Northwest ENERGY STAR Homes specification are expected to save an average of 1,000 to 1,500 kWh per year for gas-heated homes and 3,700 kWh per year for electrically heated homes.

In order to achieve these levels of projected energy savings, NEEA and other stakeholders in the program developed prescriptive standards for program certification customized to conditions in the Pacific Northwest: state building codes in force, climate, existing construction practices, and the historic presence of utility-sponsored programs designed to promote energy efficiency in electrically heated homes. These Northwest Builder Option Packages differ from their national counterparts on a number of features, notably: higher levels of duct insulation, requirements for mechanical ventilation, and specification that 50 percent of installed lighting meet ENERGY STAR standards, versus a count of five fixtures.

The Northwest ENERGY STAR Homes program features two prescriptive Builder Option Packages or BOPs:

> **BOP-1:** Builder Option Package 1 is the prescriptive method for homes with gas-fired forced air heating equipment.
>
> **BOP-2:** Builder Option Package 2 is the prescriptive method for homes heated using zonal electric components or central heating systems fueled by propane or oil. For many building component types, the minimum requirements are identical to those for BOP-1. For a few others, though, the minimum requirements are more stringent.

In addition to the above described prescribed options, there were ten component trade-off options that could be exercised to allow a more tailored approach. These allow builders to trade off measures that exceeded the program requirements for measures that did not meet the program requirements in a prescribed manner. These are referred to as “Technical Compliance Options (TCOs).”

3.3 Participant Survey Methods

This section presents key elements of the methods used for both the Participant and Baseline Surveys.

3.3.1 Sampling Plan

Objectives: The objective of the sampling approach for the ENERGY STAR participant sample was to develop a representative sample of the homes that were certified by the program during the period 2006 and 2007. Moreover, the sponsors wished to ensure that all segments of the participant market, defined by sub-region and heating system type were adequately represented.

Sample Frame: KEMA used program records, in some cases verified by local program administrators, as the starting point for developing the sample frame. NEEA and KEMA agreed to set the cut-off date for certification at September 2007 in order to ensure that a sufficient number of monthly records would be available for the billing analysis. With the agreement of NEEA, some homes certified during this period were eliminated from the sample frame. These included 330 homes built on the Fort Lewis, WA military base to which access was restricted and 97 served by widely scattered utilities that had very low participation rates. We believed that the potentially high costs associated with including this small group of homes in the sample would not be justified by potential gains in accuracy or representativeness.

Table 3-1 displays the number of participating homes in the sample frame by region and heating system type.

Table 3-1. Sample Frame Homes by Region and HVAC Type

Region	HVAC Type				
	Gas no AC	Gas with AC	Heat Pump	Zonal Electric	Total
Puget Sound	1,108	24	2	4	1,138
SW WA / NW OR / SW OR	1,224	171	90	0	1,485
Central WA	0	79	97	0	176
E. WA / N. ID / C. OR	170	118	183	1	472
S. ID / E. OR	12	587	36	14	649
Montana	33	24	0	4	61
Total	**2,547**	**1,003**	**408**	**23**	**3,981**

Sample Size. In consultation with NEEA, KEMA set the sample size at 350 ESNHs. We selected this sample size to achieve estimates of key results for the program, as a whole, with ±10 percent precision at the 90 percent confidence level. This sample size was also expected to provide reasonably precise estimates for larger segments defined by state and heating system type.

Sample Design. In designing the sample we sought to balance two potentially conflicting objectives. The first was to achieve acceptably representative and precise estimates for key segments shown in Table 3-1. The second was to meet the targeted 90/10 precision for the main results of the overall effort. To achieve this balance, KEMA set sample quotas for some of the smaller region/heating system type cells higher than they would be if simple proportions had been applied. We set the minimum quota size to 20 and collapsed a number of cells with low numbers of participants in order to apply those quotas. Table 3-2 shows the resulting allocation of the 350 targeted survey completions.

Table 3-2. Sample Design by Region and HVAC Type

Sample	HVAC Type				
	Gas no AC	Gas with AC	Heat Pump	Zonal Electric	Total
Puget Sound	83	2	0	0	85
SW WA / NW OR / SW OR	90	20	14	0	124
Central WA	0	9	11	0	20
E. WA / N. ID / C. OR	12	8	30	0	50
S. ID / E. OR	1	43	6	1	51
Montana	11	8	0	1	20
Total	**197**	**90**	**61**	**2**	**350**

3.3.2 Recruitment of the On-Site Sample

Approach. KEMA recruited the Participant sample through the following steps.

1. **Mail survey to all participants in the sample frame.** We mailed a short survey to all 3,981 participants in the sample frame, using home addresses included in local program records. The key objectives of this mail survey were to solicit the current owners' participation in the on-site survey, collect contact information on the current owners that would be necessary for scheduling on-site visits, and collect a few items of information we considered useful in interpreting on-site results and understanding the operation of the program. These items included:

    a. Move-in date

    b. Awareness of the ENERGY STAR Label for homes

    c. Sources of information on ENERGY STAR Homes

d. Awareness of the ENERGY STAR rating of the respondents' own home
e. Rating of the value of having an ENERGY STAR Home

Four hundred sixty-five participants or 11.7 percent of the target population completed and returned the mail survey, indicating that they would be willing to take part in the on-site component.

2. **Recruit on-site survey sample.** KEMA recruiters used the contact information contained in the returned mail surveys to recruit customers in certified homes into the Participant sample. During this process, the recruiters also solicited the participation of customers in the lighting logger study. The recruiters attempted to fill all sample quotas by sequencing calls to smaller segments first.

3. **Scheduling.** Once KEMA confirmed a home owner's willingness to be surveyed, we sent the contact information and schedule preferences to field engineers in the respective sub-regions. It was the field engineers' responsibility to make final scheduling arrangements.

3.3.3 Realization of the Sample Plan

Table 3-3 shows the final count of surveyed homes by location and HVAC type. Table 3-4 shows the same information in terms of percentage of sample allocations achieved. KEMA field engineers visited 350 homes and completed surveys in 345 of them. Surveys could not be completed at 5 of the homes due to customer convenience issues. The recruiters and field engineers were able to realize most aspects of the planned sample allocation, with the following exceptions:

- We completed surveys in 30 homes with heat pumps versus 61 targeted in the sample plan. In some cases, this discrepancy may have been due to inaccuracies in the tracking system database in regard to HVAC equipment installed. However, even if all HVAC system installations are correctly characterized in the database, we were still able to survey over 7 percent of the full population of homes with heat pumps. This high level of sampling should yield a relatively accurate characterization of these homes.

- We were not able to reach our minimum target of 20 homes for each of the Central Washington and Montana regions. However, these two regions taken together represent less than six percent of the population of certified homes. Thus, the shortfall in these two cells is unlikely to affect the overall representativeness of the sample or expansion of sample results to the population.

- Other deviations from the sample plan, such as the relative overrepresentation of the second and fifth regions are compensated for by weighting and will not affect the accuracy or precision of the results.

Table 3-3. Surveyed Homes by Region and HVAC Type

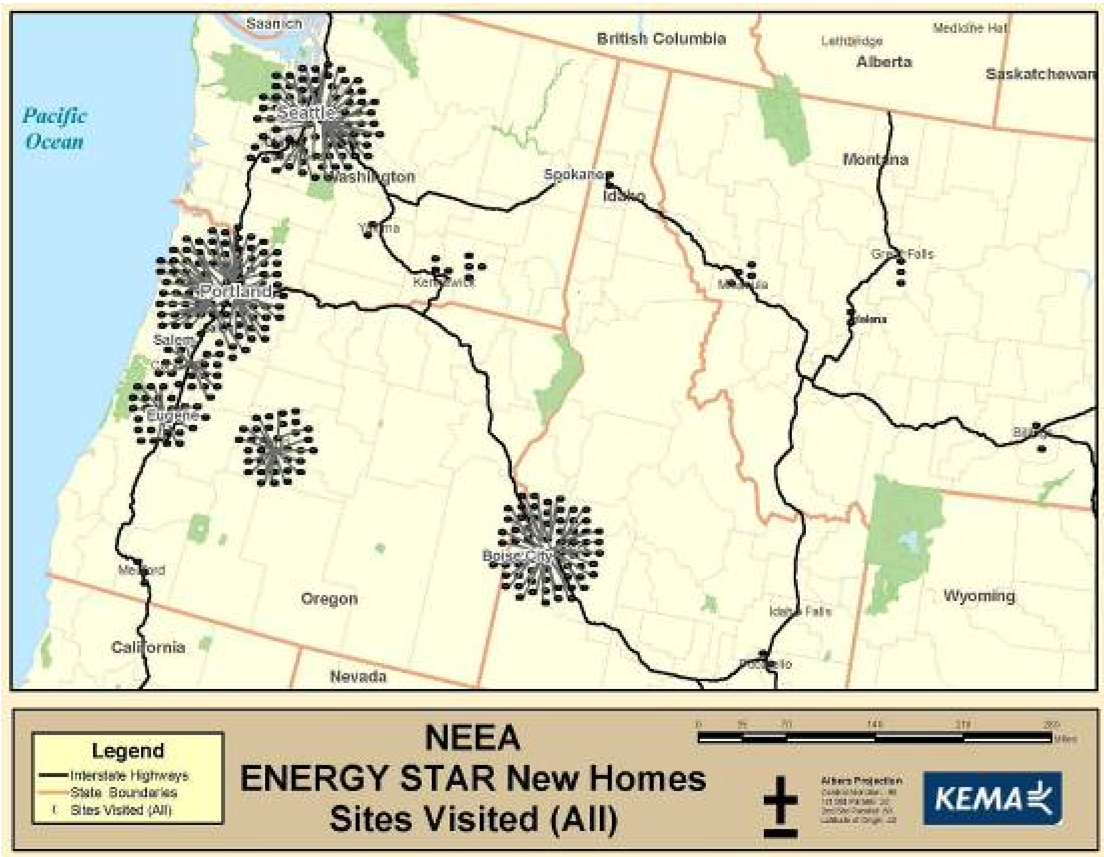
Completed Surveys	HVAC Type				
	Gas no AC	Gas with AC	Heat Pump	Zonal Electric	Total
Puget Sound	70	5	1	2	78
SW WA / NW OR / SW OR	110	16	14	0	140
Central WA	0	3	6	0	9
E. WA / N. ID / C. OR	22	7	8	0	37
S. ID / E. OR	1	68	1	0	70
Montana	8	3	0	0	11
Total	**211**	**102**	**30**	**2**	**345**

Table 3-4. Percent of Completed Sites Compared with Sample Design

Survey Completes Compared to Sample Design Goal	HVAC Type				
	Gas no AC	Gas with AC	Heat Pump	Zonal Electric	Total
Puget Sound	84%	250%	--	--	92 %
SW WA / NW OR / SW OR	122 %	80 %	100 %	--	113 %
Central WA	--	33 %	54 %	--	45 %
E. WA / N. ID / C. OR	183 %	88 %	27 %	--	74 %
S. ID / E. OR	100 %	158 %	600 %	0 %	137 %
Montana	73 %	38 %	--	0 %	55 %
Total	**107 %**	**113 %**	**49 %**	**100 %**	**99 %**

Figure 3-1 maps the location of homes that were inspected for this study.

Figure 3-1. ENERGY STAR Participant Homes Visited and Surveyed



3.3.4 Data Collection

Table 3-5 displays the types of information and data collected in the four components of the data collection protocol: the mail survey, an initial interview conducted on-site with the home owner, the on-site inspection of construction practices and materials, and on-site performance measurements.

Table 3-5. Data Collection Overview

Collection Means	Categories	Information
Mail Surveys	ENERGY STAR Knowledge (Mailed)	Date of Move-in ENERGY STAR Awareness and Value
On-site Interview	Single Family Demographics	Number/Ages of Occupants Household Income Owner/Renter
	General Building Information	Type Year of Construction Conditioned/Unconditioned Floor Areas
Onsite Inspection Construction Practices, Materials, and Equipment Installed	Building Envelope	Windows Walls Roof/Attic Basement
	HVAC Systems	System & Fuel Types Thermostat(s) and Usage
	Domestic Hot Water	System & Fuel Types
	Lighting	Fixture Types Lamp Types/Wattages/Quantity Control Types
	Large Appliances	Refrigerators/Freezers Dishwashers Clothes Washers Clothes Dryers
	Other	Pool and Spa Small Appliances Contributing to Plug Load
On-Site Measured Performance Test Results	Duct System	Leakage Rate: using Minneapolis Duct Blaster equipment. n = 239 Airflow Rate: Using TrueFlow Air Handler Flow meter equipment. n = 226
	Building Envelope	Infiltration Rate: using Minneapolis Blower Door equipment

3.3.5 Analysis

KEMA staff analyzed the results using a weighting scheme derived from the population distribution shown in Table 3-1. We assessed the statistical significance of observed differences between the Participant and Baseline surveys using conventional tests for differences in means and proportions between two independent samples.

3.4 Baseline Survey Methods

This section briefly reviews the sampling and data collection methods that RLW Analytics used in conducting the Baseline Survey.

3.4.1 Sampling

Objectives. The objective of the sampling plan was to develop a representative sample of newly constructed single family and multifamily buildings in the states of Montana, Idaho, Washington and Oregon. Here we discuss only the development of the sample of single-family homes.

Sample Size. Through negotiations with NEEA and other stakeholders in the project, the sample size for single-family homes was set at 604. Of these 264 were sub-sampled to undergo duct leakage, duct air flow, and infiltration functional tests. The 304 remaining sample homes were inspected to develop detailed data on construction practices and equipment installed.

Sample Design. RLW used records of housing construction permits issued by county to guide the development of its sample design. These data are developed by F. W. Dodge and compiled and maintained by the U. S. Bureau of the Census. The initial sample allocation assigned sample points to the four states according to the ratio of permits issued in the state to total permits issued in the region for calendar year 2004.

Table 3-6. Baseline Sample Allocation: Single Family

State	Audit Only	Functional Tests	Total Sites	% of Total Sample Sites	% of Total 2004 Permits
ID	135	45	180	30%	20%
MT	14	4	18	3%	4%
OR	56	125	181	30%	28%
WA	135	90	225	37%	48%
Total Sites	**340**	**264**	**604**	**100%**	**100%**

As Table 3-6 shows, RLW was able to realize a state-level sample allocation that corresponded closely to the distribution of permits. RLW further stratified the sample into three groups of counties:

- Counties with at least 0.6% of the total units permitted in the region (Group 1)

- Counties with less than 0.6% of the permits, but at least 250 permits (Rural A)
- Counties with less than 250 permits (Rural B)

RLW planned to sample homes in each of the group 1 counties. All counties in rural groups A and B were aggregated and one county from each group was selected for sampling. The number of sample sites allocated to the rural groups was in proportion to the sum of the units in each of the counties in these groups.

3.4.2 Recruitment and Scheduling

Sample Frame. RLW used the F. W. Dodge compilation of permits as the sample frame. These records contain information on the type, expected date of completion, and address of the property. The records contain no contact information for the current owner.

Recruitment. RLW used the same sequence of steps to recruit customers into the survey as did KEMA: mail survey (customer letter) to solicit interest in participation in the survey, followed up by telephone contact to all customers who returned the initial letter. Roughly 7.5 percent of customers who received the mailing responded to the customer letter.

3.4.3 Data Collection

RLW implemented the survey using handheld personal digital assistants (PADs) and an application for collecting the specified information. A total of 604 on-site surveys were completed in single family homes between October 2005 and June 2006. Of the 604 single-family homes, RLW tested 264 for duct leakage, infiltration, and HVAC system airflow.

While on site, the surveyors collected data on the major appliances in the home: Refrigerator-Freezers, Dishwashers, Clothes Washers, Clothes Dryers, Water Heaters, Heating Equipment, Spa/Pool Equipment, and Cooling Equipment. Data on thermostats, large appliances, and consumer electronics were also gathered. The surveyors collected lamp, fixture and wattage data for each lighting fixture within the home, as well as the front porch fixture. The surveyors also collected data on attic, floor and wall area, insulation R-values, wall construction, and window type, as well as demographic data.

KEMA used the data collection protocols that RLW developed as the point of departure for the corresponding components of the Participant survey.[6] To the extent possible, we left data collection forms and methods unchanged in order to facilitate comparison of Baseline and Participant survey results.

[6] KEMA acquired RLW in 2008. Many of the RLW staff who worked on the Baseline Study also worked on the Participant survey.

4. Sample Demographic and Housing Characteristics

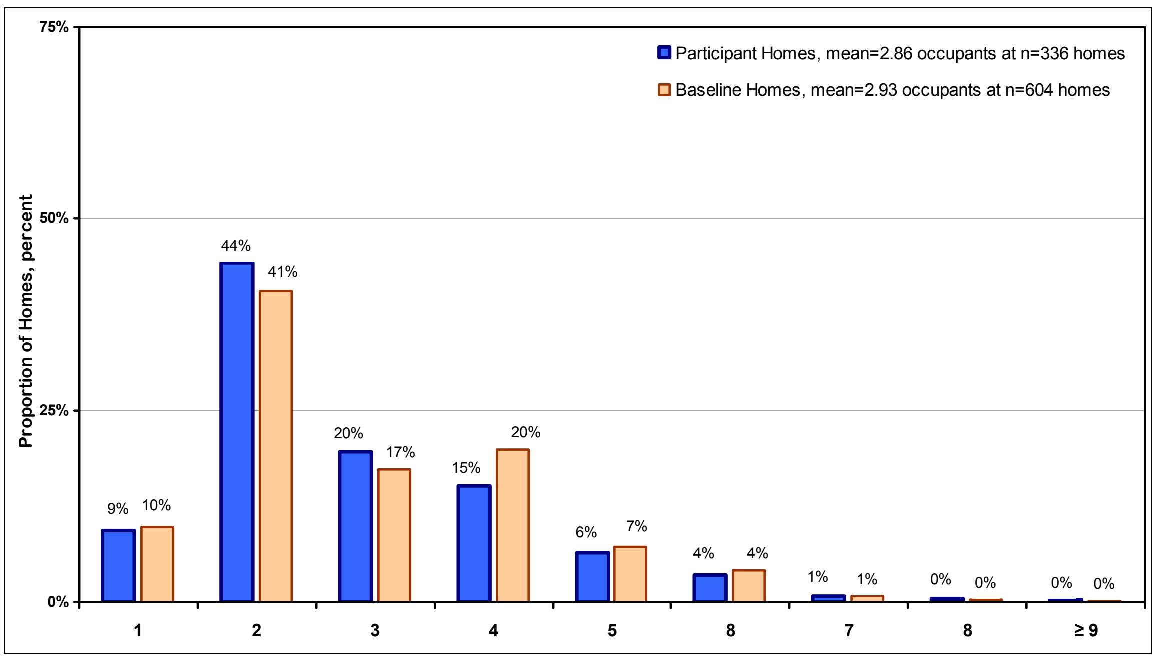
This section presents comparisons between the demographic and basic housing characteristics of the Baseline and Participant samples, with significant differences noted.

4.1 Household Characteristics

4.1.1 Number and age of occupants

Figure 4-1 shows the distribution of the Baseline and Participant samples by the total number of occupants currently living in the home. More than half of the homes in both samples had two or fewer occupants. The portion of the Participant sample accounted for by three-person households (20 percent) was slightly higher than that in the Baseline sample (17 percent). This difference was more or less balanced out in the four-person category. There were no significant differences between the two samples in terms of their distribution by size.[7]

Figure 4-1. Total Number of Occupants per Household

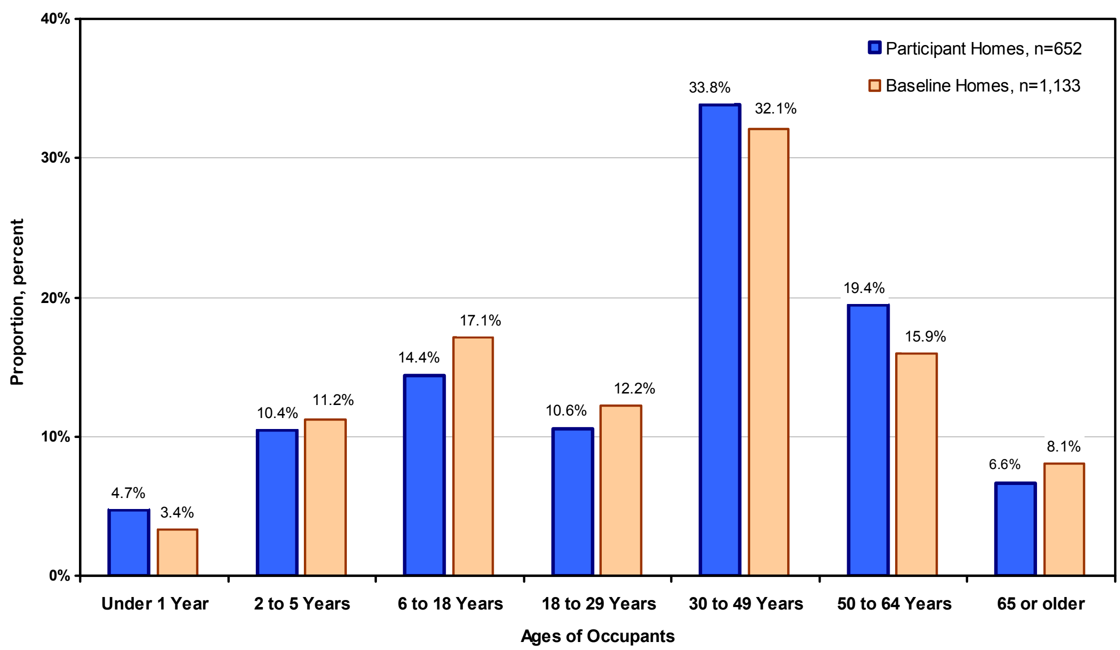


Site Question 3, Combined: A total of how many people live in this household?

[7] That is, the difference between proportions in the various categories was not statistically significant at the 90 percent confidence interval.

Figure 4-2 shows the age distribution of residents in study homes. Adults made up a slightly higher proportion of total residents in the Participant sample --70.5 percent – than in the Baseline sample (68.3 percent). Also, the portion of total occupants in the 56 – 64 year old range was higher in the Participant than in the Baseline sample. None of these differences were statistically significant.

Figure 4-2. Age Ranges of Occupants of ENERGY STAR & Baseline Homes



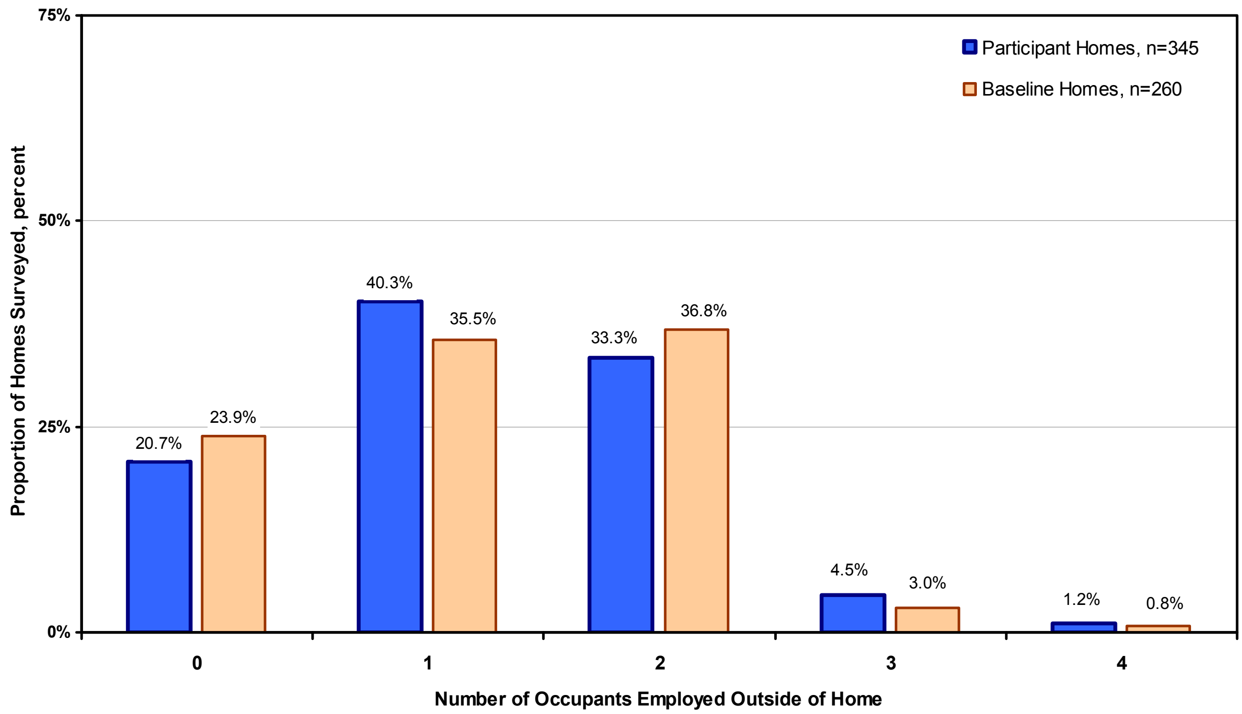
Site Question 3: How many people live in this household in the above age ranges?

4.1.2 Number of Occupants Employed Inside/Outside of the Home

Figure 4-3 displays the distribution of the Participant and Baseline samples by the number of household members currently working outside the home. The reported sample sizes reference the total number of household members and should not be confused with the number of surveys completed. We were interested in this information because it could provide a proxy for the portion of daytime hours a home is occupied.

As Figure 4-3 shows, the distribution of the Participant and Baseline samples were nearly identical in this regard. None of the respondents in the Participant sample reported that they operated a business out of their home.

Figure 4-3. Occupants Employed Outside of Home



Site Question 4: Number of people working outside the home?

4.1.3 Home Ownership

During the visit to the ENERGY STAR home, the resident was asked whether they owned or rented the home. A little over one month into the field effort, it was decided to no longer schedule home surveys with renters so that the sample distribution would remain similar to that of the Baseline Study, in which 97.5 percent of the single-family sample was owner-occupied.

For renters in the Participant survey, two additional questions were asked:

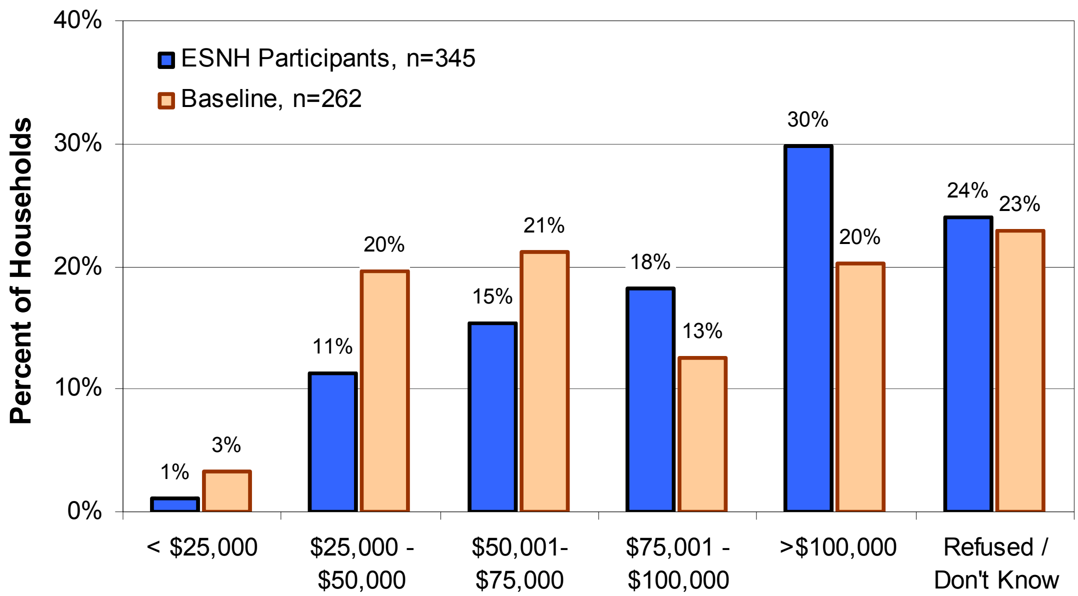
- Who pays the electric bills?
- Who pays the gas bills?

In only one of the nine homes that were occupied by renters, were these utilities paid for by the landlord. In this particular instance, the home was on a military base.

4.1.4 Household Income

Figure 4-4 displays the distribution of the Participant and Baseline samples by reported annual income. Roughly one-quarter of each of the samples either refused or were unable to answer this question. The households in the Participant sample reported generally higher incomes than those in the Baseline survey, with differences between the samples in the proportions in the $75,000 - $100,000 and >$100,000 ranges being statistically significant.

Figure 4-4. Household Incomes at ENERGY STAR and Baseline Homes

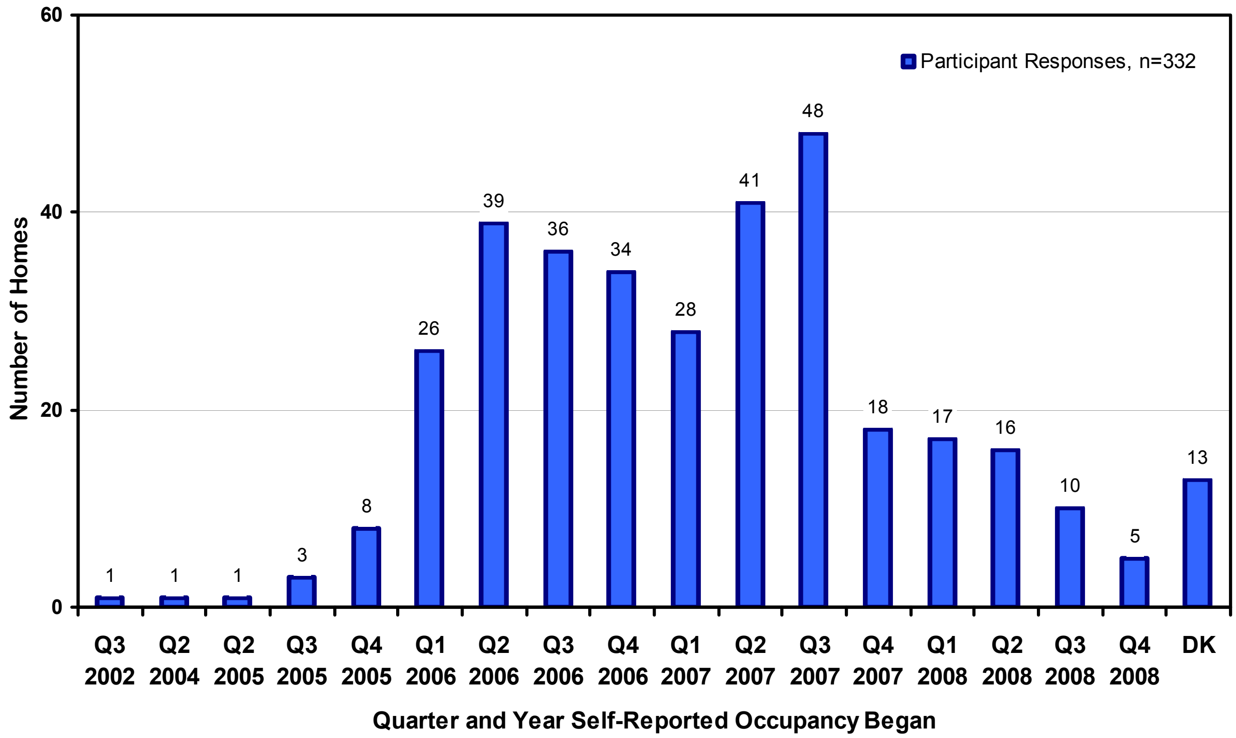


Site Question 7. What is the total annual income for the home per the [above] ranges?

4.1.5 Tenure in the Home

Figure 4-5 shows the distribution of homes in the on-site sample by the current occupant's reported move-in date. Among the 332 homeowners who responded to this question, 81 percent reported moving in during calendar years 2006 and 2007. Fourteen percent reported moving in during 2008.. Note: the Baseline study did not contain data on respondents' tenure in the home

Figure 4-5. Date of Move-In Among ENERGY STAR Participants

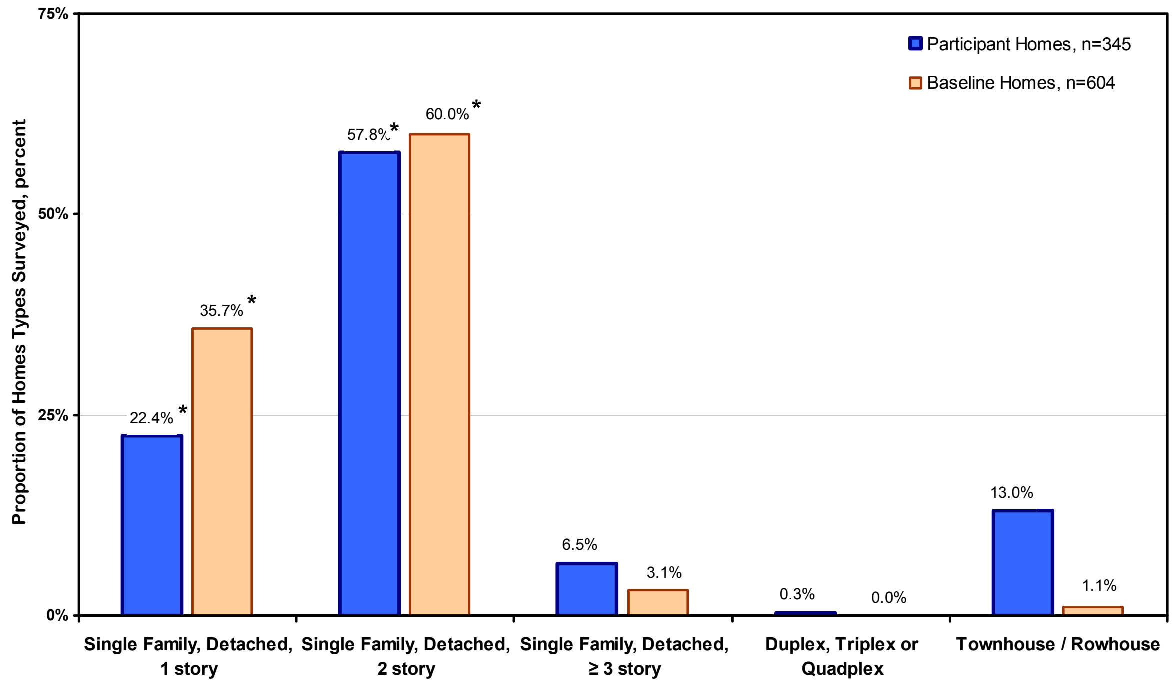


4.2 Housing Characteristics

4.2.1 House Type

Figure 4-6 displays the distribution of the Participant and Baseline sample by type of home. The participant sample contained a significantly higher portion of attached townhouses than the Baseline sample: 13.3 percent v. 1.1 percent. Also the “Single Family” sample developed for the baseline contained single-family structures only, not 2 – 4 unit buildings. This last category constituted only 0.3 percent of the Participant sample.

Figure 4-6. Distribution of Home Types Surveyed

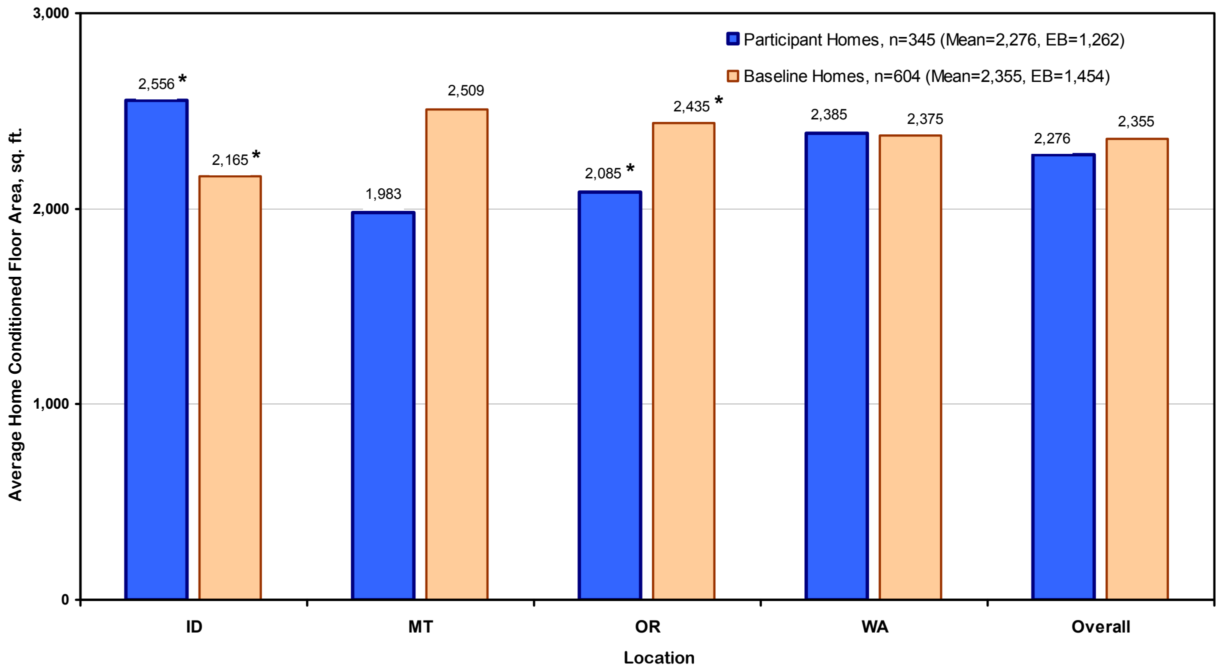


4.2.2 House Size

Figure 4-7 displays the average size of the homes in the Participant and Baseline samples by state and for the full samples. Inspection of Figure 4-7 yields the following observations.

- Home size varies widely in both samples. The 90 percent confidence interval for the Participant sample is 1,262 sf, or 56 percent of the mean. The 90 percent confidence interval for the Baseline sample is 62 percent of the mean.
- For the sample as a whole, the observed difference in average size is small and not statistically significant. The average home in the Baseline sample is 59 square feet larger than average home in the Participant sample.
- At the state level, differences in size are more pronounced. In Idaho, homes in the Participant sample are, on average, 391 square feet or 18 percent larger than their counterparts in the Baseline sample.

Figure 4-7. Average Sizes of Homes Surveyed



4.2.3 Saturation of HVAC Equipment Types and Fuels

Clearly, any significant differences between the Participant and Baseline samples in saturation of heating and cooling equipment and heating fuels will cloud comparisons between them. The two samples are similar to each other in regard to key aspects of HVAC equipment. Specifically:

- The proportion of homes with forced air furnaces as their primary heating system is nearly identical: 84.6 percent for the Participant sample and 85.2 percent for the Baseline sample. The Participant sample had a higher percentage of hydronic systems than the Baseline sample (8.5 percent v. 1.7 percent). However, the market share for hydronic systems is too small to obscure the comparison between the two groups.

- Among the homes with forced air furnaces, 97.6 percent of Participants and 93.1 of homes in the baseline sample used natural gas as their primary heating fuel.

- Among the customers with heat pumps, electricity was the primary fuel, accounting for 82.3 percent of systems in the Participant sample and 92.9 percent in the Baseline sample. Twelve percent of the Participants with heat pumps had geothermal models, versus none in the Baseline sample.

- The fraction of homes in the two samples with central air conditioning was nearly equal: 60.1 percent in the Participant sample versus 58.0 percent in the Baseline sample.

See Section 6 for more detailed analysis of HVAC systems installed.

4.3 Program-related Characteristics of the Participant Sample

In this section we present selected characteristics of the homes and customers in the Participant sample. In some cases, we developed these findings from the returned initial mail surveys; in others from interviews with occupants on-site, application database records, and on-site observations. We identify the information source used for each item discussed.

4.3.1 Home Characteristics

Builder Option Package Classification. As discussed in Section 2, the Northwest ENERGY STAR Homes program has developed two prescriptive specifications, known as Builder Option Packages or BOPs, for qualification of new homes for the ENERGY STAR label. BOP-1 applies to homes with gas-fired forced air furnaces and heat pumps of any type. BOP-2 is somewhat more stringent and applies to homes with zonal electric heat or central systems fired by propane and fuel oil. Among all homes certified by the program during the study period, 99.3 percent applied using BOP-1. The corresponding figure among homes in the Participant sample was 99.1 percent.

Throughout this report we use the relevant BOPs as benchmarks for characterizing home characteristics in both the Participant and the Baseline samples. The HVAC equipment in the Baseline homes is such that 92.2 percent would have been covered by the BOP-1 specifications.

Application of Technical Compliance Options. Examination of program records found that a relatively small fraction of homes exercised Technical Compliance Options (TCOs) to trade off various required components for more efficient approaches to other aspects of the project.

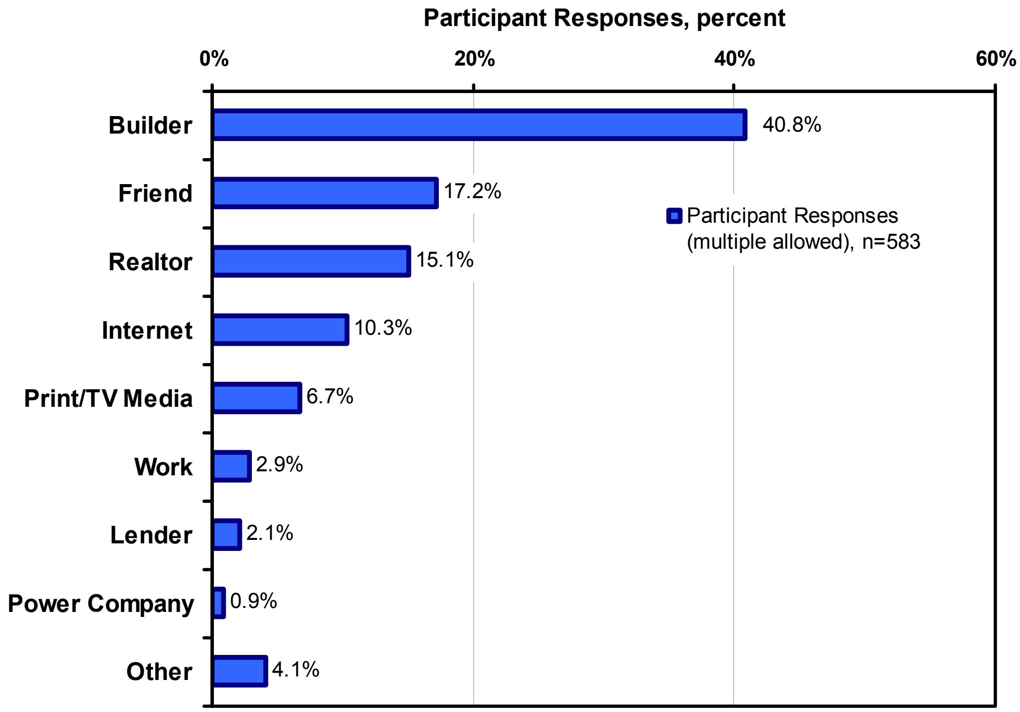
4.3.2 Customer Characteristics

Participant awareness of the ENERGY STAR label for homes. Among the 465 participants who returned mail surveys, 92.3 reported that they had heard of the ENERGY STAR label for homes.

Participant awareness of the ENERGY STAR status of their own homes. The 429 respondents who indicated that they were aware of the ENERGY STAR label for homes were also asked whether they knew their home was an ENERGY STAR home. About three-fourths of the respondents (76.9 percent) reported that they were aware that they lived in an ENERGY STAR home. Interestingly, 12 of the respondents affirmed that they did not live in an ENERGY STAR home. There are a number of reasons why respondents might not have known that the home was ENERGY STAR certified. For example they might not be the original owner, or it is possible that the builder or realtor did not emphasize the feature in their interactions with the owner.

Sources of information on ENERGY STAR Homes. The 429 respondents who indicated they were aware of ENERGY STAR homes were asked how they found out about the program. Respondents were allowed to provide multiple responses and list all the various sources that were applicable; a total of 583 responses were tallied. As shown in Figure 4-8, Participants identified builders most often as the source of information, followed by friends (word of mouth), realtors and the internet.

Figure 4-8. Means of Learning about ENERGY STAR for New Homes (n=583)

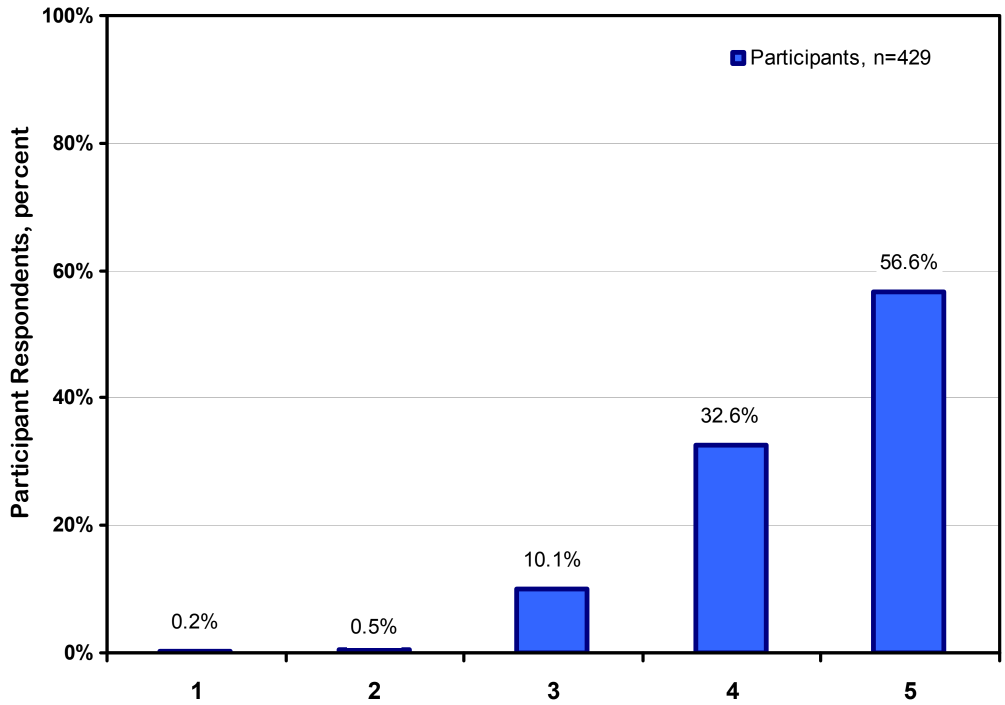


Mailed Question c. If yes [to Mailed Question b], how did you find out about ENERGY STAR homes? Circle all choices that apply

.

Perceived Value of ENERGY STAR for New Homes Rating. The mail survey contained an item that asked respondents to rate the value of an ENERGY STAR home on a 1-to-5 scale. Figure 4-9 shows the results of this question for the 429 respondents who had heard of the ENERGY STAR label for homes. Over 55 percent of the respondents gave the highest rating possible and only a few respondents (three) provided low valuations. Respondents who were aware that they live in an ENERGY STAR Home tended to rate the value of the homes somewhat higher than respondents who were unaware.

Figure 4-9. Perceived Value of ENERGY STAR Certification for Homes



Mailed Question e: How would you rate the value of having an ENERGY STAR-certified home using a scale of 1 to 5, where 1 is not at all valuable and 5 is extremely valuable?

Household and Housing Characteristics

5. Building Envelope

This section presents findings from Participant and Baseline studies that characterize the energy efficiency of building envelope elements including wall construction, attic and floor insulation, and windows. We also compare the air infiltration rates of homes in the two samples.

5.1 Infiltration Rates

In order to gain ENERGY STAR certification, candidate homes must meet standards for air infiltration as measured using a blower door test. This test uses a fan assembly connected to an exterior door to draw air out of the house and achieve a controlled pressure differential of 50 Pa between the indoor and outdoor air pressure. By measuring the air flow rate (cubic feet per minute) required to maintain the 50 Pascal pressure differential and dividing that result by the volume of the home (cubic feet), the air tightness of the house can be quantified in terms of Air Changes per Hour or ACH.

The BOP-1 standard applied to homes heated by gas furnaces or heat pumps is 7.0 ACH at 50 Pa. The BOP-2 standard for homes with zonal electric heat and oil or propane-fired systems is 2.5 ACH50.

Table 5-1 summarizes the results of the blower door tests for both samples, with segmentation by homes to which the BOP-1 and BOP-2 standards apply. Among the homes covered by BOP-1, the average infiltration rate was 4.95 ACH50 for the Participant sample and 5.87 for the Baseline sample. While this difference is relatively large (16 percent of the Baseline rate), it is important to bear in mind that infiltration rates at homes tend to increase as homes age. The homes in the Baseline sample are two years older, on average, than those in the Participant sample

Table 5-1. Envelope Infiltration Rates at Participant and Baseline Homes

Whole House Infiltration Rates	Builder Option 1 Homes (BOP-1)		Builder Option 2 Homes (BOP-2)	
	ACH50	EB (n)	ACH50	EB (n)
Program Requirement, Max.	≤ 7.00	-	≤ 2.50	-
Participant Homes, Average	4.95 *	2.94 (334)	3.99	2.75 (5)
Baseline Homes, Average	5.87 *	2.96 (235)	4.91	2.97 (8)

* = Statistically significant difference in means at $p<0.10$

Figure 5-1 displays the distribution of BOP-1 homes by measured infiltration rate. Twelve percent of Participant homes and 29 percent of the Baseline sample did not meet the BOP-1 standard of 7.0 Air Changes per Hour (ACH) at 50 Pa. There were only 5 Participant homes and 14 Baseline homes covered by the BOP-2 standards. None of the Participant homes and only one of the Baseline homes met the more stringent BOP-2 infiltration standard.

Figure 5-1. Envelope Infiltration Rates for Participant and Baseline Homes, BOP-1

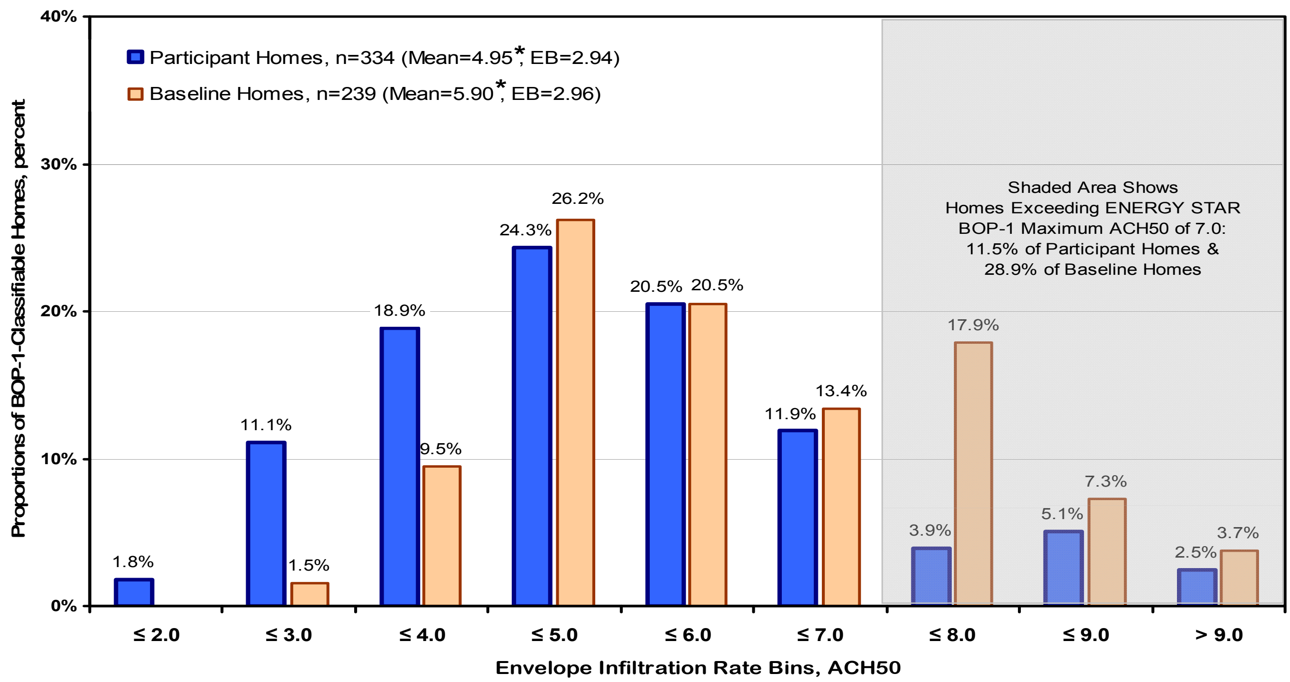


Table 5-2 shows the average air infiltration rates by state. Infiltration rates for the participant homes cluster in a narrow range around the average of 4.95, perhaps reflecting a standardization in treatment for infiltration that is related to program requirements and procedures. Average air infiltration among the baseline homes is higher in all states, with the largest differences between baseline and participants appearing in Montana and Oregon.

Table 5-2. Average Air Infiltration in Air Changes Per Hour by State

State	Participant n=340	Baseline n=253	Significant Difference
Idaho	4.4	5.2	*
n =	*71*	*44*	
Montana	5.3	7.1	
n =	*11*	*4*	
Oregon	5.4	6.4	*
n =	*158*	*117*	
Washington	4.6	5.4	*
n =	*100*	*88*	

5.2 Windows

KEMA field engineers collected information on 7,493 windows covering 101,029 sq. ft. in the 345 Participant sample homes. We collected details of construction, materials, and U-values for all of the observed windows. The paragraphs below compare the findings from the Participant and Baseline surveys in regard to windows.

5.2.1 Window-to-floor area ratio

Heat loss through windows, no matter how well made, is greater than the heat loss through solid walls. The higher the area of windows in a home (relative to indices of size such as floor area), the higher the heat loss, other things being equal. In recent years, the window-to-floor area ratio in new homes has increased substantially in most markets. This trend is recognized in the BOP specifications, both of which allow for a maximum ratio of 21 percent. As Figure 5-2 shows, the window-to-floor area ratio in both samples was well below the maximum. The average ratio for the Participant homes was 9.4 percent v. 15.3 percent for the Baseline homes. These ratios were very consistent across the four states in the region, with the exception of Montana. There, the window-to-floor area ratio was only 6.6 for Participant homes and 11.9 percent for the Baseline homes. This finding may reflect generally colder conditions in Montana. The observed differences on this indicator between the Participant and Baseline samples were not statistically significant.

Figure 5-2. Window Area Divided by Conditioned Floor Area

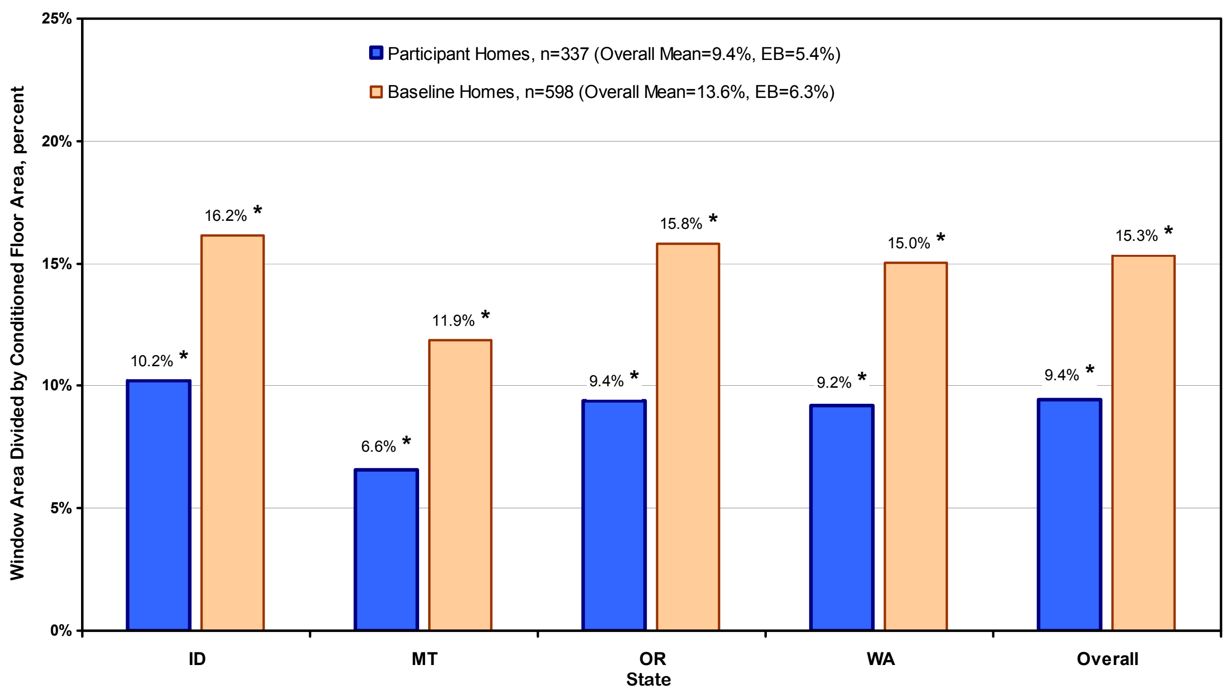
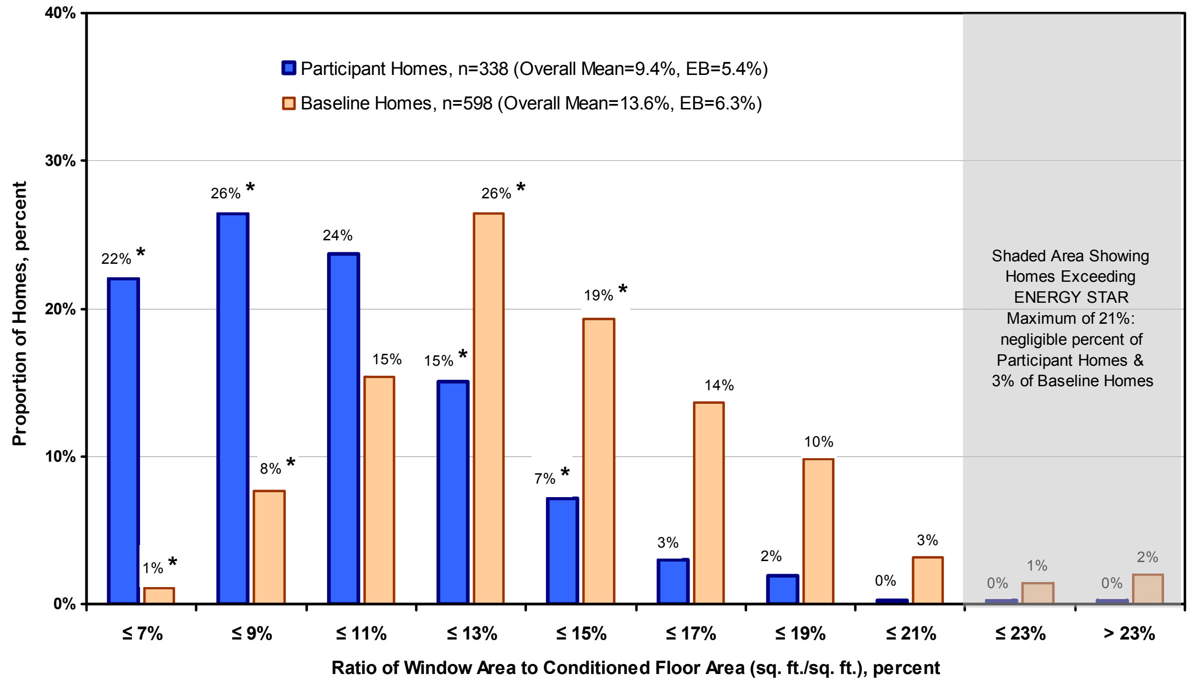


Figure 5-3 shows the distribution of the Participant and Baseline homes by window-to-floor area ratio. All of the Participant homes and 97 percent of the Baseline homes met the BOP standards on this indicator.

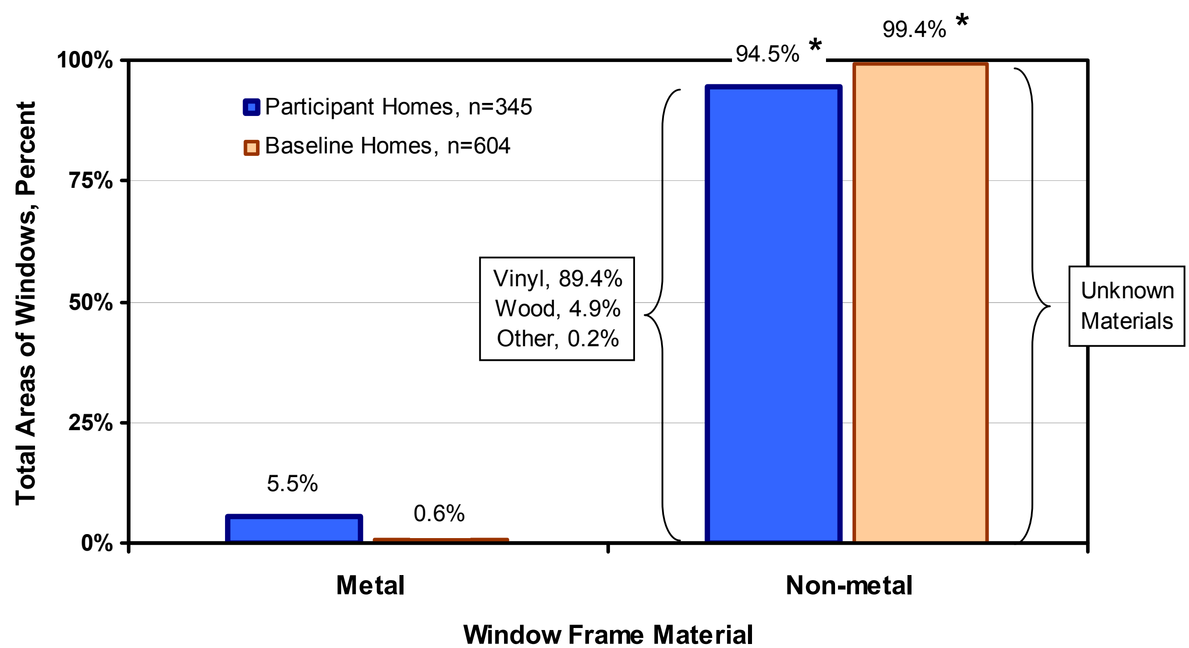
Figure 5-3. Distributions of Ratio of Window Area Relative to Conditioned Floor Area



5.2.2 **Frame Type**

The window frame material was gathered for more than 100,000 sq. ft. of windows in ENERGY STAR certified homes in the region. Across the four states, metal window frames were used more extensively than observed during the Baseline study. Throughout the region, the ENERGY STAR home window frames were predominantly comprised of vinyl frames as shown in Figure 5-4. It was not possible to further distinguish the composition of the non-metal windows for the Baseline homes as that level of detail was not gathered.

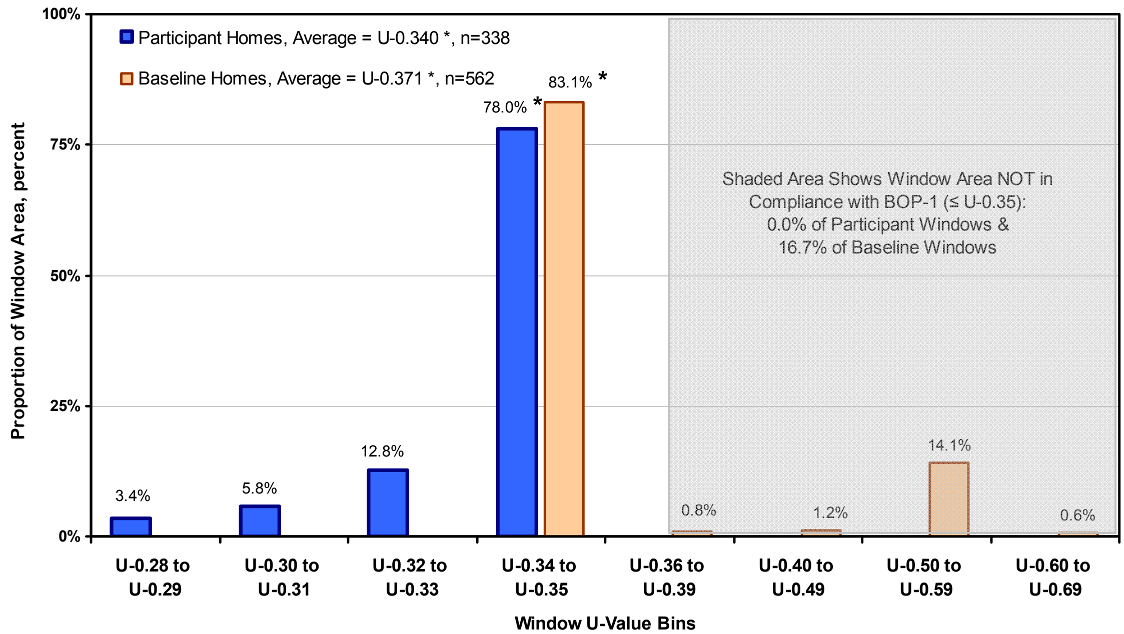
Figure 5-4. Window Frame Material



5.2.3 Insulation Properties of Windows

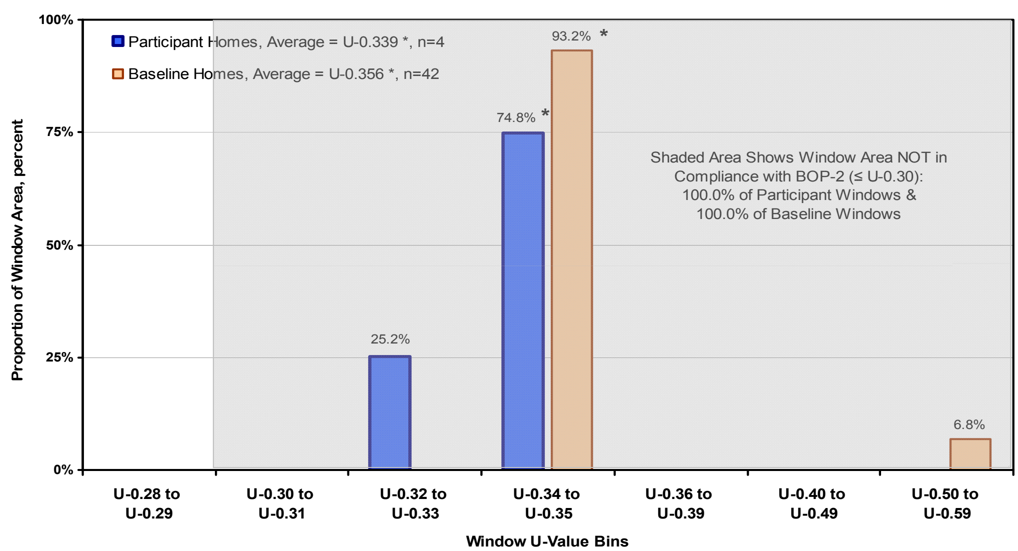
At each window, the field surveyor attempted to ascertain the U-value of the window assembly. In nearly all cases, however, the manufacturer's label was no longer present and it was only possible to report on the value indicated in the ENERGY STAR program's tracking database. Glazing heat conductance value is one of the few building component characteristics for which the BOP-1 or BOP-2 standards were different: U-35 for BOP-1 and U-30 for BOP-2. Figure 5-5 shows the distribution of total window area in BOP-1 homes by U-value bins. All windows installed in Participant BOP-1 homes met or exceeded program standards. Windows accounting for 22.0 percent of the glazed area exceeded program standards. Among Baseline homes, 83.1 percent of those to which BOP-1 applied met minimum program standards for window U-values. None exceeded the program standard.

Figure 5-5. Window U-Values at BOP-1 Homes



As Figure 5-6 shows, none of the BOP-2 homes in either sample met program requirements for window U-value. It is possible that Technical Compliance Options were invoked on one or more of the Participant homes to use a composite U-value for the home exterior.

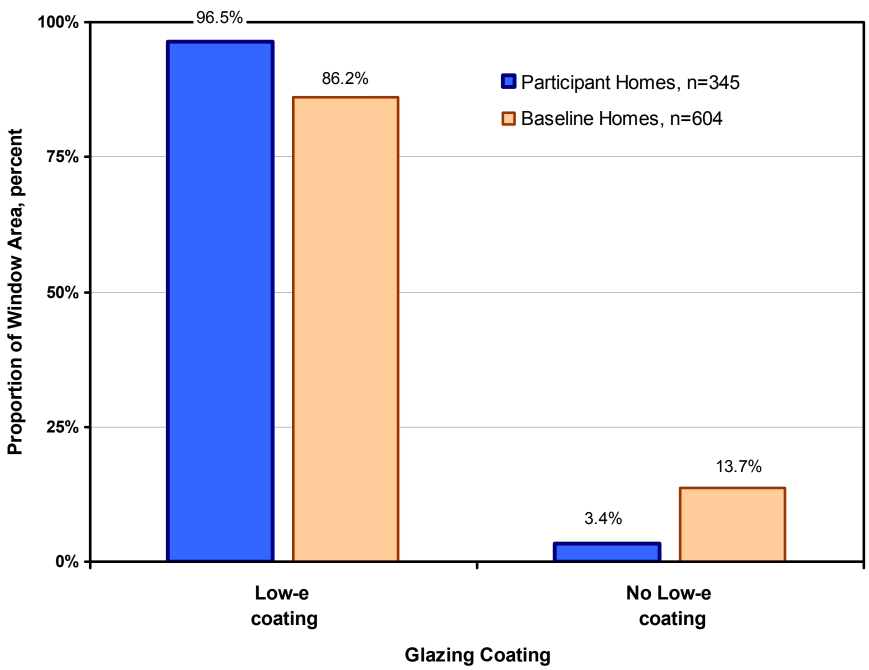
Figure 5-6. Window U-Values at BOP-2 Homes



5.2.4 Glazing Coating

KEMA field engineers used a low-e detector to determine the presence of low-emissivity coatings on window glazing. As Figure 5-7 shows, 96.6 percent of total window area in the Participant survey had low-e coating, versus 86.3 percent.

Figure 5-7. Prevalence of Low-e Coating at Window



5.2.5 Exterior Shading Elements

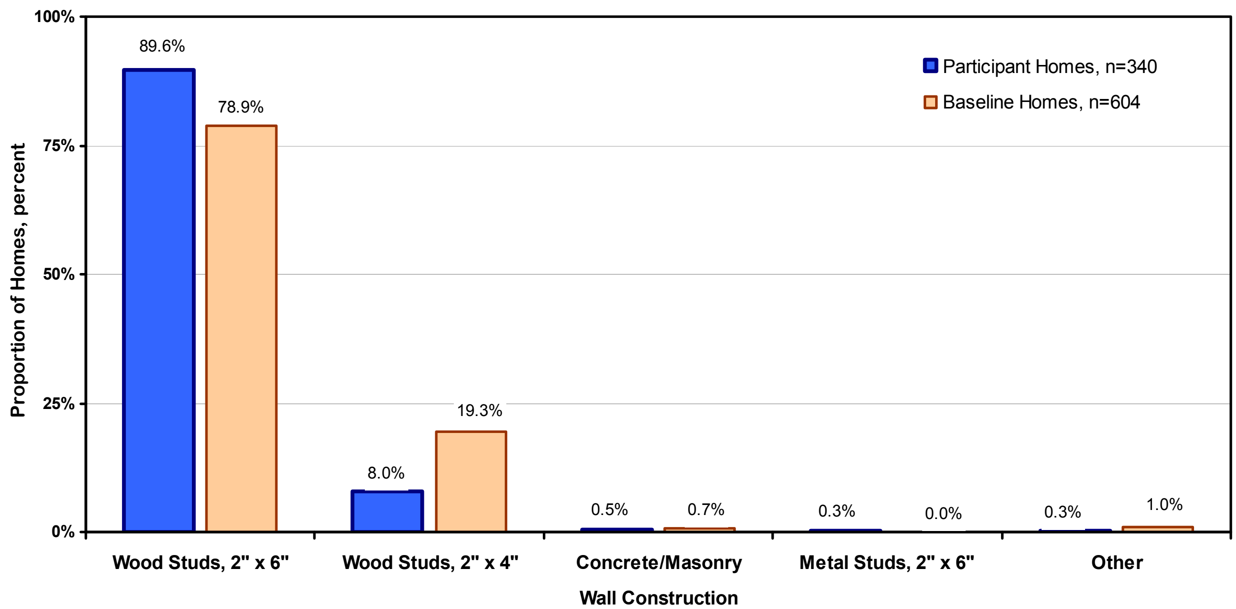
More than half of the windows at the ENERGY STAR homes surveyed had a building element that provided exterior shading to varying degrees. Since this information was not gathered during the Baseline study, it was not possible to make comparisons between the two samples.

5.3 Wall Insulation

Both the BOP-1 and BOP-2 standards call for minimum wall insulation levels of R-21. Generally, inspectors were not able to observe interior cavities directly. However, the depth of wall studs which is approximated by door and window frame dimensions, can serve as a proxy measure for the amount of insulation present. Since nearly all of the ESNH homes surveyed were BOP-1 homes, they were nearly all required to have either R-21 insulation between 2” x 6” studs, on 16-inch centers (called “Standard Framing”), or R-19 insulation in 2” x 6” studs, on 24-inch centers (called “Advanced Framing”).

Figure 5-8 shows the distribution of Participant and Baseline homes by exterior wall construction type. Almost 90 percent of the Participant homes have wood frame walls with 6” studs, versus 78.9 percent of the Baseline sample.

Figure 5-8. Distribution of Sample Homes by Exterior Wall Construction Types



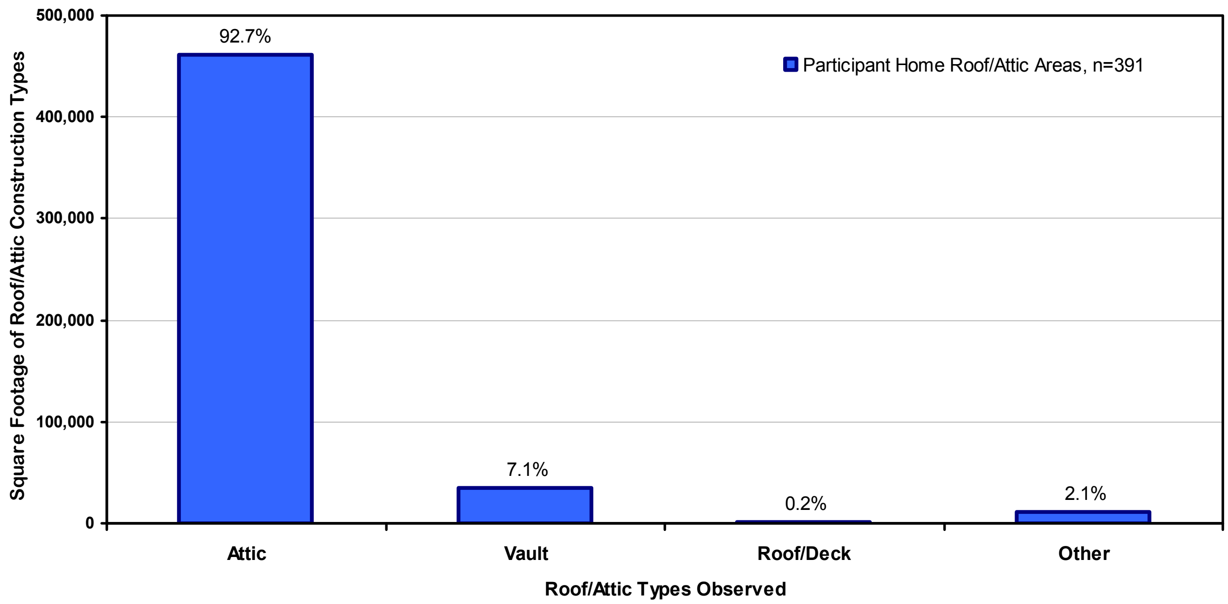
Technical Compliance Option #6, which allows for the use of a composite insulation calculator, was invoked at seven of the BOP-1 homes surveyed. This may explain the appearance in the sample of a few homes that do not comply with the required 6” stud depth.

5.4 Roofs/Attics

5.4.1 Roof/Attic Assemblies

Wherever possible, KEMA field engineers accessed attics and inspected roof assemblies. Figure 5-9 displays the distribution of total ceiling area in the Participant sample by type of roof assembly. We take this approach to displaying the results for this item because a given home could have multiple roof/attic types. The Baseline survey did not collect information on roof/attic assemblies.

Figure 5-9. Distribution of Ceiling Area by Roof/Attic Assembly Type



5.4.2 Attic Insulation

KEMA field engineers observed the type and depth of the attic insulation. Attics in 90 percent of the Participant homes had loose fill insulation installed, and 6.2 percent had fiberglass batts. The Baseline study did not collect information on attic insulation type. Where the type of insulation could be ascertained, its R-value was either recorded from labels or estimated by its type and measured thickness. BOP-1 and BOP-2 require attic insulation levels of R-38 or higher.

Table 5-3 shows the average attic insulation R-values for the Participant and Baseline samples by state and overall. In the Participant sample, mean attic insulation levels exceeded program requirements in all states. The average attic insulation level was 40.7 for the full Participant sample and R-38.1 for the Baseline sample. The differences between the two samples in average attic insulation levels are statistically significant in all states despite being relatively small.

Table 5-3. Average Insulation Values at Attics

State	Participant Homes			Baseline Homes			Significant Difference
	Mean	90% CI	n	Mean	90% CI	n	
Idaho	42.5	0.9	70	37.8	0.4	173	*
Montana	44.7	4.5	9	39.4	1.6	17	*
Oregon	40.6	0.9	132	38.1	0.4	178	*
Washington	39.7	0.9	87	38.2	0.3	211	*
Overall	40.7	0.5	298	38.1	0.2	579	*

5.5 Basement Configuration and Insulation

Only 12.8% of the Baseline homes and 6.8% of the Participant homes had basements, and as shown in Figure 5-10, most of these were concentrated in Montana. On average, basements in the Participant homes were slightly smaller than those in the Baseline sample. This finding is consistent with the relationship between the two samples in terms of overall house size.

Figure 5-10. Proportions of Homes with Basements

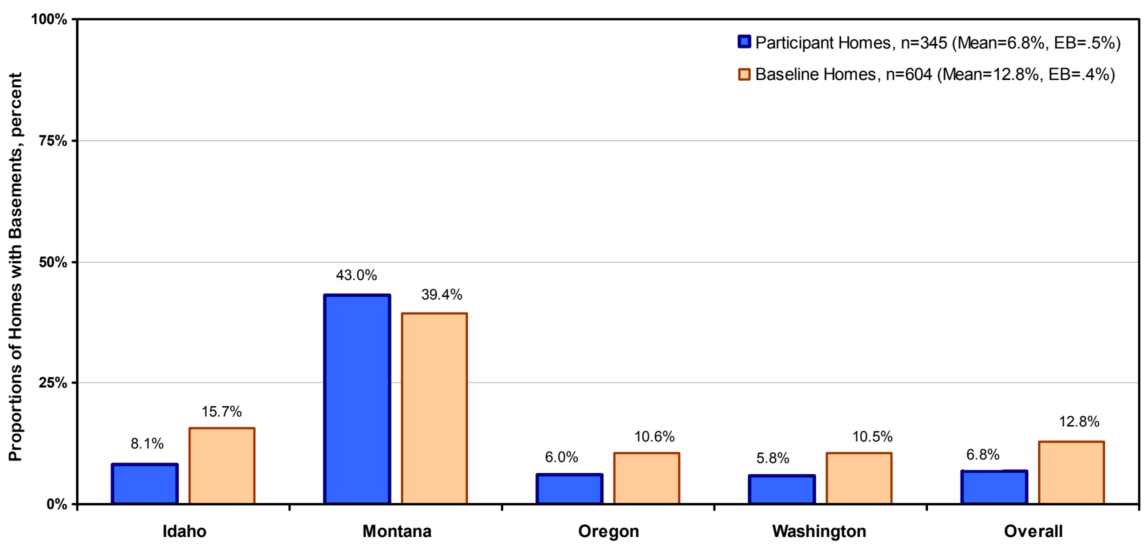
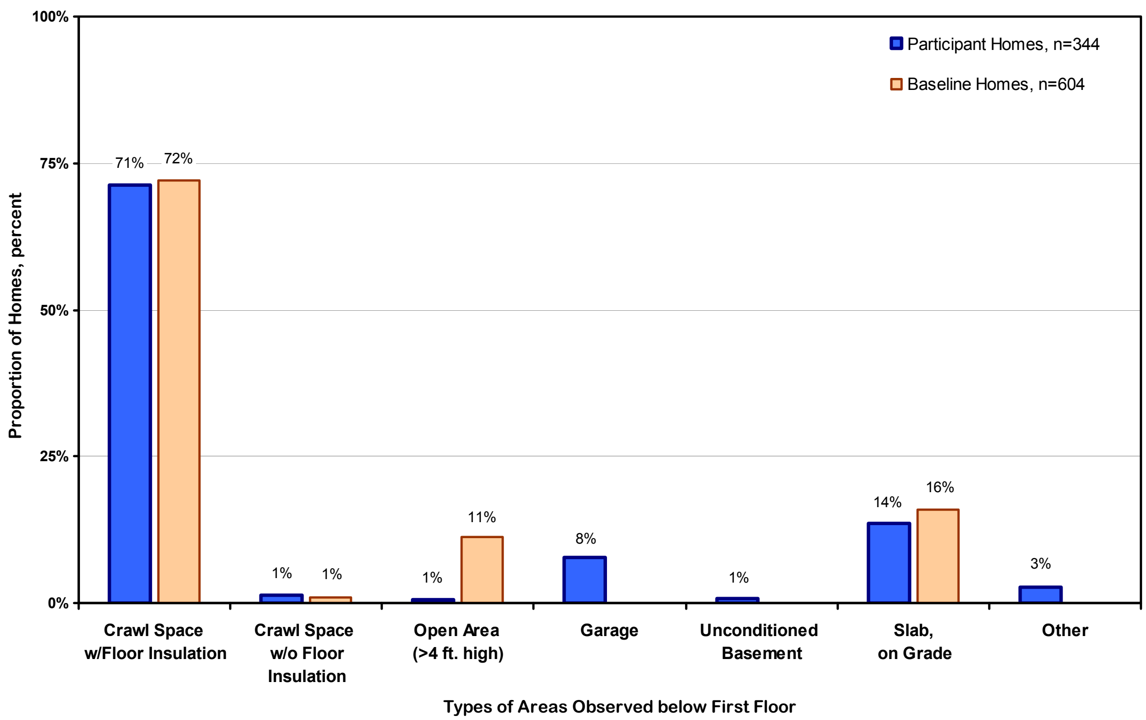


Figure 5-11 shows the distribution of the Participant and Baseline samples by the type of space that the KEMA field engineers observed below the first (lowest) habitable floor. More than 70 percent of the homes in both samples had crawlspaces with insulation below the lowest habitable floor. Fourteen percent of the Participant homes and 16 percent of the Baseline homes used slab on grade construction.

Figure 5-11. Types of Spaces Located Below First Habitable Floor of Home



The field engineers gathered the R-values of any floor insulation, if installed, at the homes in both samples. Table 5-3 shows the average insulation value found in the various spaces shown in Figure 5-11. Among the Participant homes, the average R-values in the floors was R-26.7 compared with R-22.7 at Baseline Homes. The program requirement for insulation in floors over unconditioned space is R-30.

Table 5-4. Average Insulation Values of Floors at First Habitable Level of Home

First Story Floor Type	Participant Homes			Baseline Homes			Significant Difference
	Mean	90% CI	N	Mean	90% CI	n	
Crawlspace w/ Floor Insulation	27.0	0.7	188	25.2	.04	415	*
Crawlspace w/out Floor Insulation	0.0	n/a	1			4	
Open Area (>4 feet high)	27.5	4.1	2	24.6	1.4	37	
Garage	32.2	3.9	10				
Unconditioned Basement	35.6	12.3	2				
Slab on Grade	21.0	4.3	13	21*		37	*
Other	17.4	10.6	5				
Overall	26.7	0.8	223	22.7	0.7	493	*

* Assumed based on 2009 survey results.

6. HVAC and Domestic Hot Water Equipment

This section presents the findings of the Participant and Baseline surveys in regard to heating, cooling, and ventilation equipment observed in the respective samples. In addition to information on the type, fuel, and efficiency ratings of the installed equipment, this section presents the result of functional testing of various aspects of equipment performance. Specifically, the field engineers conducted tests to determine the amount of airflow provided by ducted systems and the amount of duct leakage to outside the conditioned area. The test procedures used followed the guidelines for performance testing developed by the Regional Technical Forum (RTF); these are similar to the Performance Tested Comfort Systems (PTCS)[8] guidelines.

6.1 Heating Systems

6.1.1 Primary Heating System Types and Fuels

ENERGY STAR home specifications allow for all types of heating systems except electric resistance forced air furnaces and open loop, water-source heat pumps. All of the Participant homes had compliant primary heating systems, and 9 percent had supplemental heating systems. Figure 6-1 shows the distribution of Participant and Baseline homes by primary heating system type. Roughly 85 percent of both samples have forced hot air furnaces. None of the observed differences between the two distributions are statistically significant.

[8] The ENERGY STAR for New Homes Northwest Program utilizes the same performance test procedures.

Figure 6-1. Distribution of Participant and Baseline Homes by Primary Heating Equipment Type

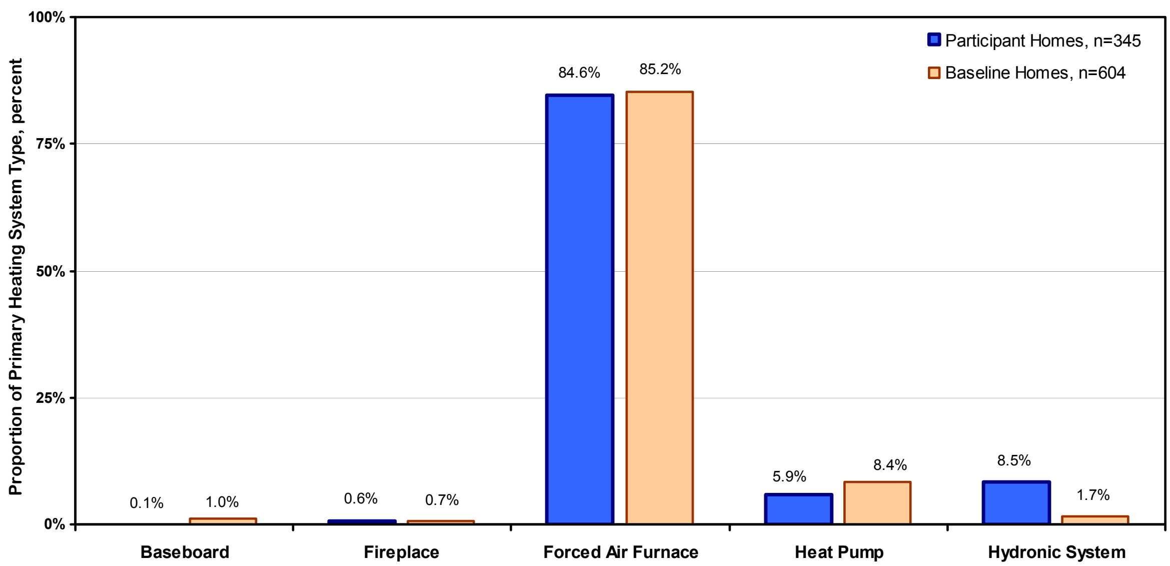


Table 6-1 displays the distribution of Participant and Baseline homes by primary heating fuel for each major type of primary heating system. Observed differences between the Participant and Baseline samples in these distributions were small but statistically significant. The Participant sample contained a few homes with that used renewable sources – solar and geothermal – to power primary heating equipment. The Baseline sample contained a higher portion of homes with electric and propane primary heat, perhaps reflecting the greater number of sample homes in rural areas.

Table 6-1: Distribution of Participant and Baseline Homes by Primary Heating Fuel

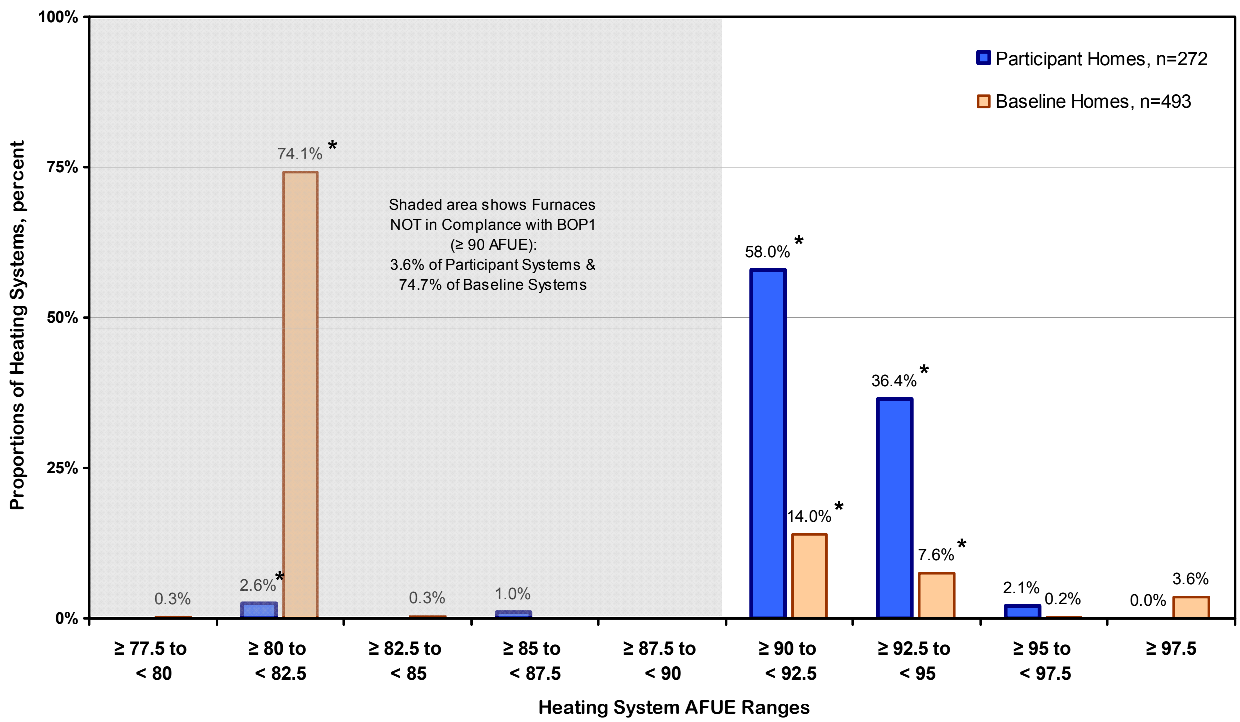
	Primary Heating System Type							
	Forced Air furnace		Hydronic System		Heat Pump		All Homes	
Fuel	Parti-cipant	Baseline	Parti-cipant	Baseline	Parti-cipant	Baseline	Parti-cipant	Baseline
Electricity	1.5%	2.2%	16.2%	0.0%	82.1%*	92.9 %*	7.0%	13.0%
Natural Gas	97.5%*	93.1%*	71.1%*	84.0%*	5.5%	7.1 %	90.0%	82.0%
Propane	1.0%	4.7%	4.7%	16.0%			1%	5.0%
Solar			8.0%	0.0%			1%	
Geothermal					12.4%	0.0%	1%	
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
n =	294	526	23	8	22	43	345	604

* - Observed difference is statistically significant at the 90% confidence level.

6.1.2 Efficiency Ratings of Installed Heating Equipment

The field engineers recorded the Annual Fuel Utilization Efficiency (AFUE) ratings for as many of the systems as possible in both the Participant and Baseline samples. The gray area in Figure 6-2 shows the range of AFUE ratings that ***do not*** meet BOP-1 requirements.[9] A small portion of the Participant homes with forced hot air furnaces - 3.6 percent did not comply with the BOP-1 requirement of a minimum 90 AFUE. Nearly three-quarters (74.7 percent) of the forced air furnaces in the Baseline sample did not meet the BOP-1 standard. Moreover, virtually all of them were towards the bottom of the efficiency range. The Federal minimum standard at the time of construction was AFUE 78. Seventy-four percent of the forced air furnaces in the Baseline sample clustered in the range from 80 to 82.5 AFUE.[10]

Figure 6-2. Furnace AFUE Ranges at BOP-1-Classifiable Homes



[9] NOTE: We follow this graphical convention in may subsequent charts.

[10] The survey was designed to capture HSPF ratings for heat pumps. Only 32 heat pumps were observed, and of those we could determine the HSPF for only 2 units.

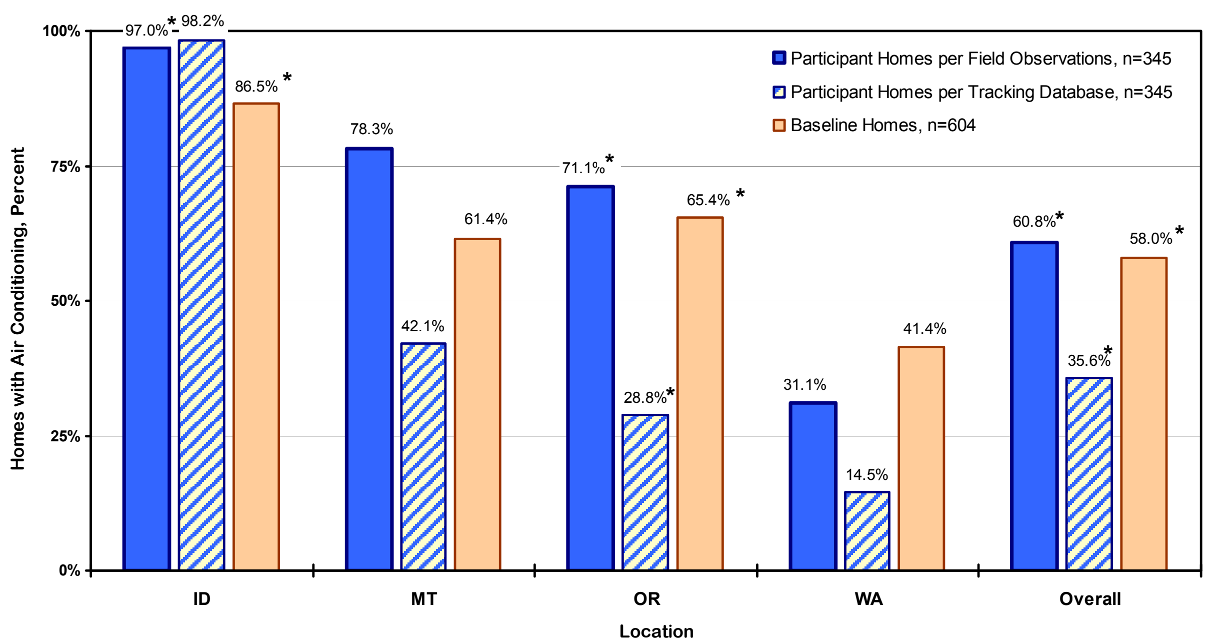
6.2 Cooling Systems

6.2.1 Cooling System Saturation

According to the program tracking database, 35.6 percent of the sample ENERGY STAR Participant homes had air conditioning/cooling systems installed at the time of certification. The on-site inspections found that 60.8 percent of these homes had some type of central air conditioning installed. This finding suggests that over 25 percent of the sample had had central air conditioning systems installed since the time of ENERGY STAR certification.

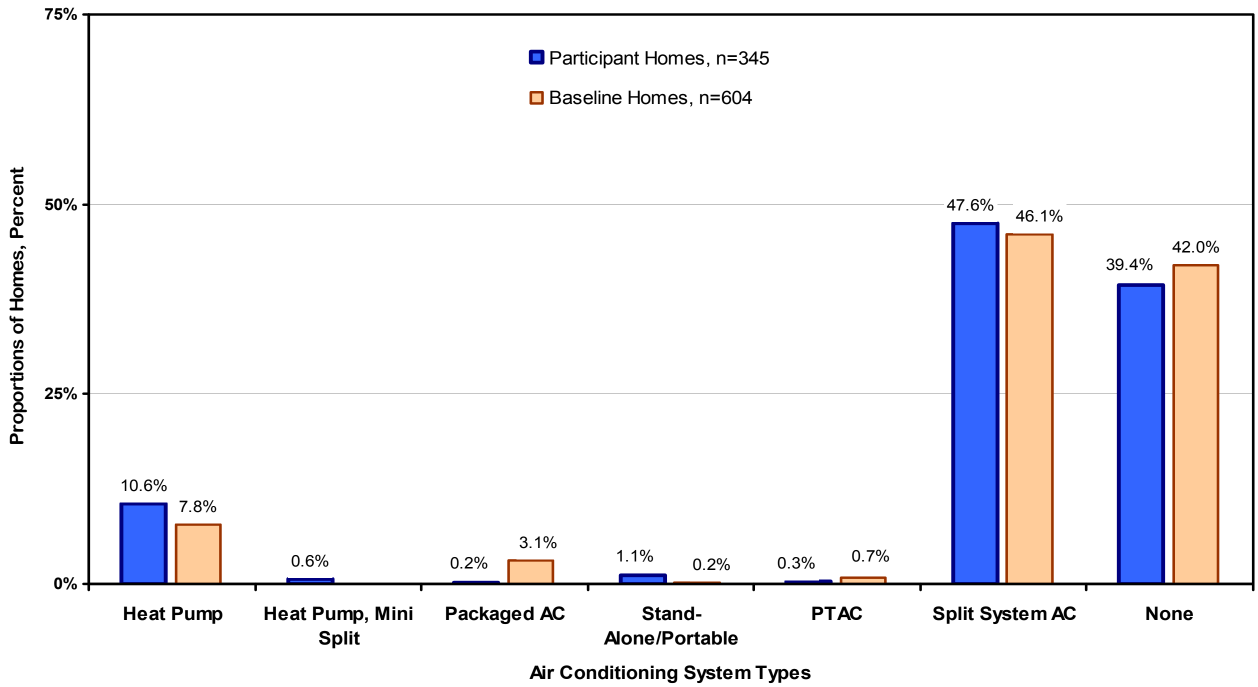
Figure 6-3 shows the percentages of homes with cooling for Participant homes, both at the time of ENERGY STAR certification and at the time of home surveys for this study, and for Baseline homes. Saturations of central cooling equipment were highest in Idaho; lowest in Washington. While the saturation of central cooling differed between Participant and Baseline samples in the individual states, they were very close at the regional level: 60.8 percent for Participant homes, 58.0 percent for Baseline homes.

Figure 6-3. Proportions of Homes with Air Conditioning/Cooling Systems



The Participant and Baseline samples were nearly identical in terms of the distribution of central cooling systems among principal types. In both samples, 79 percent of the central air conditioning systems installed were split systems. The portion of heat pumps was slightly higher in the Participant sample. Figure 6-4 shows the distribution of the two samples by type of central cooling equipment installed.

Figure 6-4. Air Conditioning System Type Proportions

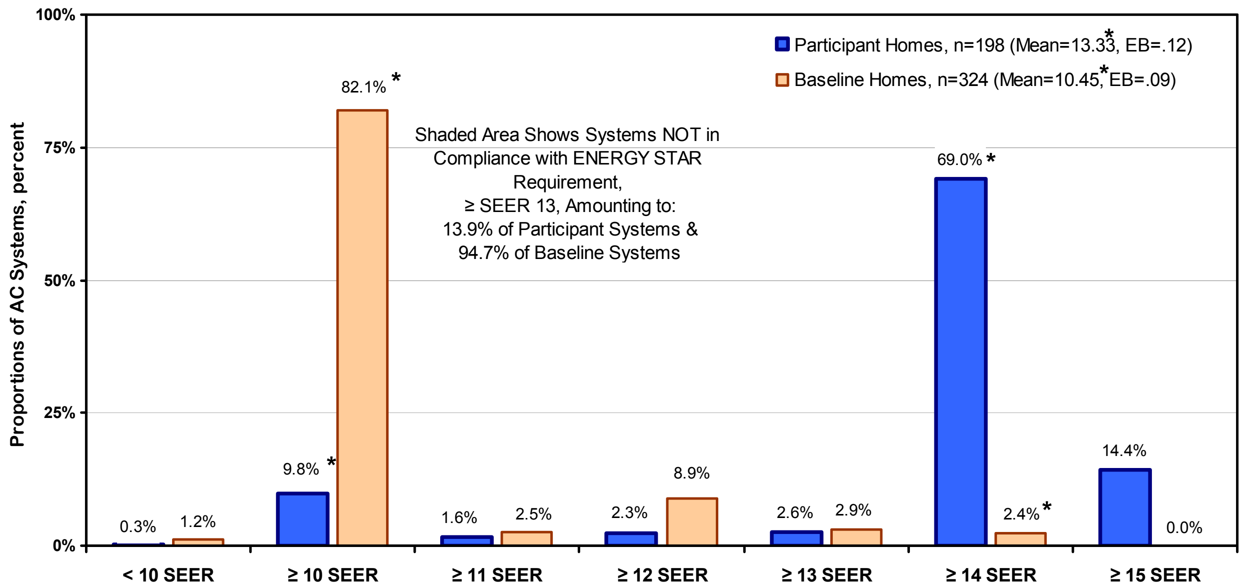


6.2.2 Efficiency of Central Air Conditioning Systems Installed

The program required a minimum SEER rating of 13 for air conditioning systems. Figure 6-5 shows the distribution of cooling systems in the Participant and Baseline homes by energy efficiency rating. Interpretation of data on the efficiency of central air conditioning equipment installed is complicated by the promulgation in January 2006 of new Federal standards that raised the minimum efficiency of such systems from 10 SEER to 13 SEER, which is the minimum efficiency level in BOP-1. Among Baseline homes, which were built in 2004 – 2005, 82.5 percent of the installed systems were rated at 10 to 11 SEER. Only 5.3 percent of the systems installed in the Baseline homes were rated at 13 SEER or above. Roughly 14 percent of the systems installed in the Participant sample had SEER ratings below 13.[11] However, 69.0 percent of the installed systems were rated at 14 SEER, and an additional 14.4 percent were rated at 14 – 15 SEER. Thus, nearly three-fourths of the central air conditioning systems installed in Participant homes exceeded minimum standards for the program.

[11] That is, 14 percent of the 60.8 percent of homes in which central air conditioning is installed, or 8.5 percent of all ENERGY STAR new homes.

Figure 6-5. SEER Ratings of Air Conditioning Systems at Pacific Northwest Homes



6.3 Airflow Measurements

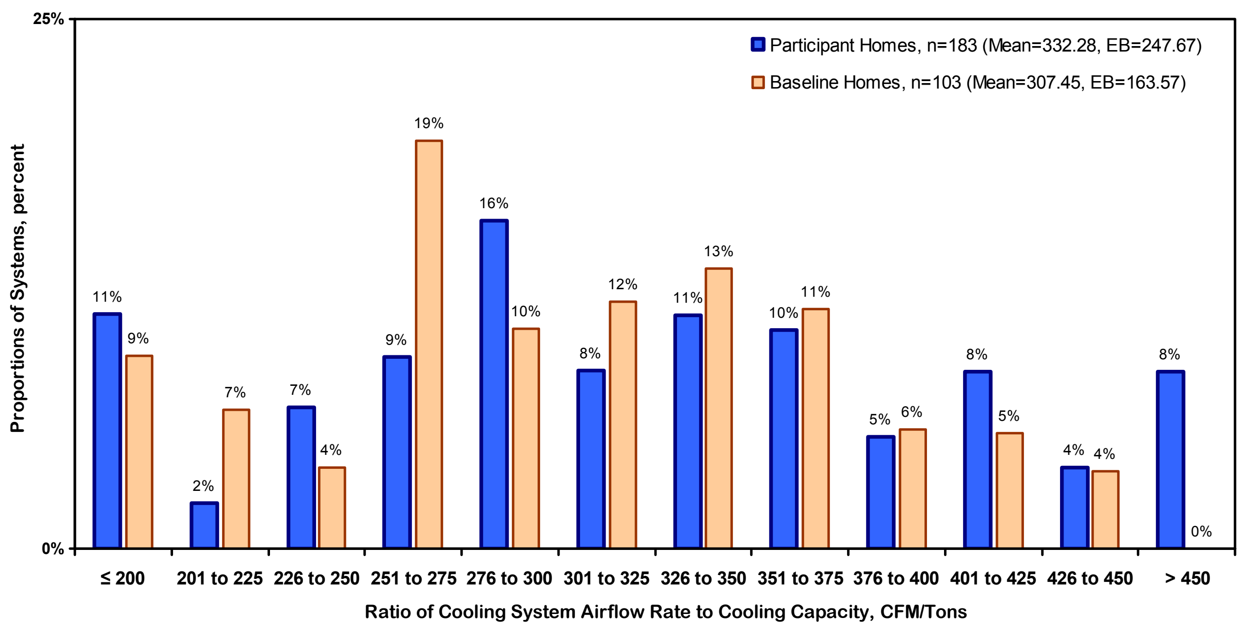
Maintenance of proper air flow over heating and cooling coils in forced air systems is critical to the efficient operation of both functions. For heating, if the air flow (in Cubic Feet per Minute or CFM is too low, the heat output of the furnace is not distributed efficiently to the various rooms of the house, and thermostatic controls will call for more heat even if the BTU output of the furnace is sufficient to have heated the space. If heating system fan volume is too high, the exiting air may not be sufficiently warmed to meet thermostatic setpoints. If CFM over the cooling coils is too low, the coils may become too cold and begin to generate ice build up, which impedes efficient heat transfer. If cooling CFM is too high, the system may not be able to meet thermostatic setpoints.

The field engineers used a TrueFlow® Air Handler Flow Meter to measure the air flow generated by heating and cooling system plants. In the first step of the process, a pressure probe was placed immediately downstream of the supply fan to determine the standard system operating pressure with the fan on. Next, the air filter was removed and the TrueFlow® meter, an orifice metering device, was installed in its place. With the metering plate in place, the system fan was turned on and the fan's airflow rate was measured while using a differential pressure gauge.

Measured air flow rate versus cooling capacity. Manufacturers test air conditioner energy efficiency at an air flow of 400 CFM per ton. HVAC system maintenance manuals identify 300

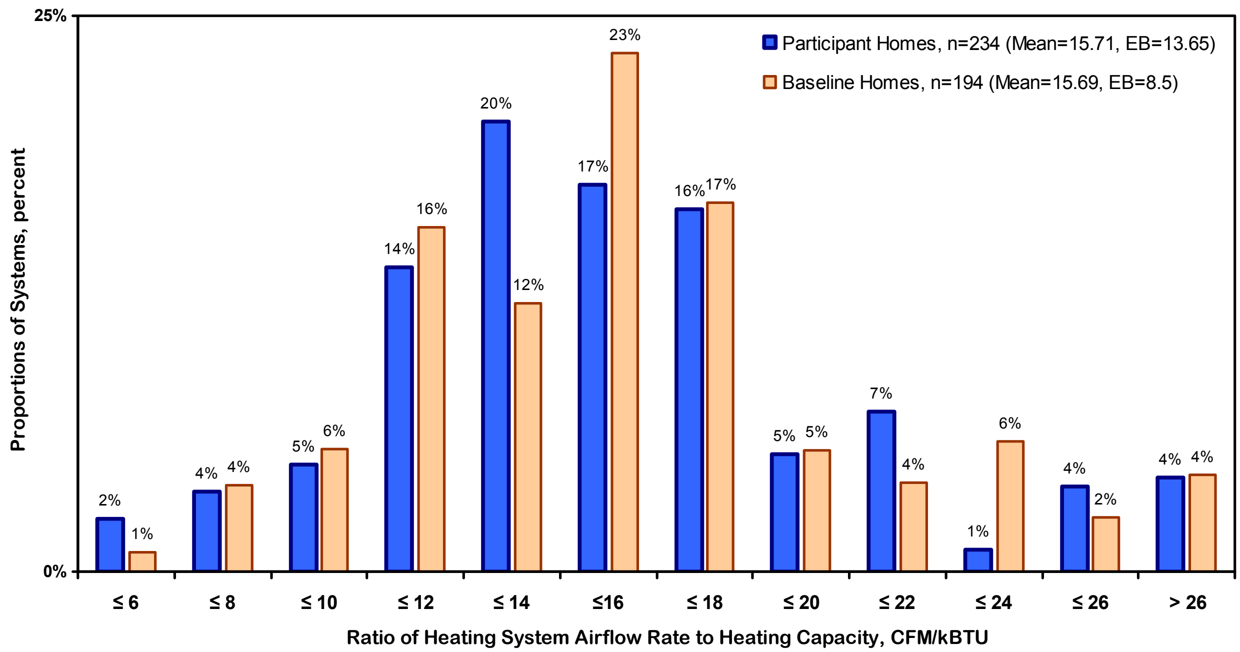
CFM as a minimum airflow level, below which problems with heat transfer and freezing may occur. Figure 6-6 shows the distribution of the Participant and Baseline samples by the ratio of cooling system fan CFM per ton of installed cooling capacity. Only 26 percent of the central air conditioning systems in the Participant sample and 15 percent of the systems in the Baseline sample met the 400 CFM per ton criterion. Forty-four percent of the systems in the Participant sample and 49 percent of the systems in the Baseline sample fell below this level. Thus, it appears that undersizing or underperformance of fans is a common problem in residential cooling systems in the Northwest, regardless of ENERGY STAR status.

Figure 6-6. Distribution of Participant and Baseline Sample by Ratio of Cooling System Airflow to Cooling System Capacity



Measured air flow versus heating capacity. We are aware of no Northwest regional standards or program requirements for air flow over furnace heating coils. The California Title 24 *Residential Compliance* Manual does not contain a standard for air flow over heating coils in a forced air system. However, it does recommend a rate of 21.7 CFM per kBTU as a rule of thumb for fan sizing. Figure 6-7 shows the distribution of forced hot air systems in the Participant and Baseline homes by the ratio of measured air flow to heating system capacity. As in the case of cooling, average fan volume is considerably lower than the benchmark: 15.7 CFM per kBTU for both samples. Eighty-six percent of the systems in both samples fall below the benchmark, which suggests that the fans are either undersized or underperforming.

Figure 6-7. Distribution of Participant and Baseline Sample by Ratio of Heating System Airflow to Heating System Capacity



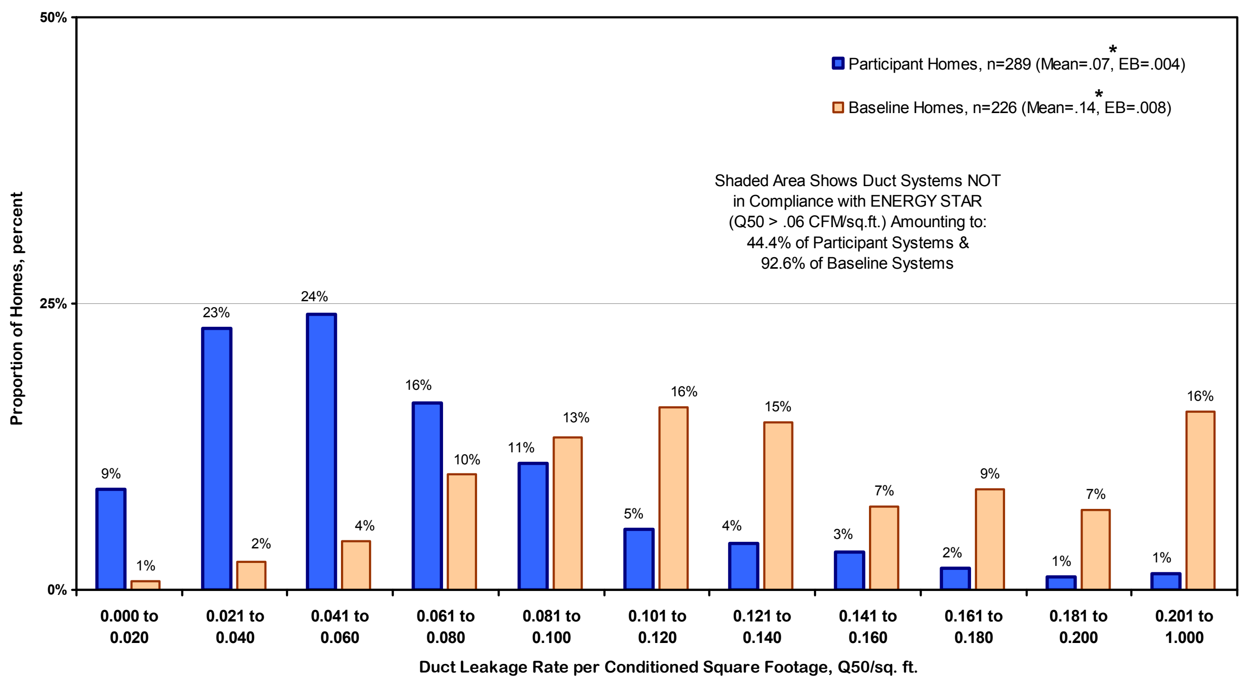
6.4 Duct Leakage to Outdoors

According to evaluations of HVAC tune-up and quality installation programs recently completed in California, high levels of duct leakage are a the major correctable factor in increasing overall central air conditioning system efficiency. To measure the HVAC system duct leakage, a Minneapolis Duct Blaster® was used to measure the rate of air leakage from the duct system while pressurized using a calibrated fan. The Duct Blaster® fan was connected directly to a specific duct system within a house, typically at a central return or at the cabinet of the given air handling unit. To achieve the required pressures of 25 and 50 Pascals (Pa) within the duct system, all diffusers and remaining return air grilles were blocked off while the Duct Blaster® fan was operating. The required pressure within the given duct system was confirmed using a digital pressure gauge. The purpose of measuring the rate of duct leakage to the outdoors is to quantify the amount of heating and, if relevant, cooling energy that escapes the thermal envelope of the house. We were able to obtain duct leakage measurements for 226 of the 316 sample homes that had ducted heating systems.

The maximum rate of duct leakage allowed under the Northwest ENERGY STAR specification is 0.06 CFM per conditioned square foot of floor area. Figure 6-8 shows that 44 percent of the Participant homes did not meet the standard and that the mean leakage rate to outdoors was

0.07 CFM per square foot. By contrast, 93 percent of the Baseline homes failed to meet the ENERGY STAR standard, and their mean leakage rate of 0.14 CFM per square foot was twice that at Participant Homes.

Figure 6-8. Total Duct Leakage to Outdoors and ENERGY STAR Requirement



The 2007 Market Evaluation Progress Report for the Northwest ENERGY STAR Homes Program[12] contained an analysis of duct leakage tests conducted as part of the home certification process. The analysts obtained records of 353 measurements of duct leakage to the exterior. They found that 95 percent of the homes tested had met the 0.06 CFM/square foot criterion, and that the average duct leakage to the exterior was 0.05 CFM/per square foot. This finding suggests that there duct integrity begins to decrease fairly soon after installation, even when those installations initially meet program criteria.

Table 6-2 displays average levels of duct leakage to the exterior by state. Among the participant homes, average duct leakage clusters in the range of 0.69 to 0.78 CFM per square foot, except in Montana, where it is less than half that amount. This finding may reflect the relatively small sample and high representation of BOP-2 homes in Montana.

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[12] ECONorthwest. *ENERGY STAR Homes Northwest Program: Fourth Market Evaluation Progress Report.* Portland OR: Northwest Energy Efficiency Alliance. August 31, 2007.

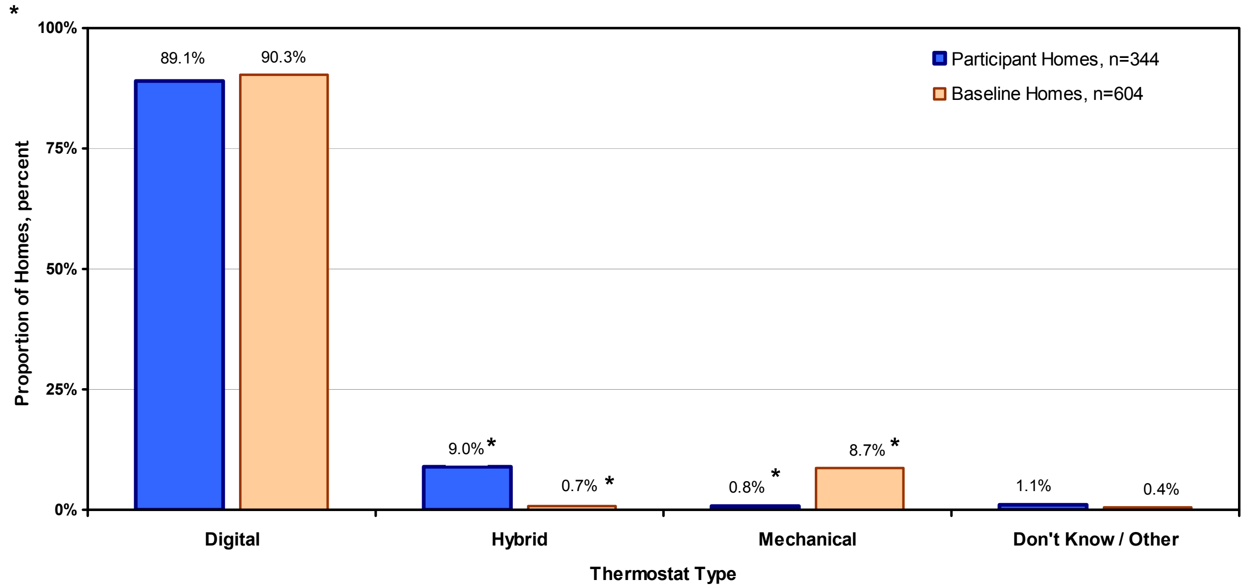
Table 6-2. Average Duct Leakage to Exterior by State: CFM/SF

State	Participant n=303	Baseline n=213	Significant Difference
Idaho	0.078	0.161	*
n =	*66*	*40*	
Montana	0.033	0.140	*
n =	*7*	*3*	
Oregon	0.075	0.131	*
n =	*151*	*99*	
Washington	0.068	0.135	*
n =	*79*	*71*	

6.4.1 Controls

Figure 6-9 shows the distribution of thermostats in the Participant and Baseline samples by type. The prevalence of electronic digital thermostats was identical in the Participant and Baseline samples at 90 percent. However, in the Participant sample the remaining units nearly all used hybrid digital/mechanical technology whereas the remaining units in the Baseline sample were all mechanical.

Figure 6-9. Distribution of Thermostats Installed by Type



6.5 Domestic Hot Water Equipment

6.5.1 Water Heaters Installed by Type and Fuel

The field staff gathered information about the types of water heaters found in ENERGY STAR New Homes. Figure 6-10 shows the distribution of the Participant and Baseline homes by type of hot water heater installed. Virtually all of the Baseline homes had standard storage hot water heaters, as did 89.1 percent of the Participant homes. One interesting finding from Figure 6-10 is that 9.5 percent of the Participant homes had instantaneous hot water heaters, which can be 24 to 34 percent more energy efficient than conventional storage systems using the same fuel.

Figure 6-10. Distribution of Participant and Baseline Homes by Water Heater Type

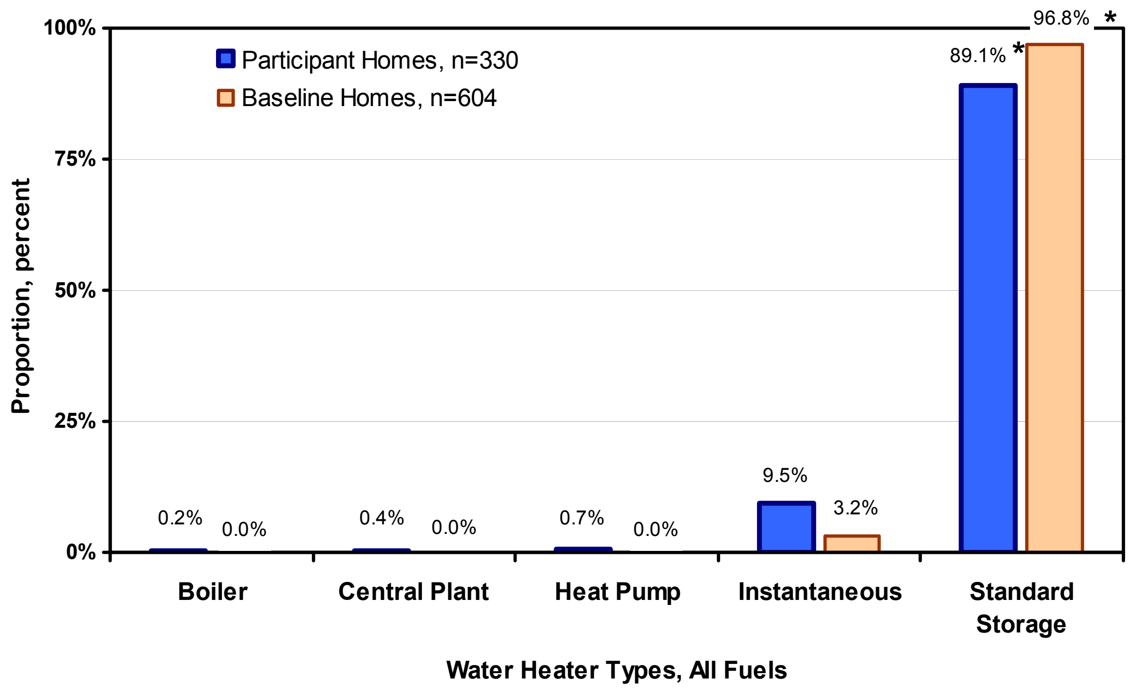


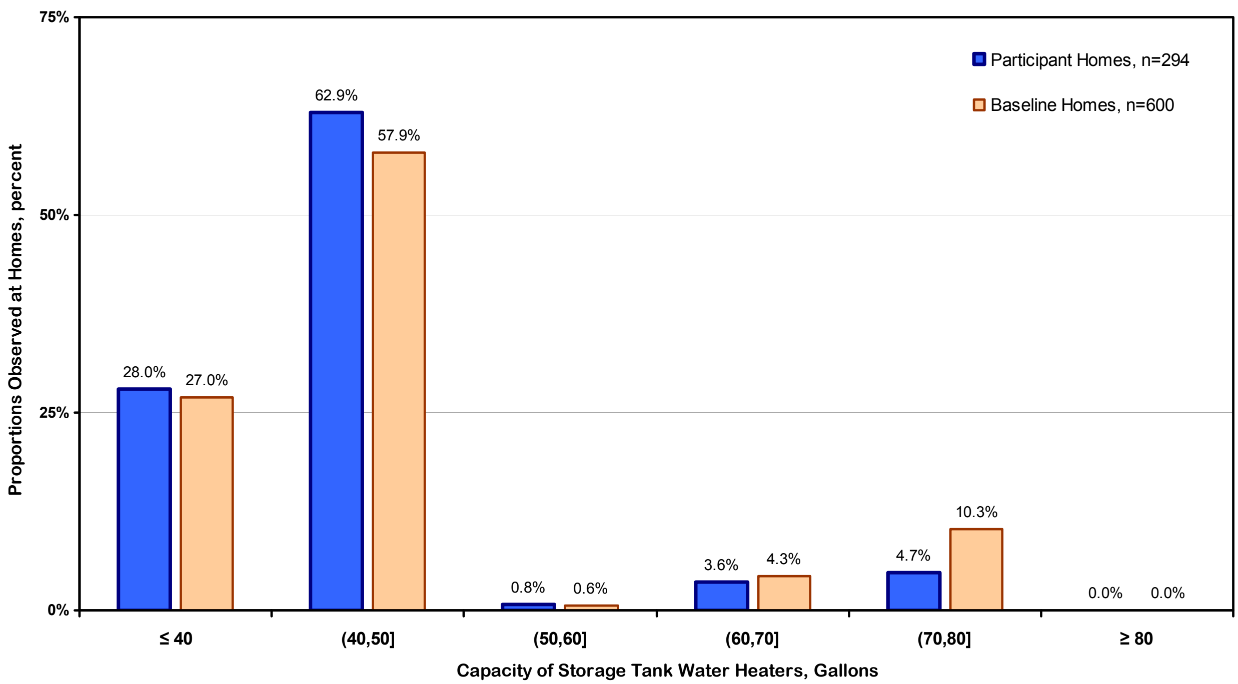
Table 6-3 shows the distribution of Participant and Baseline Homes by water heater type and fuel. Natural gas is the predominant water heating fuel, accounting for 88 percent of all units in the Participant sample and 82 percent of all units in the Baseline sample.

Table 6-3. Distribution of Participant and Baseline Homes by Water Heater Fuel and Type

	Water Heating Fuel					
	Natural Gas		Electric		Propane	
Type	Parti-cipant	Baseline	Parti-cipant	Baseline	Parti-cipant	Baseline
Storage	90.5%	96.5%*	85.9%	85.9%*	16.2%	100%*
Boiler/Central	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%
Heat Pump	0.2%	0.0%	5.3%	16.0%	0.0%	0.0%
Instantaneous	8.6%	3.5%	8.8%	0.0%	83.8%	0.0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
n =	294	509	29	72	4	23

Figure 6-11 displays the distribution of Participant and Baseline Homes by water heater capacity. The two distributions are nearly identical, with 57.9 percent of baseline and 62.9 percent of participant samples clustered in the range including 40 up to but not including 50 gallons and 27.0 percent baseline and 28.0 percent participant samples clustered equal to or below 40.0 gallons.

Figure 6-11. Distribution of Participant and Baseline Homes by Water Heater Capacity



6.5.2 Energy Efficiency Ratings of Water Heaters Installed

Table 6-4 displays the levels of energy efficiency, as measured by Energy Factor (EF) that are required for certification under BOP-1 and BOP-2. The requirements are the same under both specifications except for electric water heaters larger than 70 gallons.

Table 6-4. Energy Factor Requirements for Water Heaters at ENERGY STAR Homes

Minimum Energy Factors for Water Heater Categories	Builder Option 1 (BOP-1)	Builder Option 2 (BOP-2)
Natural Gas, ≤ 60 gal.	0.61	
Natural Gas, > 60 gal.	0.60	
Electric, ≤ 70 gal.	0.93	
Electric, > 70 gal.	0.92	0.93

Table 6-5 shows the percentage of water heaters that complied with ENERGY STAR requirements by type as defined by BOP-1 and BOP-2. The table also shows the number of homes in which each type of water heater was observed. Natural gas storage heaters with capacity ≤ 60 gallons account for the vast majority of units in both samples. In Participant homes, 92.8 percent of such units were compliant, compared to 6.4 percent in the Baseline homes. Among the small number of homes with larger gas units, 100 percent were compliant in the Participant sample, versus 13.8 percent in the Baseline sample. This pattern was continued for electric units with capacity ≤ 70 gallons. The numbers of other types of units in the two samples are too small to support meaningful comparisons. Technical Compliance Option (TCO #8) allowed builders to trade off a lower DHW Energy Factor for increased wall and attic insulation. According to the Tracking Database, this option was exercised at four of the Participant homes that were surveyed.

The clear conclusion to be drawn from Table 6-5 is that domestic hot water heaters are significantly more efficient in the Participant than in the Baseline homes.

Table 6-5. Percentage of Participant and Baseline Homes with ENERGY STAR-compliant Water Heaters

Type	Applicable EF Standard	% Compliant Participant	% Compliant Baseline	n Participant	n Baseline
BOP-1					
Natural Gas ≤ 60 gallons	0.61	92.8%	6.4%*	238	337
Natural Gas > 60 gallons	0.60	100.0%	13.8%*	5	29
Electric ≤ 70 gallons	0.93	84.3%	29.6*	20	13
Electric > 70 gallons	0.92	0.0%	47.7%	3	6
BOP-2					
Electric > 70 gallons	0.93	100.0%	0.0%	3	6

7. Lighting

7.1 Interior Lighting

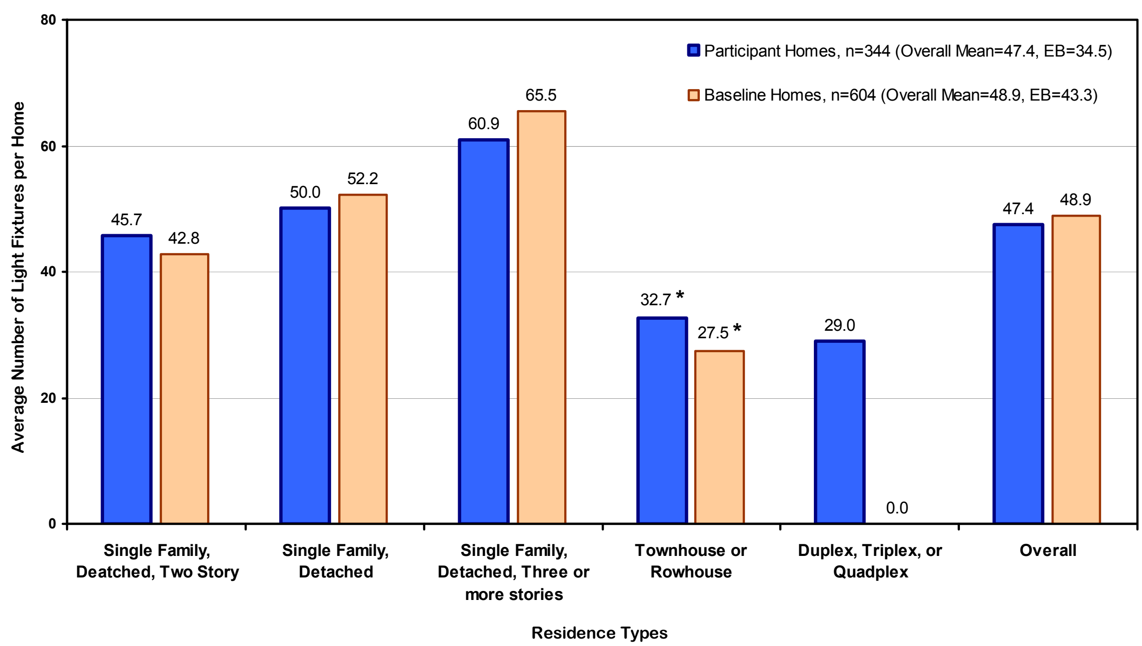
Field engineers inventoried every lighting fixture in the all homes in the Participant sample by room, fixture type, fixture control type, number of lamps, lamp type and lamp wattage. Very similar kinds of data were gathered for the Baseline study. This approach supports close comparison of the results of both studies in regard to interior lighting.

This section begins with a comparison of the two samples in terms of the number and type of fixtures and lamps installed, as well as other measures of saturation such as socket counts and lighting power density. It concludes with an assessment of compliance with Northwest ENERGY STAR standards. The Northwest ENERGY STAR Builder Option Packages require that 75 percent of permanent fixtures installed either be ENERGY STAR compliant or fitted with ENERGY STAR-compliant bulbs (CFLs).

7.1.1 Number and Type of Fixtures Installed

Figure 7-1 displays the mean number of interior lighting fixtures installed per home in the Participant and Baseline samples by housing type.

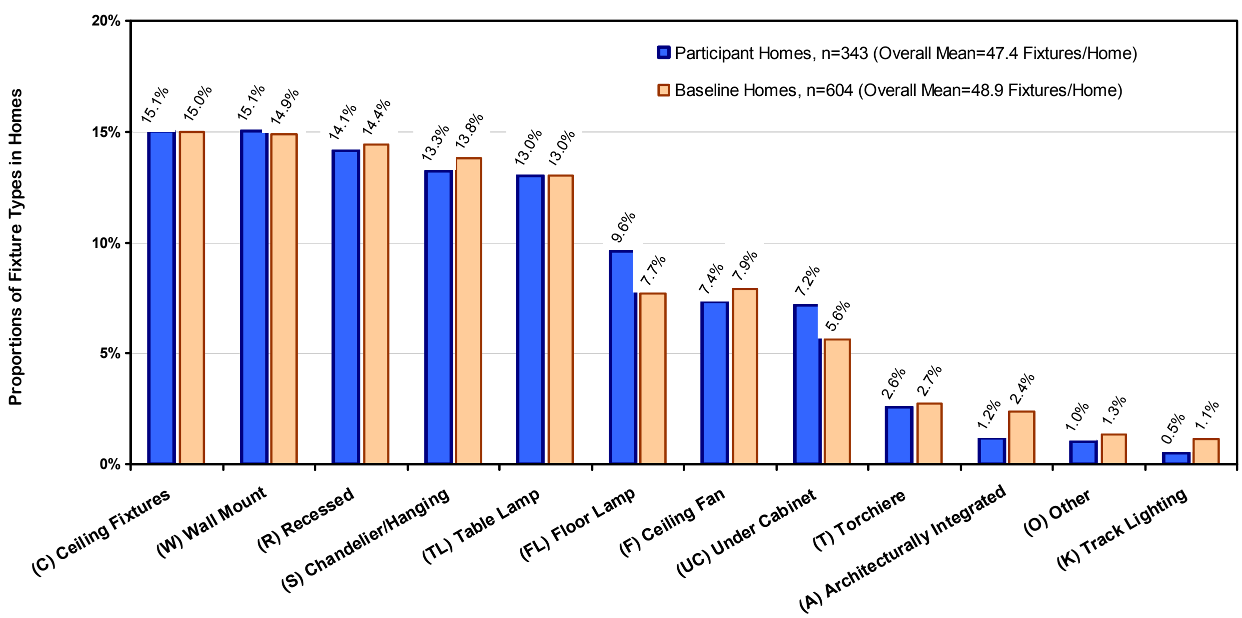
Figure 7-1. Mean Fixtures Installed by Housing Type



The mean numbers of fixtures installed for the samples as a whole are nearly identical: 47.4 in Participant homes and 48.9 in the Baseline homes. Only in single-family attached homes is there a significant difference between the two samples in the number of fixtures installed.

Figure 7-2 displays the distribution of fixtures installed by fixture type. The distribution of total fixtures among the various types is very similar for the Participant and Baseline samples, and nearly identical for the five most common fixture types: ceiling, wall mount, recessed cans, chandeliers, and table lamps. Those five categories account for roughly equal portions of the fixtures installed and together make up 70 percent of the total.

Figure 7-2. Distribution of Fixtures Installed by Fixture Type



7.1.2 Lighting Socket Counts and Related Characteristics

Most residential lighting fixtures contain more than one light socket and lamp or bulb. The average fixture in Participant homes contained 2.5 sockets versus 2.9 in the Baseline sample. Therefore, it is necessary to disaggregate our analysis to the socket level to characterize lighting saturation and frame the analysis of technology shares.

Figure 7-3 displays the average number of light sockets found in the sample homes by housing type. The mean number of sockets in the Participant homes was 73.3 versus 77.1 in the

Baseline home. This small difference is statistically significant and consistent with the slightly larger size of the Baseline homes. The average number of sockets per 100 square feet was 3.28 in the Participant homes and 3.34 in the Baseline homes. This finding is one indicator that the level of “lighting services” provided is roughly equivalent in the two samples.

Figure 7-3. Average Number of Light Sockets per Home

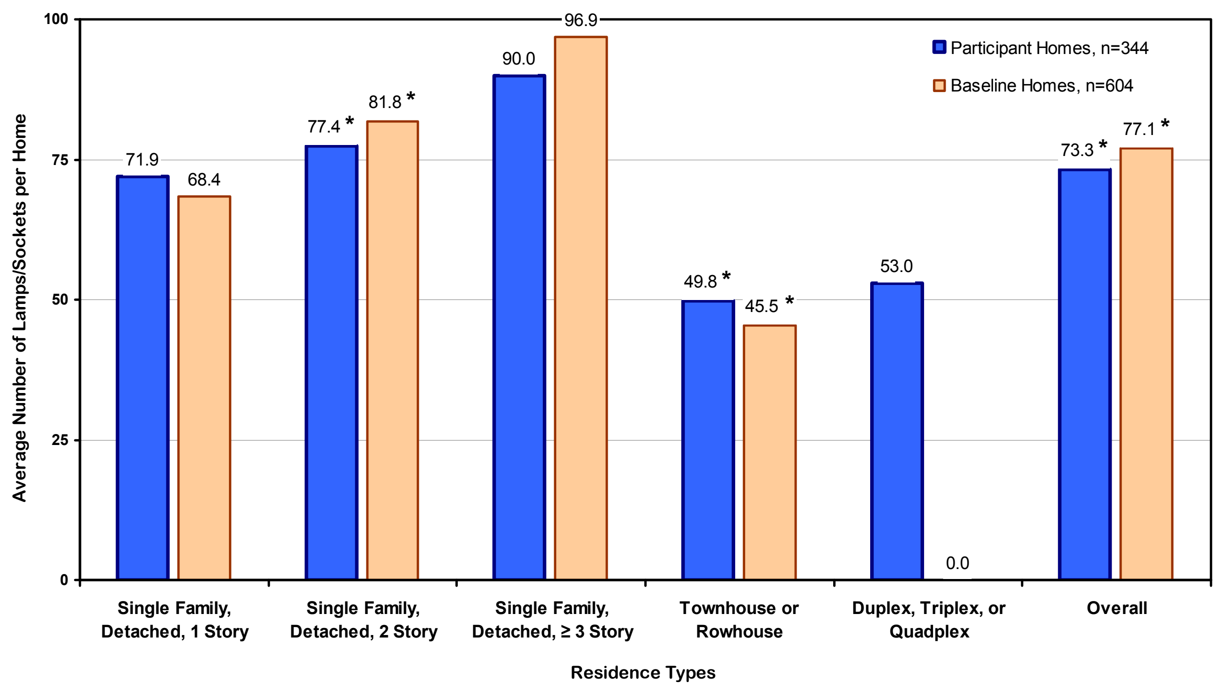
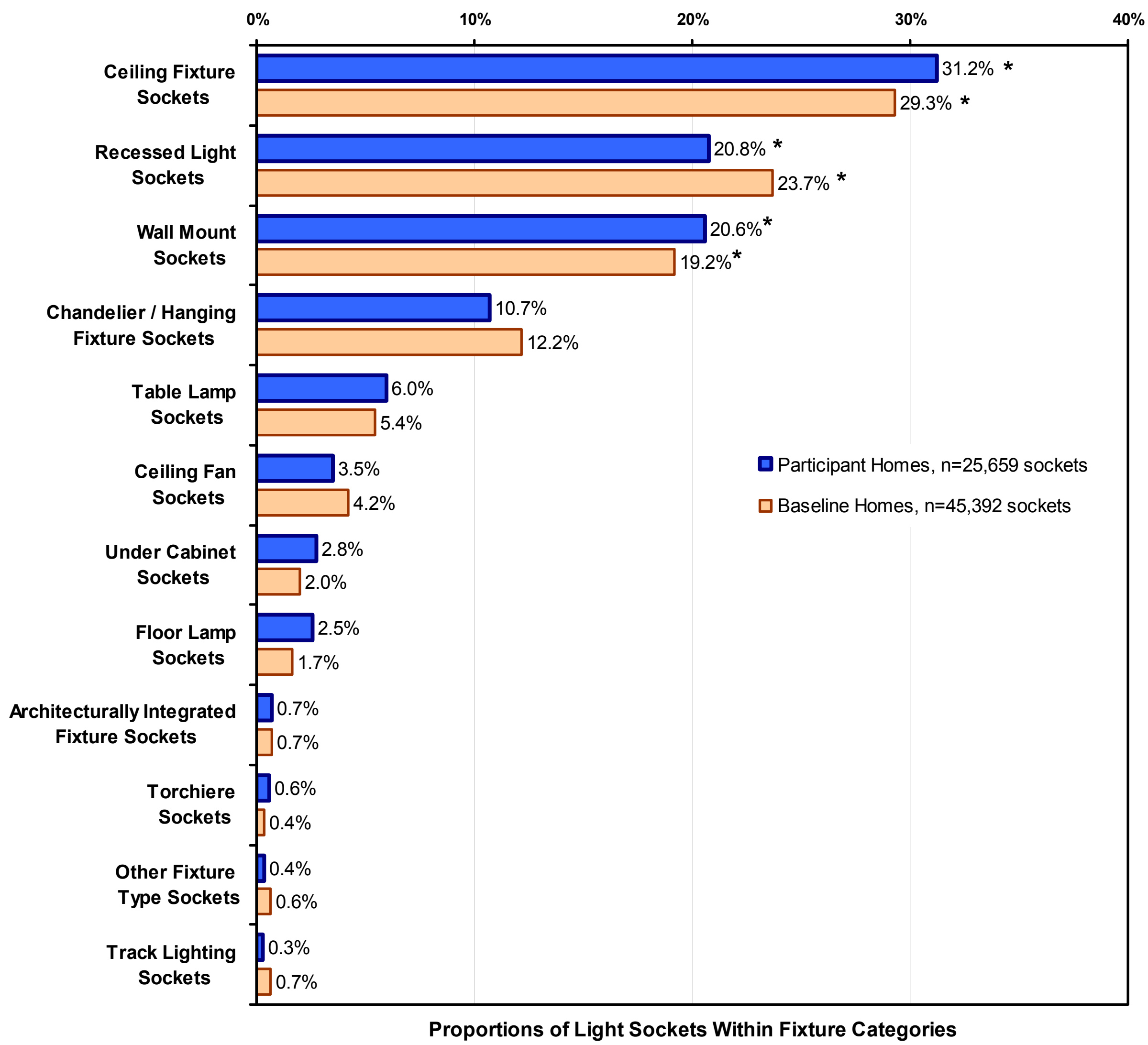


Figure 7-4 displays the distribution of lighting sockets by fixture type in the Participant and Baseline homes. Participant homes feature a slightly larger percentage of total sockets in ceiling and wall mounted fixtures than do the Baseline homes. These types of fixtures are more likely to be hard wired for CFL bulbs than are recessed cans and chandeliers, which are slightly more prevalent in the Baseline homes. Although the observed differences between the samples in the distribution of sockets by fixture type are small, they are statistically significant. These differences may reflect the influence of the program standard on lighting fixture selection.

Figure 7-4. Distribution of Light Sockets by Fixture Type



7.1.3 Lamp Type, Wattage, and Power Density

The field engineers collected information on the number, type, and wattage of each lamp installed in all of the observed sockets in both the Participant and Baseline samples. Figure 7-5 displays the distribution of lamps installed by type for the two samples. CFLs account for 47 percent of the lamps installed in the Participant homes versus 13 percent in the Baseline. This 34 percent difference is mirrored almost exactly in the saturation of incandescent bulbs. Those account for 67 percent of all lamps installed in the Baseline homes compared to 36 percent in the Participant homes. Given the program requirement that 50 percent of sockets be located in ENERGY STAR qualified fixtures or contain ENERGY STAR qualified bulbs, these differences in lighting technology are likely due, in significant part, to the effects of the program. Some of this observed difference may be due to the passage of time between the Baseline and Participant surveys. Annual national sales of CFLs nearly doubled between 2006 when the Baseline survey was conducted and 2007, and every indication is that CFL sales and market share of medium screw-based lamps have continued to rise since then.[13]

Figure 7-5. Distribution of Installed Lamps by Type

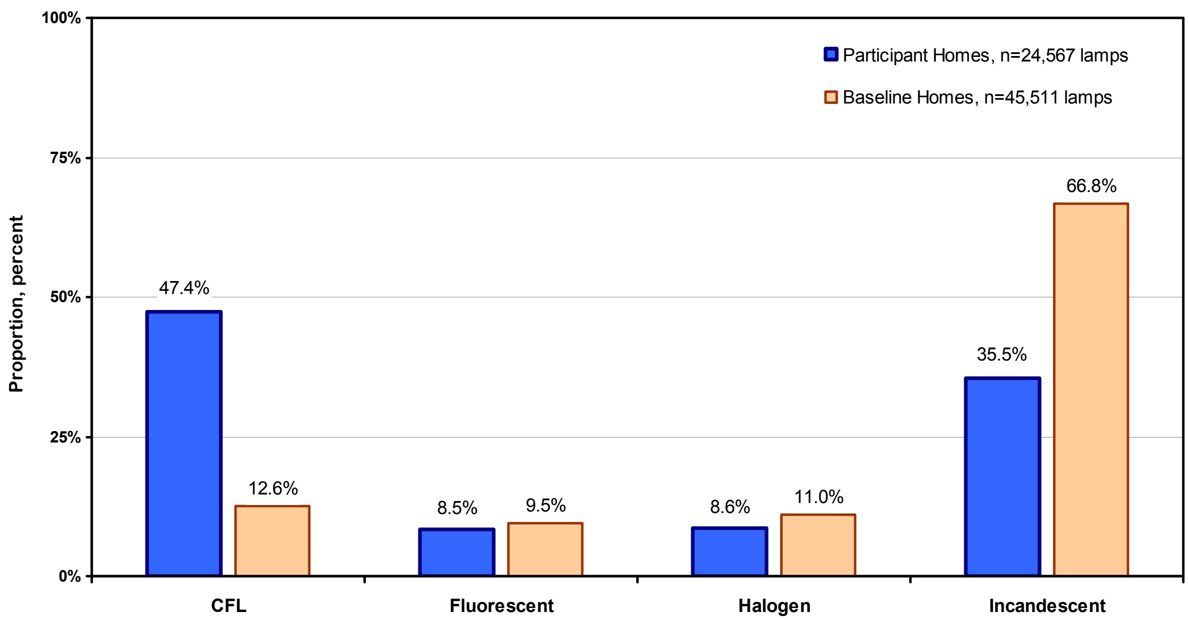


Table 7-1 displays the average wattage of lamps installed by the fixture type in which they are found. The higher prevalence of CFLs in the Participant homes is reflected in the lower wattages per fixture in certain categories that generally accept screw-in CFLs: ceiling fixtures, ceiling fans, and wall mounts. Homeowners in the Participant sample also appear to have eschewed high wattage halogen torchieres. The overall average wattage of lamps installed in the Participant sample is 42.9 watts, which is 29 percent less than the average wattage of lamps installed in the Baseline sample (60.5 watts).

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[13] The Cadmus Group, et al. 2009. *CFL Market Effects Study*. Berkeley, CA: California Institute of Energy and Environment.

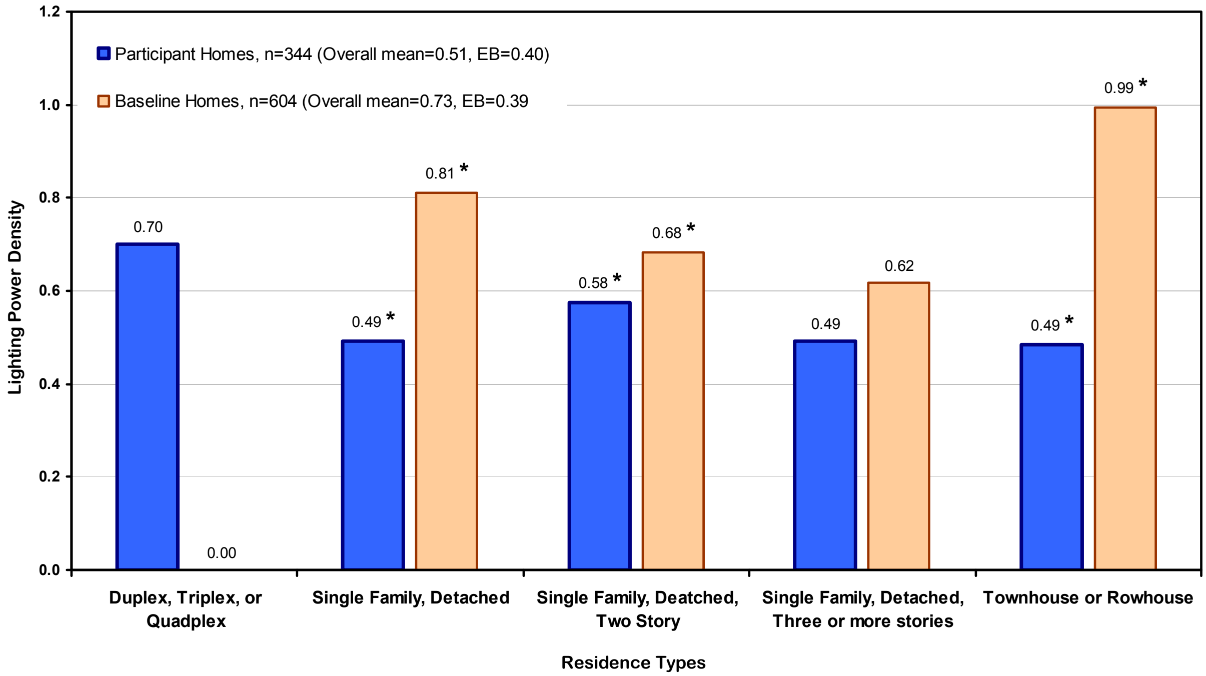
Table 7-1. Average Lamp Wattage by Fixture Type

Fixture Type	Participant	Baseline	Significant Difference @ 90% Confidence
Architecturally Integrated	32.4	38.5	
Ceiling fixtures	26.4	59.0	*
Ceiling Fan	35.0	57.2	*
Floor Lamp	74.7	66.2	*
Track lighting	57.0	54.2	
Other	35.9	68.7	*
Recessed can	45.3	68.5	*
Chandelier / Hanging	35.9	57.0	*
Torchiere	73.5	144.1	*
Table lamps	53.0	53.1	
Under Counter	31.9	35.0	
Wall mount	38.5	60.1	*
Overall	**42.9**	**60.5**	

Figure 7-6 displays the average lighting power density (LPD)[14] for the Participant and Baseline samples. The overall LPD for the Participant sample is 0.51, which is 30 percent lower than the LPD for the Baseline sample (0.73). Participant LPDs are less than those for the Baseline in all housing type categories that appear in both samples, although the differences are most pronounced in single-family detached and single-family attached homes.

[14] LPD = total wattage of all lighting interior equipment installed/enclosed square footage.

Figure 7-6: Average Lighting Power Density (w/square foot) by Housing Type



7.1.4 Saturation of ENERGY STAR-Compliant Lighting

As discussed above, the Northwest Builder Option Package Packages require that 50 percent of installed lighting sockets be in ENERGY STAR compliant fixtures or be fitted with ENERGY STAR-compliant bulbs (CFLs). To assess the degree to which the Participant and Baseline homes complied with this requirement, we computed the percentage of total fixtures fitted with linear fluorescent, pin-based fluorescent, and CFLs for the following types of fixtures which we deemed to be permanent: ceiling fixtures, recessed cans, wall mounted fixtures, chandeliers, ceiling fans, under-cabinet fixtures, architecturally integrated fixtures, and track lighting.

The field engineers encountered some difficulties in positively identifying ENERGY STAR fixtures during the home inspections. It was only possible to quantify those that were suitable for compliance since the ENERGY STAR decal was not visible in most cases. It was not possible in the case of closed fixtures to determine whether screw-based CFLs installed bore the ENERGY STAR label.

Table 7-2 shows the percentage of total permanent fixtures fitted with each type of ENERGY STAR-qualifying lamp and the overall proportion of permanent fixtures fitted with qualifying equipment. In the Participant sample, 69.3 percent of permanent fixtures are fitted with qualifying lamps, versus 22.6 percent in the Baseline sample. These results suggest that the program has exceeded the stringent Northwest ENERGY STAR standards for interior lighting.

Table 7-2. Saturation of ENERGY STAR Lighting as Percent of Permanent Fixtures

Lamp Type	Participant	Baseline
Compact Fluorescent	58.8%	14.3%
Pin Based Fluorescent	1.9%	0.3%
Linear Fluorescent	8.6%	8.0%
Total	**69.3%**	**22.6%**

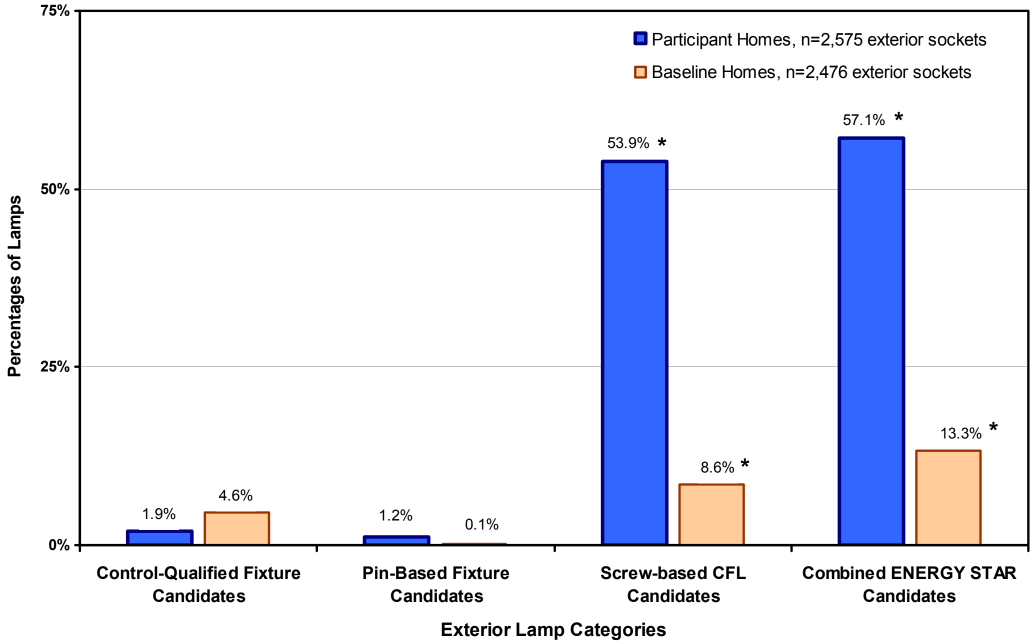
7.2 Exterior Lighting

Exterior lighting fixtures can meet ENERGY STAR requirements in two different ways:

- Use pin-based CFL lamps or others that cannot be replaced with incandescent bulbs or;
- Use screw-based CFLs with a light sensor switch built into the fixture.

Figure 7-7 shows the distribution of ENERGY STAR-compliant exterior fixtures in the Participant and Baseline samples. Overall, 57.1 percent of the exterior fixtures in the Participant sample met the ENERGY STAR requirements versus 13.3 percent of the exterior fixtures in the Baseline sample.

Figure 7-7. Distribution of ENERGY STAR-Compliant Exterior Fixtures



8. Appliances and Plug Loads

8.1 Major Appliances

8.1.1 Primary Refrigerators

Table 8-1 displays the distribution of primary refrigerators by size for the Participant and Baseline samples. Roughly two-thirds of the primary refrigerators in both samples are over 22 cubic feet in size.

Table 8-1. Distribution of Primary Refrigerators by Size

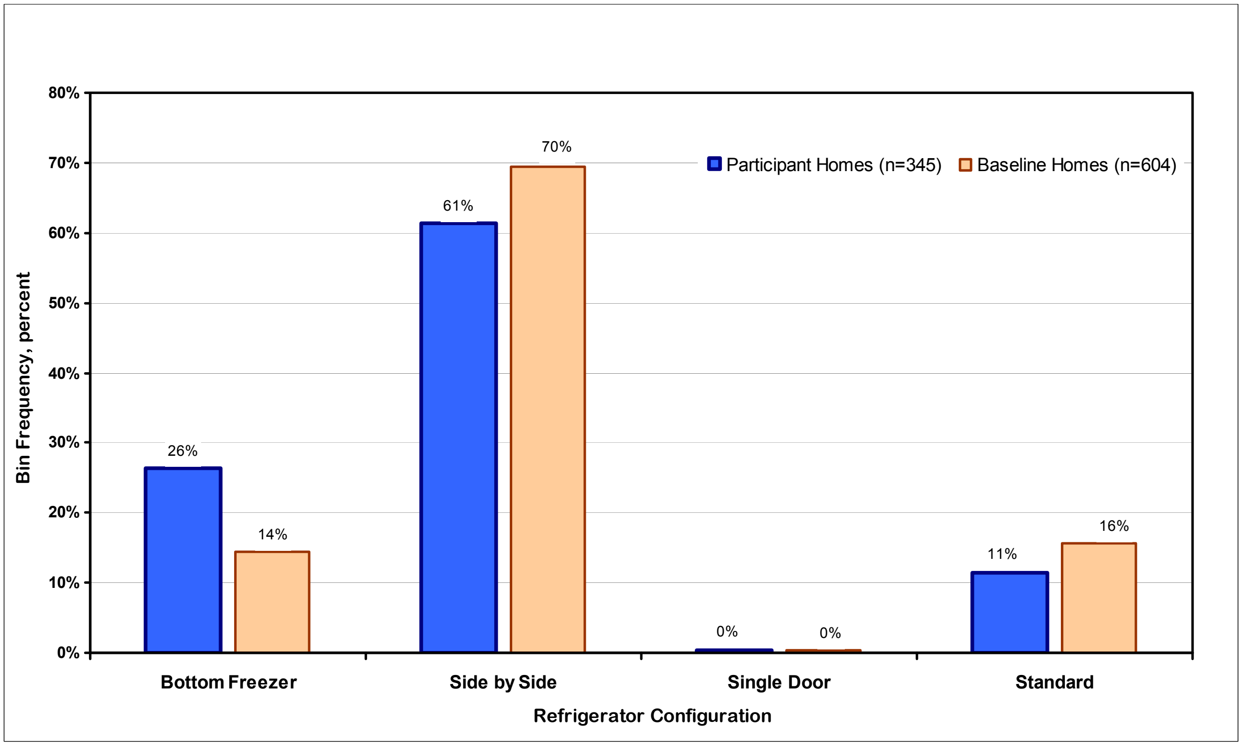
Size Range in Cubic Feet	Participant, n=345	Baseline n=604
≤ 10	2%	0%
11.00 – 14.99	<1%	<1%
15.00 – 18.99	3%	6%
19.00 – 21.99	29%	26%
≥ 22.00	65%	68%

Other key observations on primary refrigerators are as follows.

- **Year of manufacture.** The field engineers could only ascertain the year of manufacture for roughly one-third of the refrigerators in the Participant sample. In the Baseline survey, the field engineers accepted customer estimates of the age of the refrigerator and thus obtained age information for a higher proportion of primary units. Among the refrigerators in the Participant sample for which age data were available, 90 percent were purchased new upon occupancy of the home, and were thus no more than three years old at the time of the survey. Five percent had been manufactured since 2001 and the remaining 5 percent had been manufactured prior to 1999. The age distribution of refrigerators in the Baseline sample was similar: 90.7 percent had been manufactured in the 6 years prior to the survey.

- **Configuration.** Figure 8-1 shows the distribution of primary refrigerators by configuration for both samples. The side-by-side configuration is found most frequently in both samples: Participant – 61 percent and Baseline - 70 percent. Bottom freezer models are more prevalent in the Participant sample.

Figure 8-1. Primary Refrigerator Configuration



- **Through-the-door features.** Through-the-door features such as ice and water dispensers were found on 66 percent of the primary refrigerators in the Participant sample and 67 percent of the Baseline sample.
- **ENERGY STAR qualification.** Fifty-four percent of the primary refrigerators in the Participant sample carried the ENERGY STAR label. By way of comparison, the share of ENERGY STAR refrigerators sold by major appliance retailers who reported to the national ENERGY STAR Retail Partner database was 30.5 percent for the Northwest region. Thus it appears that buyers of ENERGY STAR homes were oriented towards the purchase of energy-efficiency equipment to a higher degree than residential customers in general.

  Comparison of the ENERGY STAR share of equipment purchased by Participant homeowners to the Baseline market share is complicated because ENERGY STAR efficiency criteria for refrigerators changed twice in the five years prior to the Participant survey. On January 1, 2004, the basic criterion was raised from 10 to 15 percent more efficient than the Federal minimum standard. The previous criteria had been in effect since 2001. On April 28, 2008, the criteria were raised again to 20 percent more efficient than the Federal minimum standard. All of the refrigerators in the Participant sample for which date of manufacture were obtained were made prior to the most recent change in the ENERGY STAR criteria. Over 39 percent of the refrigerators in the Baseline sample met the 2004 ENERGY STAR criteria, which had gone into effect shortly before the survey, and 55.7 percent met the 2001 ENERGY STAR criteria. Note that the portion meeting the 2001 criteria include the portion that meets the 2004 criteria.

8.1.2 Secondary Refrigerators

Twenty five percent of the homes in the Participant sample had secondary refrigerators compared to 19.5 percent in the Baseline sample. Ninety-three percent of the secondary refrigerators in the Participant sample were plugged and operating at the time of the survey.

Table 8-2 shows the distribution of secondary refrigerators by size range for the Participant and Baseline homes. Generally, the secondary refrigerators are smaller than the primary refrigerators. The size distribution for the Participant homes is more heavily weighted to the small end than is the Baseline sample: 34 percent of the secondary refrigerators in the Participant sample are smaller than 15 cubic feet versus 18 percent in the Baseline sample.

Table 8-2. Distribution of Secondary Refrigerators by Size

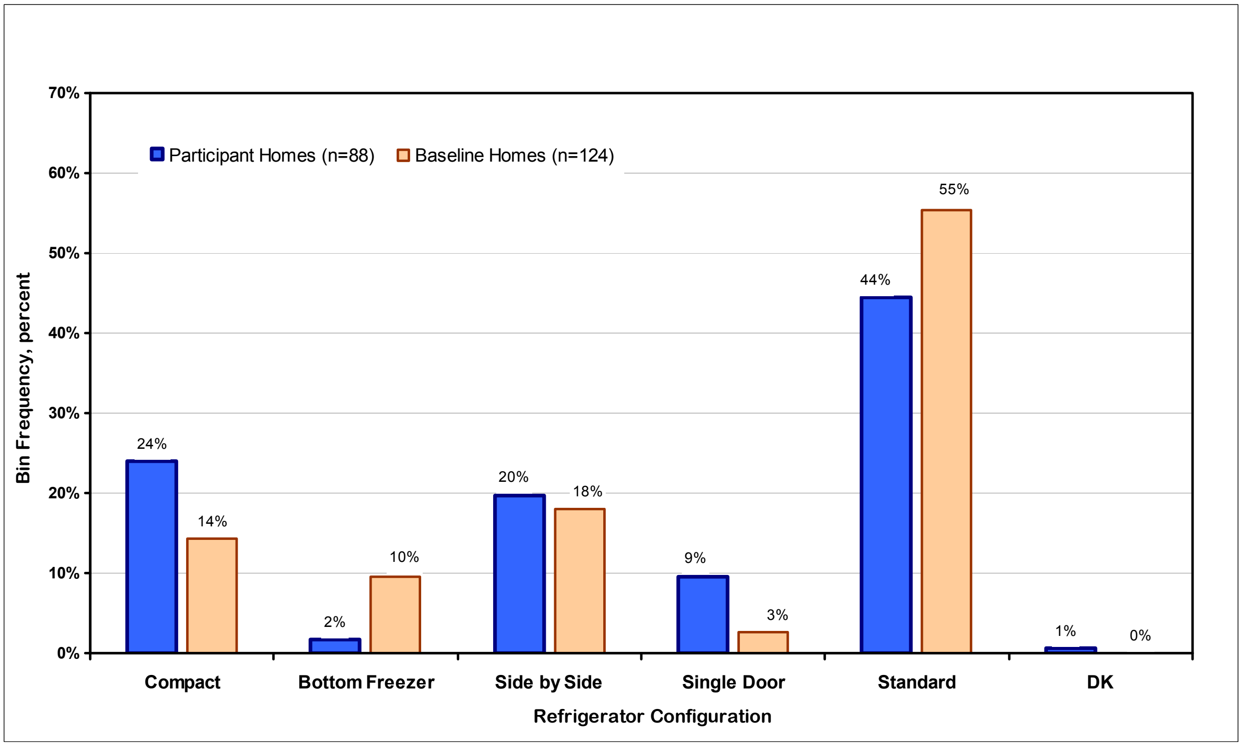
Size Range in Cubic Feet	Participant, n=87	Baseline, n=118
≤ 10	26%	14%
11.00 – 14.99	8%	4%
15.00 – 18.99	23%	29%
19.00 – 21.99	28%	35%
≥ 22.00	14%	18%

Other key observations on primary refrigerators are as follows.

- **Year of manufacture.** The field engineers could ascertain the age of only 18 of the secondary refrigerators in the Participant sample. On average, the secondary refrigerators were older than the primary refrigerators, but the age of the equipment was verified for too few units to support an overall characterization. Similarly, the secondary refrigerators in the Baseline sample were older than the primary units. Only 46.8 percent of the secondary units observed had been manufactured in the five years prior to the Baseline survey, compared to 90.7 percent of the primary units.

- **Configuration.** Figure 8-2 displays the distribution of secondary refrigerators in the Participant and Baseline samples by configuration. The standard two-door, top freezer configuration is the most common for both samples, accounting for 55 percent of units in the Baseline sample and 44 percent of the units in the Participant sample. Twenty-four percent of the units in the Participant sample are compact models versus 14 percent in the Baseline sample, which suggests that a larger proportion of Participant households purchased the units specifically to serve as secondary refrigerators, rather than using an primary refrigerator that had been replaced.

Figure 8-2. Secondary Refrigerator Configuration

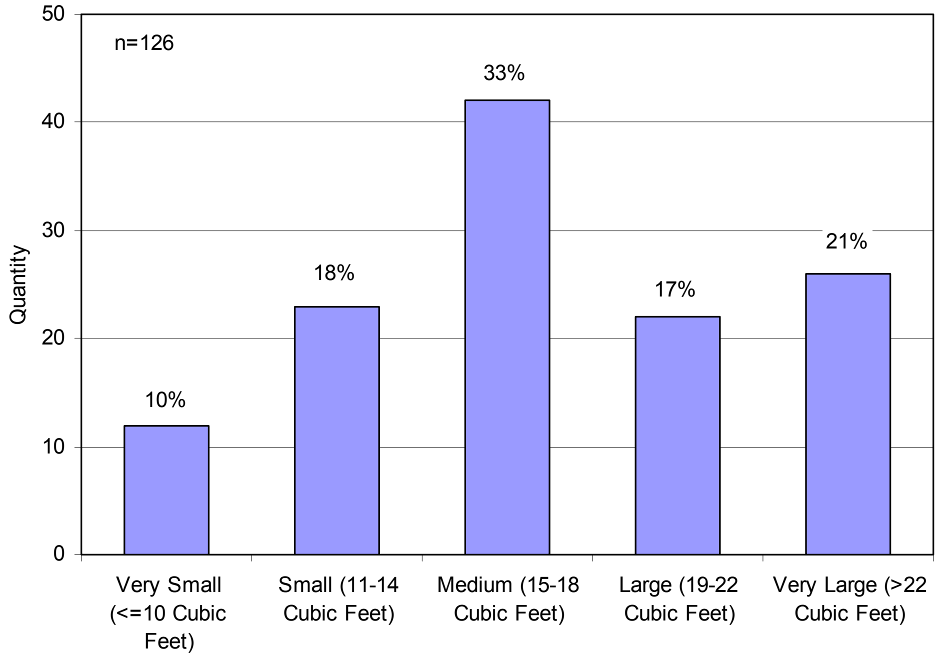


- **ENERGY STAR qualification.** Only 9.3 percent of the secondary refrigerators in the Participant sample carried the ENERGY STAR label, compared to 54 percent of the primary units. In the Baseline sample, 15.3 percent of the secondary refrigerators met the 2004 ENERGY STAR criteria, and 21.8 percent met the 2001 criteria.

8.1.3 Freezers

Free-standing freezers were observed 34.5 percent of the Participant homes; 2 percent had two free-standing freezers. Ninety-seven percent of these freezers were plugged in and running at the time of the survey. The Baseline survey did not collect information on free-standing freezers. Figure 8-3 shows the distribution of the freezers by size.

Figure 8-3. Number of Freezers in Participant Homes by Size Range



Other key findings in regard to freezers were as follows.

- Roughly two-thirds of the freezers (65.8 percent) were upright units. The remainder were chest-types.
- Only 9.2 percent of the units carried the ENERGY STAR label.

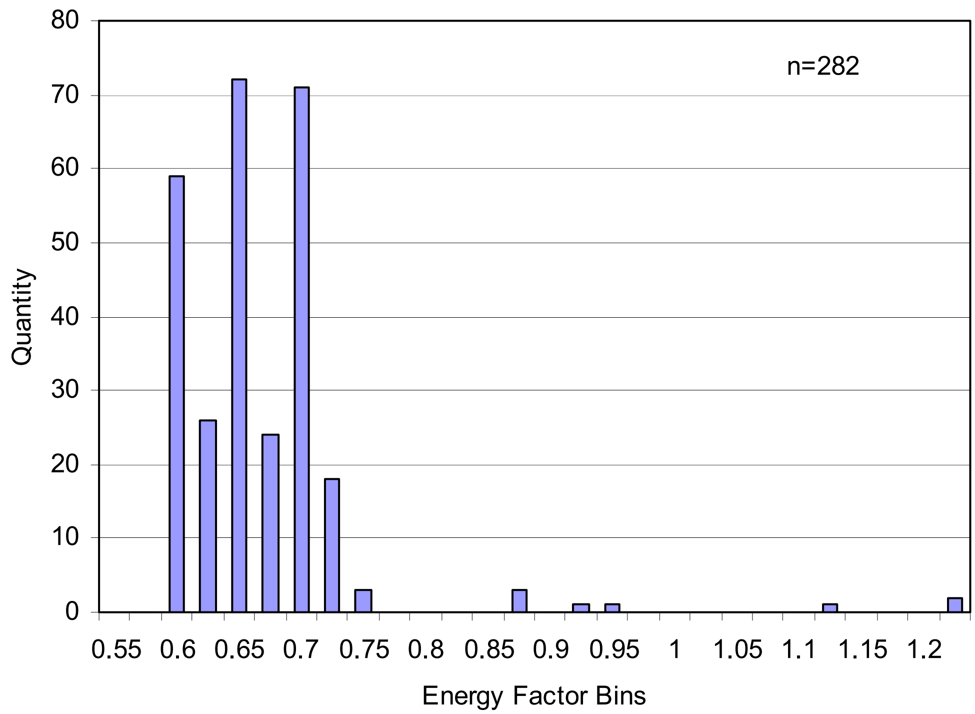
8.1.4 **Dishwashers**

Of the 345 surveyed homes, all had one dishwasher and one home had two. In the Baseline sample, 99.9 percent of homes had dishwashers installed. All of the dishwashers were purchased new for installation in the home.

KEMA was able to determine the Energy Factor – an efficiency indicator specific to dishwashers – for 281 of the 346 units observed. All of the dishwashers in the Participant sample exceeded ENERGY STAR efficiency criteria in force at the time of purchase: Energy Factor = 0.58. Figure 8-4 shows the distribution of the units for which the efficiency rating was determined by Energy Factor. The very high EFs are associated with compact models that use little energy and water per cycle. The general 2007 market share for ENERGY STAR dishwashers in the Northwest was 83.3 percent.[15]

RLW was able to determine the Energy Factor for roughly one-third of the units observed in the Baseline samples. Among these units, 30.7 percent met the EF = 0.58 standard. KEMA was able to determine the EF for those 346 dishwashers, the manufacturer and model numbers gathered were used to collect the Energy Factors associated with as many of the dishwashers as possible.

Figure 8-4. Distribution of Dishwashers in Participant Homes by Energy Factor



The large difference between Participant and Baseline samples in the saturation of ENERGY STAR dishwashers is likely attributable in large part to the program. Dishwashers are the only major appliances that are built in to new homes, and they are generally selected by the builder. According to program staff, builders typically install “contractor special” models that do not

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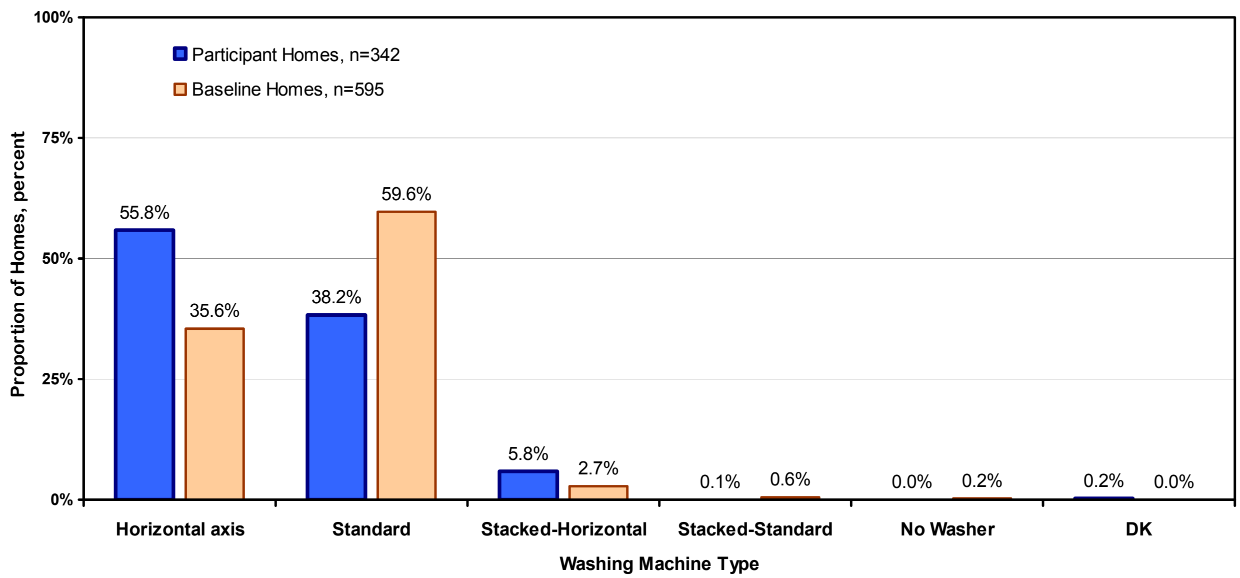
[15] The Energy Star criteria for dishwashers were reformulated in August 2009 and are now state in terms of kWh per year and gallons of water per cycle.

comply with ENERGY STAR standards. The large difference between the retail market share of ENERGY STAR dishwashers and the saturation of compliant models in the Baseline homes is consistent with this observation.

8.1.5 Clothes Washers

Ninety-nine percent of the Participant homes had clothes washers installed. The saturation of clothes washers was the same in the Baseline sample. Figure 8-5 displays the distribution of clothes washers in the two samples by configuration. The portion of horizontal axis machines in the Participant sample is 20 percent higher than the Baseline share. This difference is mirrored in the difference between the two samples in the share of standard top-loading models.

Figure 8-5. Clothes Washer Configurations



The ENERGY STAR criteria for clothes washers have evolved rapidly in the past five years, as shown in the following series of modifications:

- Criteria in force at time of Baseline Survey: Minimum Modified Energy Factor (MEF) = 1.42. [16]

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[16] MEF is the quotient of the cubic foot capacity of the clothes container divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, the hot water energy consumption, and the energy required for removal of the remaining moisture in the wash load. The units are cubic feet per kWh per cycle (cu ft/kWh/cycle).

- Revision January 1, 2007: Minimum MEF = 1.72, Water Factor $\leq$ 8.0[17]
- Revision July 1, 2009: Minimum MEF = 1.80, Water Factor $\leq$ 7.5
- Scheduled revision January 1, 2010: Minimum MEF = 1.60, Water Factor $\leq$ 6.0

In the Baseline study, 88.8 percent of the clothes washers met the ENERGY STAR criteria in force at the time, and 38 percent had MEFs over 1.8. In the Participant sample, roughly 50 percent of the clothes washers qualified for ENERGY STAR, with the recently established criterion of MEF = 1.72. This is equivalent to the market share of ENERGY STAR qualified clothes washers estimated by NEEA in its Energy Star Consumer Products Market Progress Evaluation Report for 2007.[18]

[17] WF is the quotient of the total weighted per-cycle water consumption divided by the capacity of the clothes washer. The lower the WF, the more water-efficient the machine.

[18] KEMA, Inc. 2007. *ENERGY STAR Consumer Products Market Progress Evaluation Report.* Portland, OR: Northwest Energy Efficiency Alliance

8.1.6 Clothes Dryers

Virtually all homes in both the Participant and Baseline samples had clothes dryers installed. Figure 8-6 shows the distribution of those dryers by fuel. Electricity is by far the most prevalent dryer fuel, accounting for 87 percent of the units in the Participant sample and 89 percent of the units in the Baseline sample.

Figure 8-6. Distribution of Dryers in Participant and Baseline Homes by Fuel

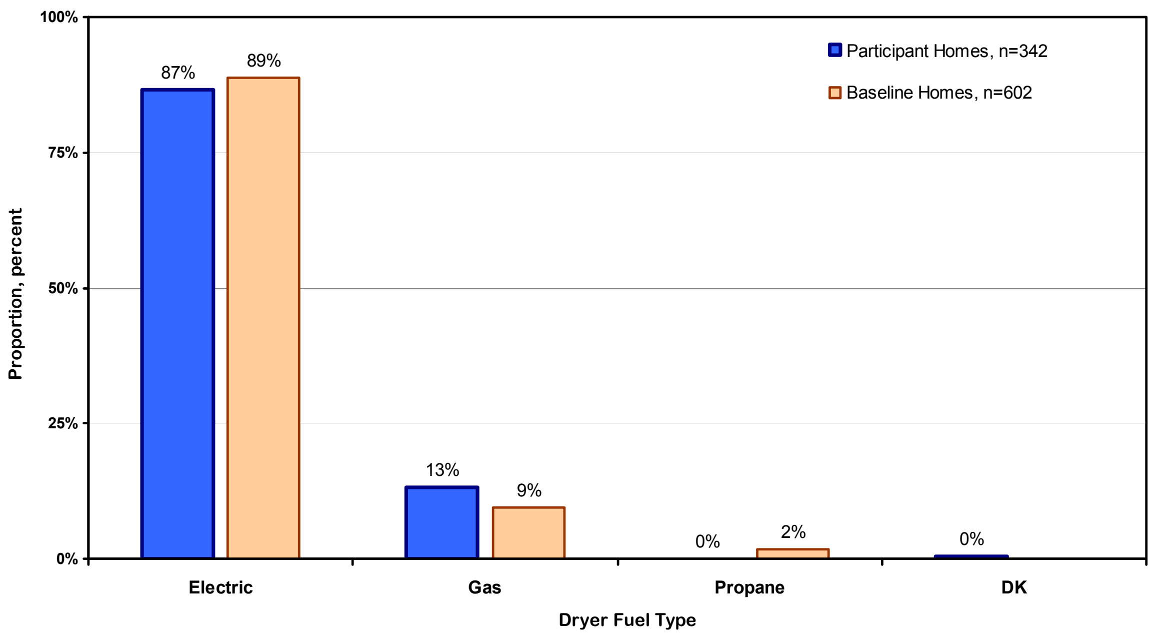
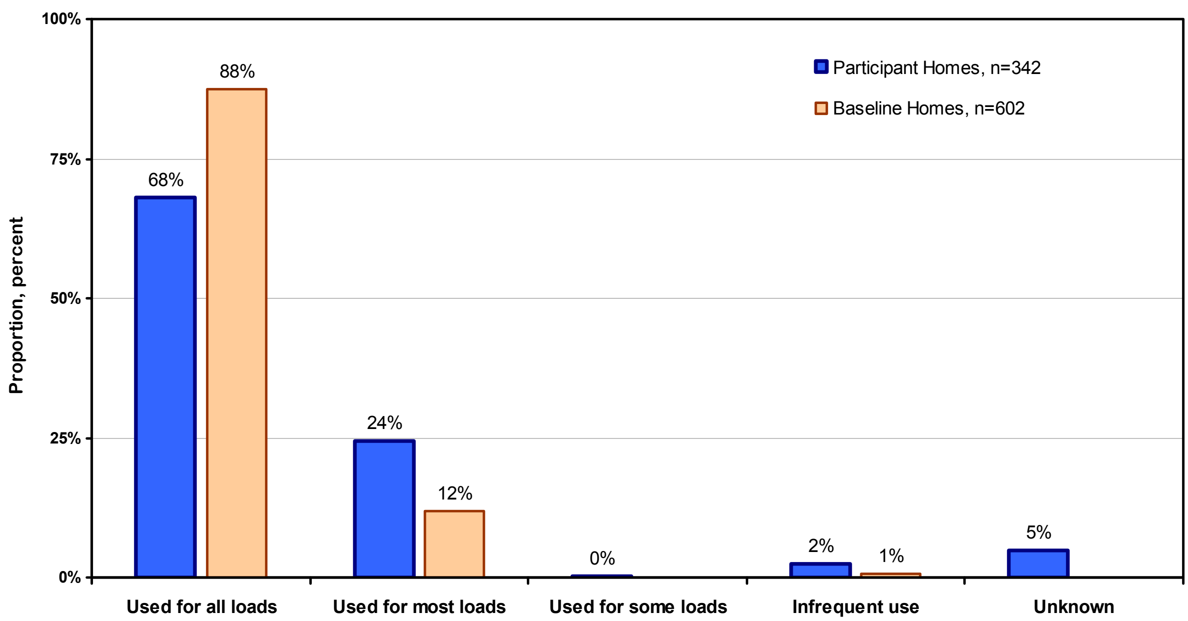


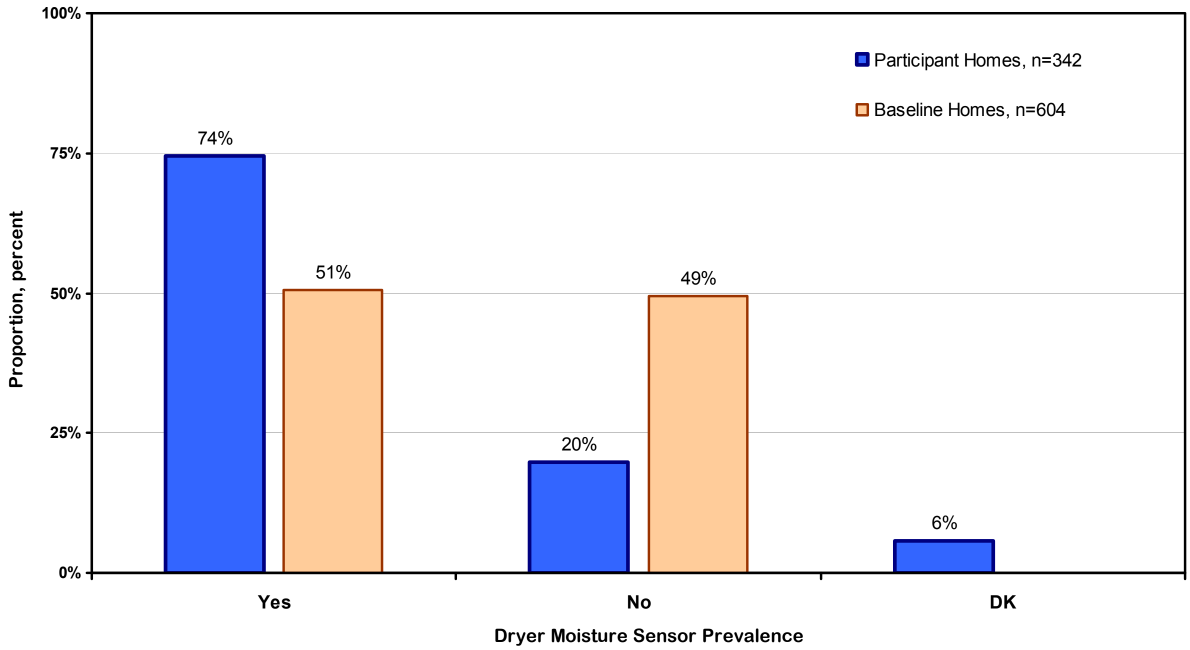
Figure 8-7 shows the distribution of the dryers found in both samples by frequency of use as reported by the homeowner. Homeowners in the Participant sample reported slightly lower frequency of dryer use compared to owners in the Baseline sample. Specifically, 68 percent of the homeowners in the Participant sample reported using their dryers for all washer loads, compared to 88 percent of the owners in the Baseline sample. Most of this difference is made up for by a higher proportion of Participant owners reporting that they use their dryers for "most" wash loads.

Figure 8-7. Distribution of Dryers by Frequency of Use



Moisture sensors detect the amount of moisture in the clothing within the clothes dryer so that the drying air will no longer be heated once the moisture drops below a certain threshold. This feature reduces energy consumption and mechanical wear. Figure 8-8 shows the distribution of dryers in the two samples by the presence of moisture sensors. Seventy-four percent of units in the Participant sample had moisture sensors versus 51 percent in the Baseline survey.

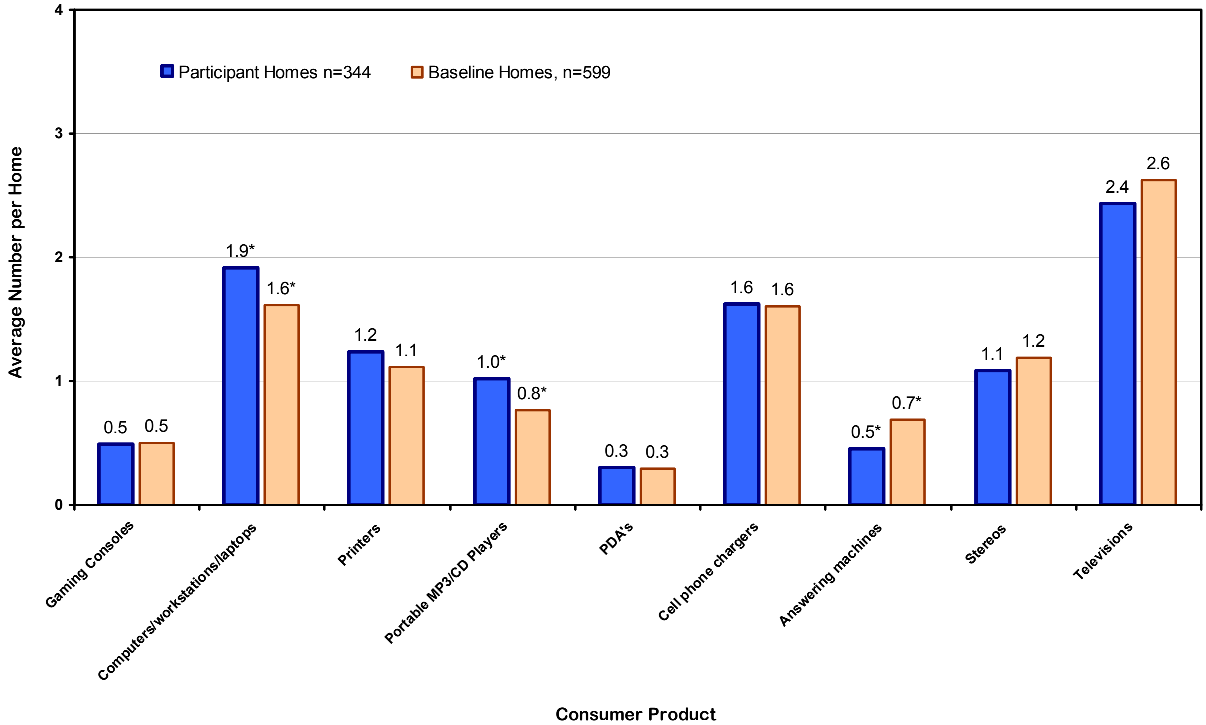
Figure 8-8. Distribution of Dryers in Participant and Baseline Homes by Presence of Moisture Sensor



8.2 Small Appliances and Plug Loads

Figure 8-9 shows the average number of consumer electronic devices of various kinds found in Participant and Baseline homes. The two samples differed very little on this set of variables. There were slightly more computers and portable MP3/CD players in the Participant homes, and slightly fewer answering machines.

Figure 8-9. Average Number of Consumer Electronic Devices in Participant and Baseline Homes



9. Lighting Hours of Use Study

9.1 Introduction

This presents the results of a lighting hours of use based on data obtained from lighting loggers installed in a subsample of the Participant homes. The loggers were installed in homes between August 2008 and May 2009, and results were annualized using seasonal hours of darkness variables. *The study addresses only interior lights.*

Hours of use estimates for residential lighting are used in the Northwest for various analyses, such as calculating CFL savings. Average annual usage estimates of just over 2.0 hours per day have been in used in recent years, based on lighting logger studies conducted in the 1990's. When these estimates were made, homes contained an average of fewer than 45 lamps per home. With the current trend to larger homes and many more lamps per home (averaging over 70 lamps per home in the current study), a reexamination of average hours of use per lamp was warranted.

9.2 Methodology

The general approach for this study was as follows:

- Install a large number of lighting loggers in a subsample of ESNHs that were already receiving onsite surveys as part of the Northwest ENERGY STAR Homes Program evaluation;
- Collect data on lighting attributes (location, fixture types, lamp types, lamp wattage, etc.) as part of the general onsite survey;
- Annualize logger data using a regression analysis that incorporates seasonal variables; and,
- Summarize average hours of use and daily usage patterns, in total and by various segments.

9.2.1 Sample Development

The sample for this study consisted of a subset of homes that were already recruited for onsite surveys as part of the Northwest ENERGY STAR Homes Program evaluation. Recruitment activities included sending out letters to over 3,900 homes that were built under the Northwest ENERGY STAR Homes Program during the January 1, 2006 – September 30, 2007 period. During recruitment activities, home occupants were asked if they would be willing to host one of two survey types: a basic onsite survey or an enhanced onsite survey that included installation of lighting loggers. Despite the offer of an incentive, customer response to the logger request was not strong. In the end, we were able to recruit 68 homes were recruited into the study. Table 9-1 shows the distribution of homes by state and city.

Table 9-1. Distribution of Lighting Logger Sites

State	City	Logger Sites	State Subtotals
ID	Boise	6	
ID	Meridian	3	9
MT	Missoula	3	3
OR	Albany	1	
OR	Bend	9	
OR	Central Point	1	
OR	Eugene	5	
OR	Hillsboro	5	
OR	Portland	10	
OR	Troutdale	1	32
WA	Auburn	1	
WA	Federal Way	2	
WA	Fort Lewis	1	
WA	Issaquah	4	
WA	Lynnwood	1	
WA	Olympia	1	
WA	Pasco	3	
WA	Redmond	1	
WA	Renton	1	
WA	Seattle	5	
WA	Snoqualmie	1	
WA	Vancouver	2	
WA	Yakima	1	24
Total		68	68

9.2.2 Onsite Approach

On arrival at participating households, auditors conducted thorough onsite surveys that included a detailed lighting inventory of the home. The lighting inventory recorded lighting attributes by fixture group (fixtures that were controlled by the same mechanism): location, control type, fixture type, number of fixtures, number of lamps per fixture, watts per lamp, and lamp type.

Lighting loggers were then installed on a random sample of interior fixtures throughout the home.

To implement the random sample, auditors determined the number of fixture groups that could reasonably be monitored. They then utilized a random number to determine the first fixture group to be monitored and proceeded to monitor every *i*'th fixture group within the home, covering the rooms in the home in a sequential pattern. Overall, 467 lighting loggers were installed in the 68 logged homes, for an average of 6.9 loggers per home.

DENT SMARTlogger TOU (time of use) 3G Lighting Loggers were utilized in the study.

Given the variability of lighting use over the course of the year, we tried to keep loggers installed as long as possible in order to support reliable annualization of the observed hours of use. Loggers were kept in the field an average of 6.5 months, with a minimum of 4.2 months and maximum of 8.2 months. Table 9-2 shows the number of loggers installed during each month of the study period.

Table 9-2. Loggers Installed by Month

Month	# Loggers Installed
Aug 08	62
Sep 08	298
Oct 08	421
Nov 08	467
Dec 08	467
Jan 09	467
Feb 09	467
Mar 09	467
Apr 09	175
May 09	18

9.2.3 Analysis

After retrieval, each lighting logger was downloaded to a computer database using the SMARTware 2008 software provided by DENT. Logger data was converted to a percent-on-per-hour format for each day of the logger install period. The loggers and data were then merged with survey data. Each logger's data was analyzed for technical deficiencies to increase the likelihood that the loggers included in final study results represented true hours of use. As a result of this analysis, loggers were removed from the study due to damage, inconsistent time stamps, and likelihood that the logger sensitivity wasn't set correctly such that the logger did not adequately record lighting activity. In addition, logger histories for 22 loggers were manually truncated because it appeared that the logger recorded accurately for an initial period after installation, but then failed to record any lighting activity subsequent to some "failure" event. Table 9-3 provides a disposition of lighting loggers utilized in the study.

Table 9-3. Lighting Logger Disposition

Disposition Category	# of Loggers
Total loggers installed	467
Damaged or malfunctioning loggers	-19
Logger not linked to survey data	-2
Loggers reviewed for reasonable results	446
Loggers with suspect data	-34
Loggers included in the final analysis	412

Extrapolation to Months without Logger Data. The logger data essentially covers the months from September 2008 to April 2009 (since August 2008 and May 2009 data were fairly sparse). In order to get at annual operating hours we needed to extrapolate our findings to the May-August period. For this extrapolation, we utilized "hours of darkness" variables to seasonally adjust each logger's results and project those results to missing months.

For fixtures in a given month that were either monitored for less than half the month or not monitored at all, we applied seasonality factors to impute the missing monthly usage values (average hours per day and percent on per hour). We ran a regression that determined the change in lighting usage as a result of a change in daylight hours. We ran separate regressions by day type (weekend versus. weekday) and room type (sensitive to daylight hours: kitchen, dining room, living room versus. not sensitive: bathroom, bedroom, hallway). The variable that was used in each equation was the "hours of darkness" in each month (calculated as 24 minus daylight hours).

Table 9-4 shows the regression results for the four models. As the table shows, there was not a real strong relationship between average daily hours of use and hours of darkness. The R^2 parameters are low and the significance of the "darkness" parameter is not very high. Given these results, we chose to only seasonally adjust the lighting hours for the "sensitive" location types. For the non-sensitive location types, we utilized mean usage for the logging period to impute lighting usage for months outside of the monitoring period.

Table 9-4. Lighting Usage as a Function of Hours of Darkness - Regression Results

Location Type	Day type	Intercept	T stat	Darkness Parameter	T stat	Adjusted R^2
Not sensitive	Weekday	1.93	2.61	-0.05289	-0.98	0.0000
Not sensitive	Weekend	0.94	1.38	0.01865	0.37	-0.0006
Sensitive	Weekday	-0.05	-0.09	0.09823	2.27	0.0038
Sensitive	Weekend	0.57	0.91	0.06084	1.33	0.0007

For loggers in sensitive locations, we then used the parameter estimates to develop lighting usage shares across 12 months. For each day type, the imputed monthly value for a fixture was calculated as follows:

$$m_{xi} = (M_x / S) \times s_i$$

where:

m_{xi} = imputed usage value for month i and fixture x

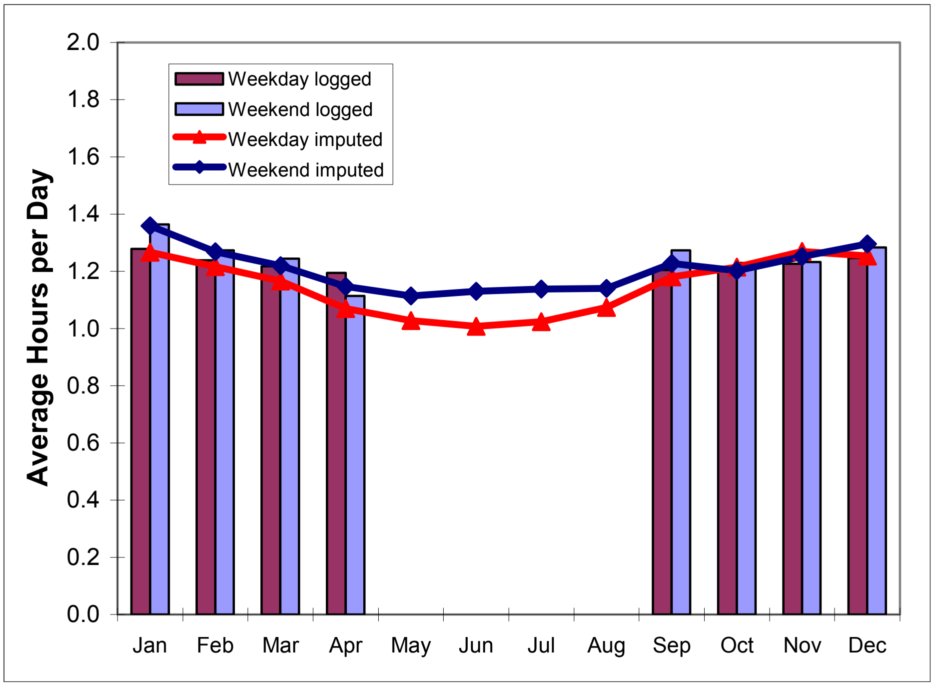
M_x = the sum of monthly monitored usage values for fixture x

S = the sum of the seasonal factors that correspond to M_x

s_i = Seasonal factor (one set per day type/room type combination) for month i

Figure 9-1 shows the relationship between recorded and imputed hours of use. The analysis seems to provide a reasonable adjustment is lighting usage for the summer months that were not logged. As shown, the weekday adjustment is somewhat more pronounced than the weekend adjustment.

Figure 9-1. Extrapolation using Hours of Darkness Variables



Weighting. We applied weights to the final cleaned dataset by room type to adjust for the fact that the monitored sample differed from the lighting inventory with respect to the distribution of lamps by room type. In our analysis, we found that the major driver of the variation in lighting usage is the location of the fixture. Since a detailed inventory was captured at every home for the 345 ESNHs surveyed, we were able to compare the monitored sample against the actual distribution of fixtures across all surveyed homes. We found slight differences and, as such, developed adjustment weights. The weights were set up to adjust the distribution of logged fixtures to the estimated lighting wattage distribution of ESNHs across room type.

Table 9-5 shows the adjustment weights.

Table 9-5 Adjustment Weights for Hours of Use

	Monitored Sample Fixtures		ESNH Wattage		
Location	Frequency	Percent	Frequency	Percent	Weight*
Bathroom	80	19.4%	2,349,292	23.0%	1.18
Bedroom	74	18.0%	1,499,812	14.7%	0.82
Closet	25	6.1%	296,224	2.9%	0.48
Hall	59	14.3%	1,164,408	11.4%	0.80
Kitchen	50	12.1%	2,215,610	21.7%	1.79
Living Room	66	16.0%	1,495,757	14.6%	0.91
Office	18	4.4%	261,176	2.6%	0.58
Other	40	9.7%	941,420	9.2%	0.95
Total	412	100.0%	10,223,698	100.0%	

* Weight = ESNH percent / Monitored Sample percent

9.3 Results

We present the following results in this section:

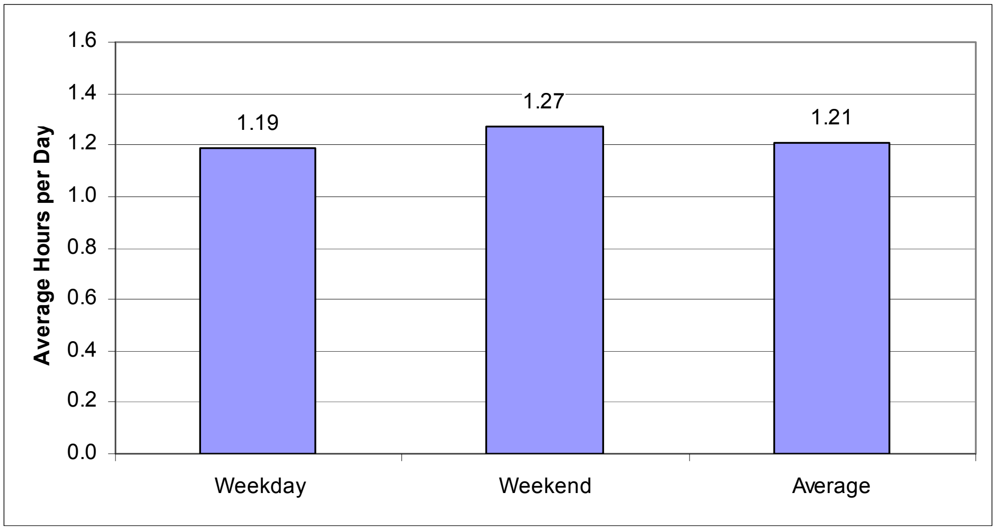
- Overall results
- Results by various categories
- Monthly and hourly results
- Usage distribution results

9.3.1 Overall

Figure 9-2 shows the overall results of the analysis. As shown, the average annual lighting hours per fixture is estimated to be 1.21 hours per day. The standard error of the average annual estimate is 0.126 or about 10.4%. This provides a 90% confidence interval of 1.01 to 1.42 hours per day.

Weekday usage is somewhat lower than weekend usage at 1.19 hours per day versus 1.27 hours per day.

Figure 9-2: Average Lighting Usage per Fixture per Day



For creating a point of comparison to experience elsewhere, we are aware of no other residential lighting logger studies that focused only on CFLs installed in new homes. New homes differ systematically from existing homes in ways that may affect lighting hours of use. Specifically, new homes tend to:

- Enclose more area than average existing homes in most geographic areas.
- Contain larger numbers of permanent lighting fixtures and sockets.
- House somewhat larger numbers of occupants.

To the extent that new homes are included in other residential lighting logger study samples at all, it is only in proportion to their representation in the population of homes at the time of the survey.

Despite these complications, comparison of the Northwest ENERGY STAR homes results to those of other recent studies show that the hours of use estimated for Participant sample are consistent with other developments in the field. Table 9-6 shows the average hours of use and other findings from the current study as well as the *Draft Evaluation Report: 2006 – 2008 Upstream Lighting Program* for the California PUC (KEMA,forthcoming) and *CFL Metering Study* prepared for the California IOUs (KEMA, 2005). The trend towards lower hours is likely associated with the increased saturation in CFLs and lighting fixtures more generally. The logic behind this hypothesis is as follows:

- New homes are larger and have more fixtures installed.
- To serve roughly similar numbers of occupants on roughly similar (on average) schedules, a smaller percentage of those fixtures need to be on at a given time. Hence the inverse relationship between number of fixtures or sockets on the one hand and average hours of operation on the other.
- The same logic applies to CFLs as more of them are installed in the home.

The clearest empirical support for this hypothesis comes from the lighting logger study carried out in support of the evaluation of the California statewide residential lighting program. This study monitored hours of use for over 8,000 CFLs installed in 1,200 homes. Based on these data, the study team developed an Analysis of Covariance (ANCOVA) model of hours of use. Room location of the bulb had the strongest relationship to hours of use, as measured by the t-statistic of the coefficients. The saturation of CFLs had a large negative impact on hours of use (-0.423 hours on average) although the statistical strength of this relationship was only moderate ($p = 0.062$). The number of sockets also had a small negative coefficient (-0.004) which was nonetheless statistically significant ($p = 0.042$).

In addition to the increased number of lamps per home, another factor that may be influencing the hours of use in the current study is occupant behavior. Since the current study involves occupants of ESNHs, there is the possibility that these households are more energy conscious than the average home and may use their lighting more sparingly. In addition, recent concern about global warming, and its relationship with energy usage, might be causing the average home to use their lights more judiciously.

Table 9-6. Comparison of Current Results to Previous Studies

Study	Lamps per Home	Fixtures per Home	Average sq. ft.	Average Lighting Hrs	Lamp-hours*	Notes
Current Study – Logged Homes	74	48	2,096	1.2%	90	Only interior monitored
Overall NW ENERGY STAR Participant Sample	73	48	2,272	n/a	n/a	
KEMA CA Lighting 2009: Single Family Subsample	50			1.8		Only interior monitored
KEMA CA Lighting 2005	40	24	1,550	2.3	92	Only interior monitored

* Lamp-hours = (lamps per home) * (average lighting hours)

9.3.2 Results by Category

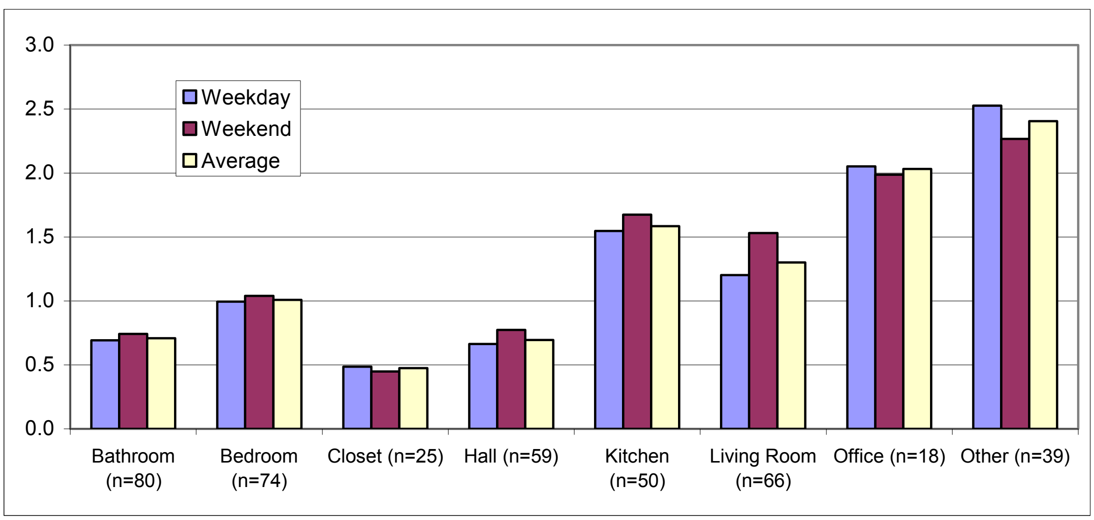
Results are next presented by a number of different categories:

- Room type;
- Lamp type;
- Fixture type;
- Lamps per home;
- Home size;
- Occupants; and
- State.

In the following charts, the "*n*=" numbers show the number of logged lamps that are being used in the calculations.

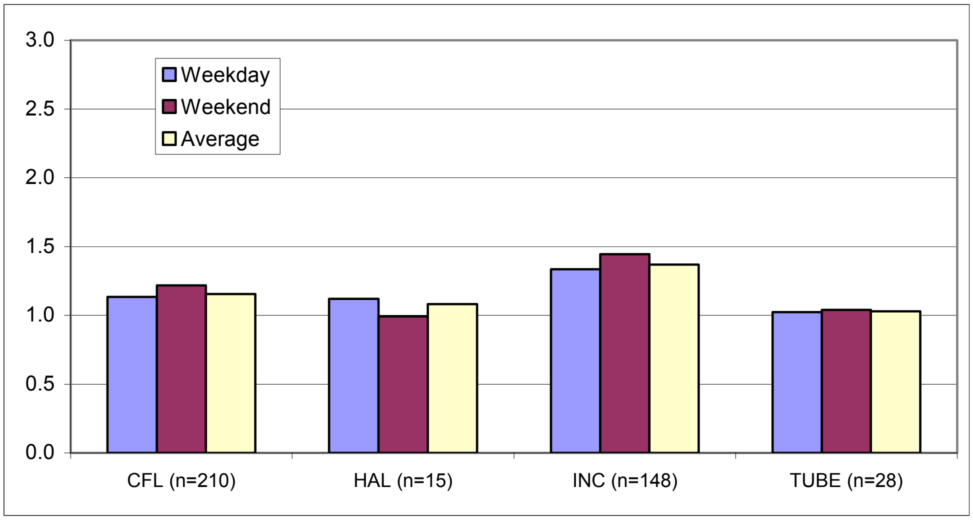
Room Type. An important factor affecting lighting usage is room type. Figure 9-3 shows lighting usage by room type. The room types with the largest lighting usage are kitchens, home offices, and "other." The other category includes locations such as garages, laundry rooms, and basements. Much of the large "other" usage is due to the presence of several garage fixtures that were on 24 hours per day.

Figure 9-3 Hours of Use per Day by Room Type



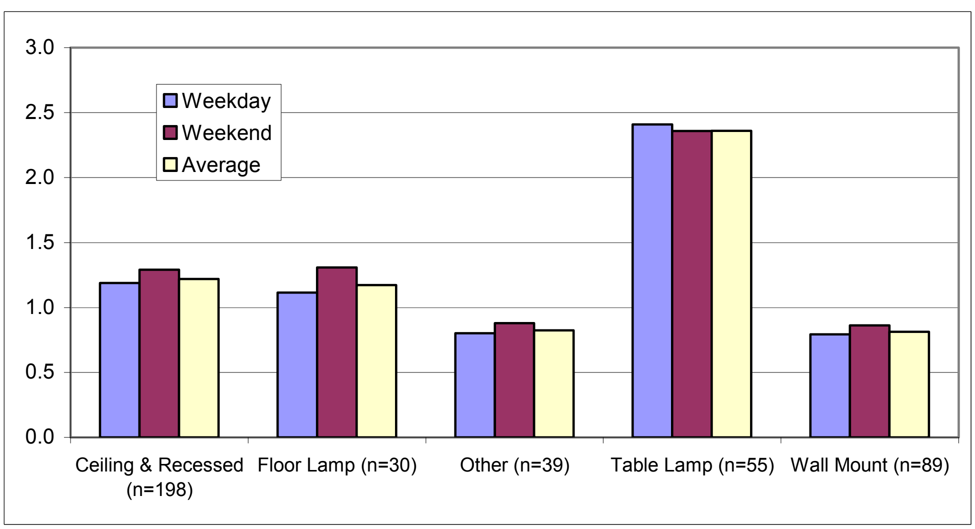
Lamp Type. Another result of some interest is the lighting usage by lamp type. Figure 9-4 summarizes this result. As shown, the hours of use don't vary much by lamp type, although the incandescent lamps appear to get a little more use. While some studies have shown that CFLs have tended to be installed in high-use fixtures, the high overall penetration of CFLs in the ESNHs might negate this result.

Figure 9-4: Hours of Use per Day by Lamp Type



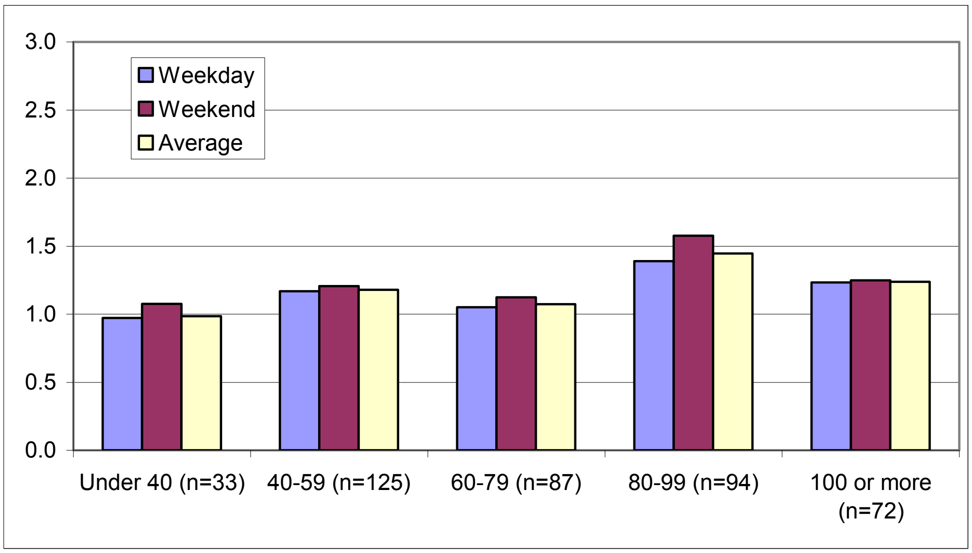
Fixture Type. A look at lighting use by fixture type (Figure 9-5) may partly explain why incandescent lamps are associated with the largest usage. As Figure 9-5 shows, table lamps average the highest hours of use of the studied fixture types. Incandescent lamps are utilized in about two-thirds of the table lamps, while CFLs are installed in about 60% of the ceiling/ recessed fixtures.

Figure 9-5: Hours of Use per Day by Fixture Type



Lamps per Home. While the discussion above hypothesized that lower average lighting usage across several studies might be associated with the number of lamps per home, within-study results don't directly support this notion. As Figure 9-6 shows, hours of use per day don't seem to vary that much by lamp count per home, except for the group with 80 to 99 lamps per home showing higher overall usage (which is counter to the argument that homes with more lamps may use each lamp less, on average). The relatively small sample size was not sufficient to support a rigorous correlation between number of lamps per home and lighting usage.

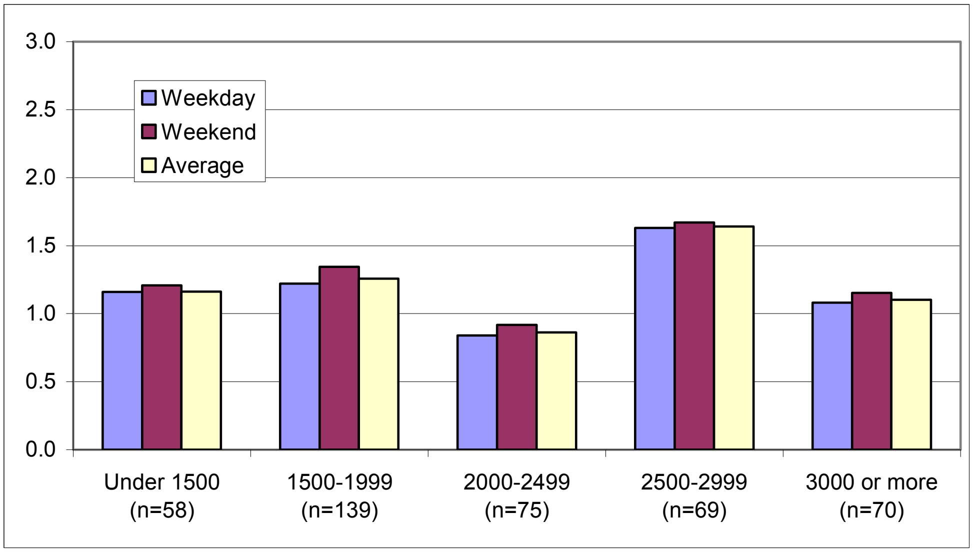
Figure 9-6: **Hours of Use per Day by Lamp Count per Home**



Home Size .

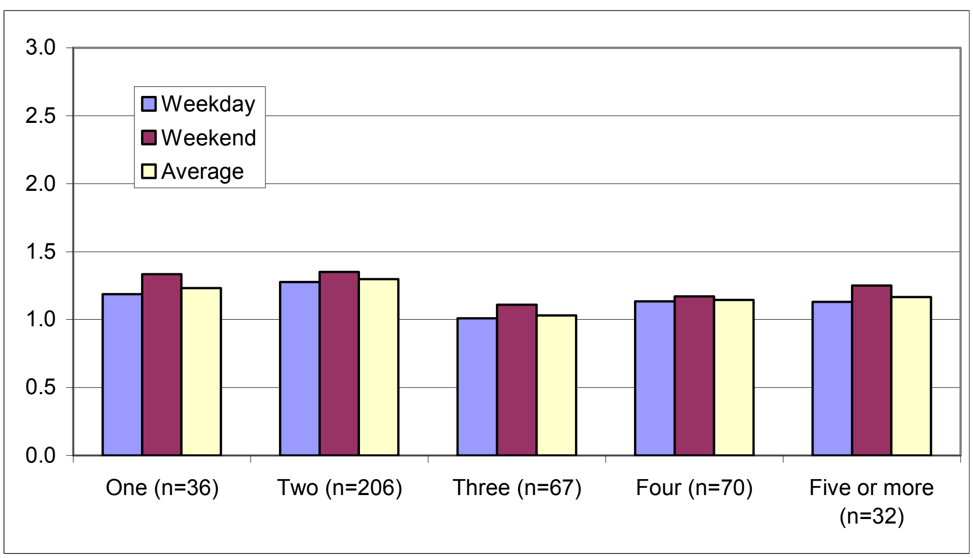
Figure 9-7 shows average lighting usage by size of the home. One might expect to see lower average usage in larger homes because it is likely there are more rooms and fixtures and, as such, on average each fixture might be used less. We did not find any significant differences by home size, although usage in the lowest use group (2000-2499 square foot homes) was only about half of that for the highest use group (2500-2999 square foot homes).

Figure 9-7: Hours of Use per Day by Home Size (in Square Feet)



Number of Occupants in the Home. Lighting usage did not vary significantly by household size, either, as shown in Figure 9-8. Somewhat interestingly, the smaller households were associated with slightly higher usage estimates.

Figure 9-8: Hours of Use per Day by Number of Residents



Figures 9-9 and 9-10 show average lighting usage by selected demographics. Homes with seniors (age 65+) tend to have lower usage, although these estimates are based on very few sample points. Average lighting usage for homes with no children is somewhat higher than usage for homes with children.

Figure 9-9: Hours of Use per Day by Presence of Seniors

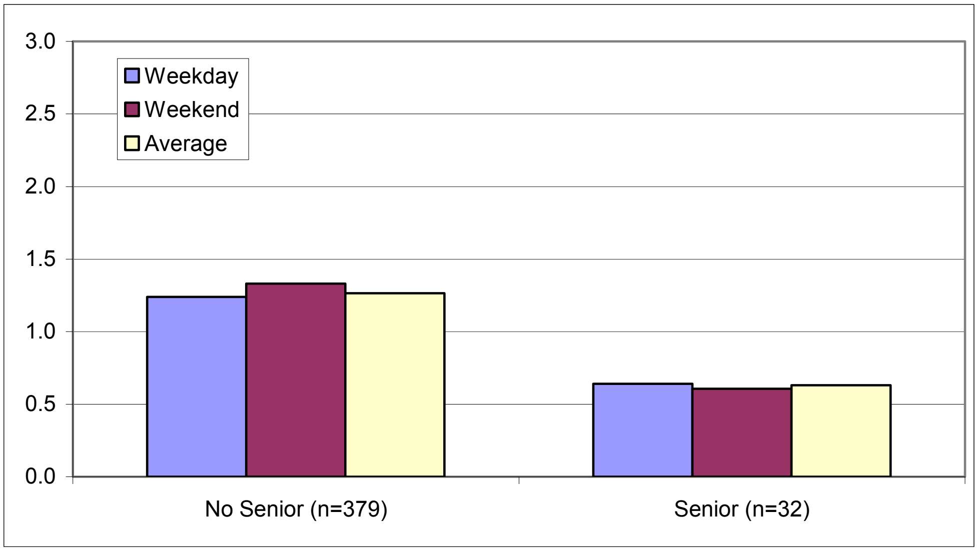
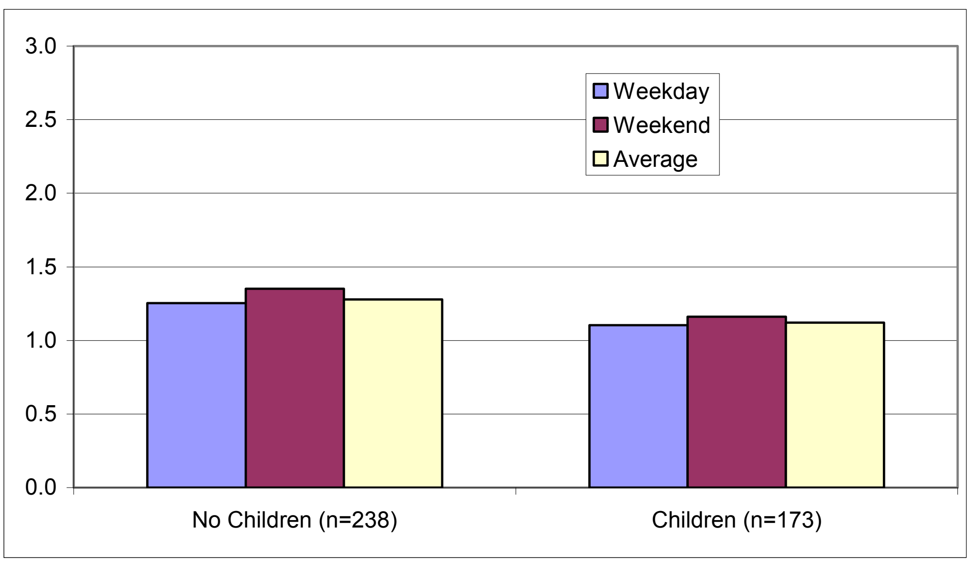
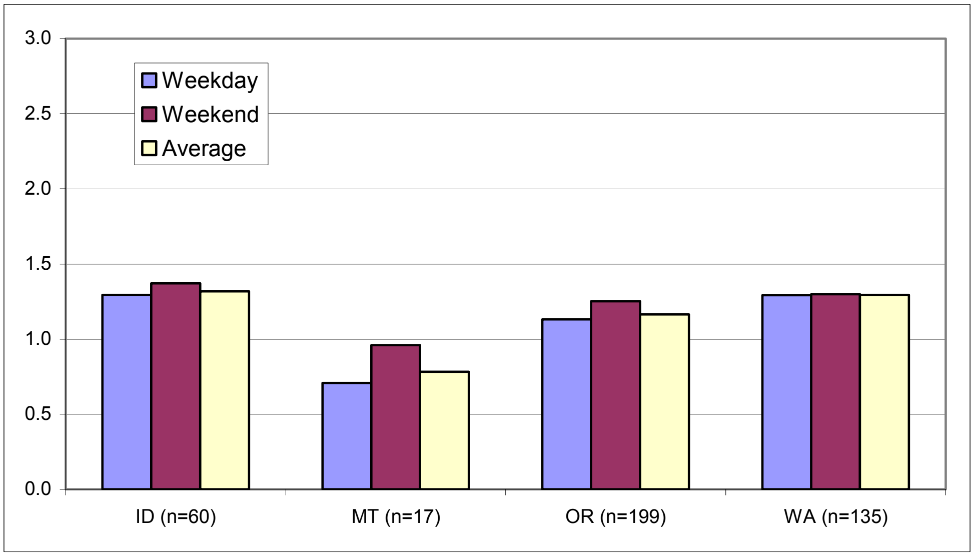


Figure 9-10: Hours of Use per Day by Presence of Children



Variations by State. Figure 9-11 shows average lighting usage by state. Overall, annual usage does not appear to vary much by state. Montana shows the lowest usage estimates, but the results are based on lamps logged in only three homes.

Figure 9-11: Hours of Use per Day by State



9.3.3 Results by Month and Hour

Figure 9-12 shows average lighting usage by day type and month. Weekend usage is higher that weekday usage in most months (exceptions being October and November). Usage tends to follow a fairly distinct seasonal pattern, with the exception of December, which has somewhat lower average usage than November (possibly due to holiday effects).

Figure 9-12: Hours of Use per Day by Month

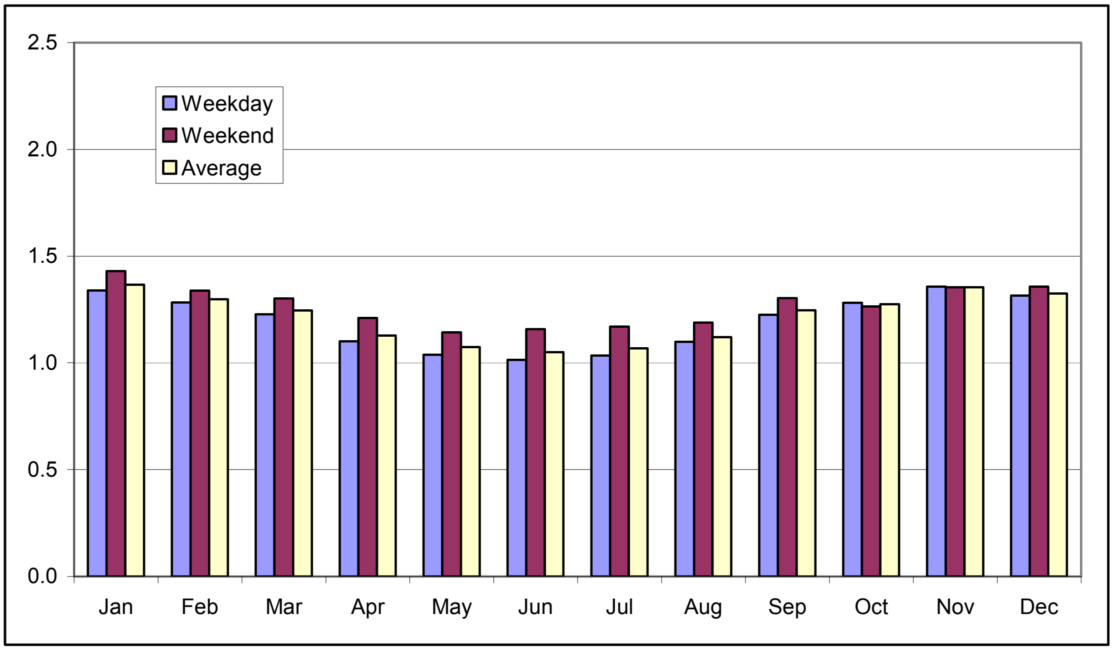


Figure 9-13 shows typical hourly usage patterns developed from the logging data. These patterns are fairly similar to other patterns we have seen in residential logger studies, although the overall level of usage is down. Weekday usage spikes between 7 and 9 in the morning and then again in the evening. Weekend usage increases gradually during the morning hours and then remains fairly level during the day and peaks during the prime evening hours (7 to 9 pm).

Figure 9-13: Lighting Load Shapes by Day Type

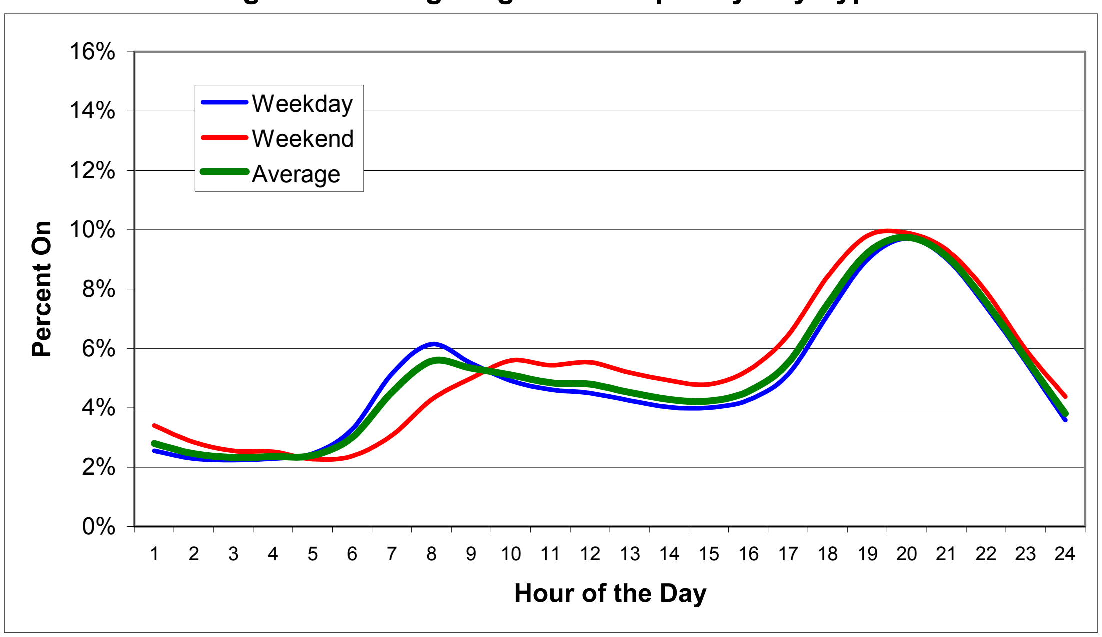
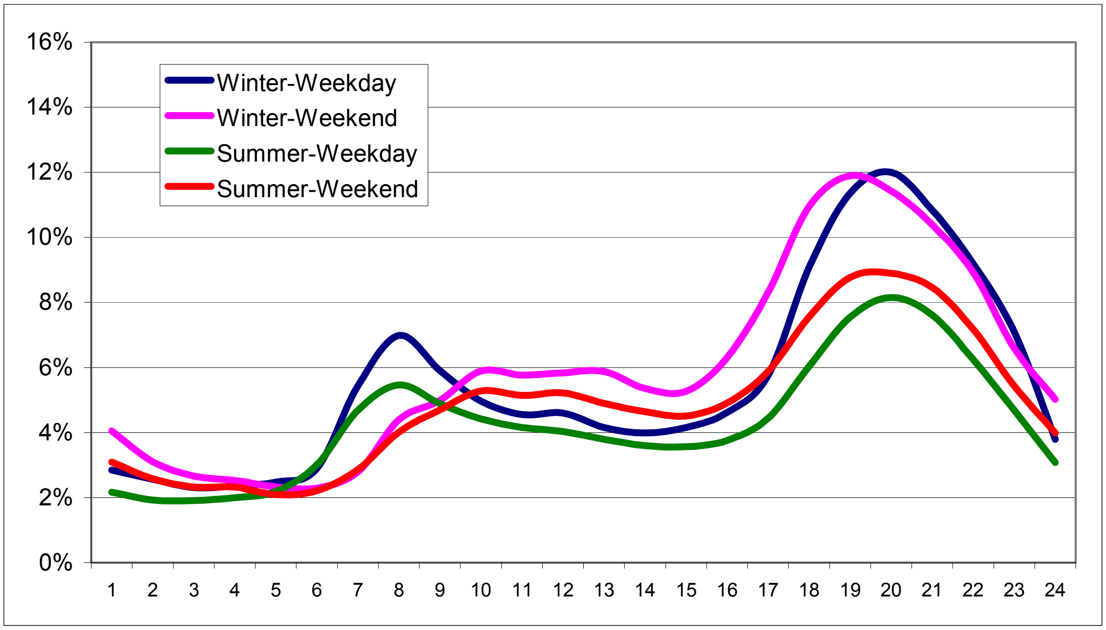


Figure 9-14 shows load shapes by season and day type. Consistent with the monthly usage pattern, winter load shapes are higher that the summer shapes (by day type). Winter shapes tend to spike at higher levels in both the morning and evening, while midday usage is more a function of day type. The weekend day type has higher midday use that the weekday day type, most likely driven by home occupancy patterns, as more people tend to be home on weekends.

Figure 9-14: Lighting Load Shapes by Season and Day Type



9.3.4 Usage Distribution Results

Figure 9-15 shows the distribution of usage across lamps in the study, and Figure 9-16 shows the cumulative distribution. As shown, over half of the lamps are used less than one hour per day, and almost all the lamps (over 90%) are used less than three hours per day. Very few lamps (less than 4%) are used more than five hours per day, and even fewer lamps (less than 1%) are used more than 10 hours per day.

Figure 9-15: Lighting Usage Distribution across Lamps

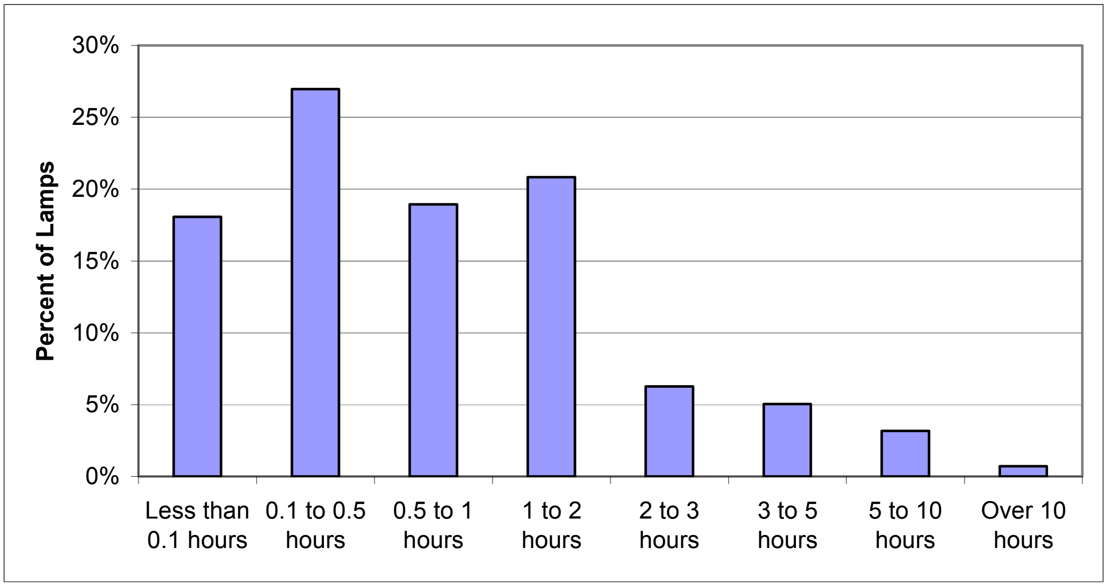
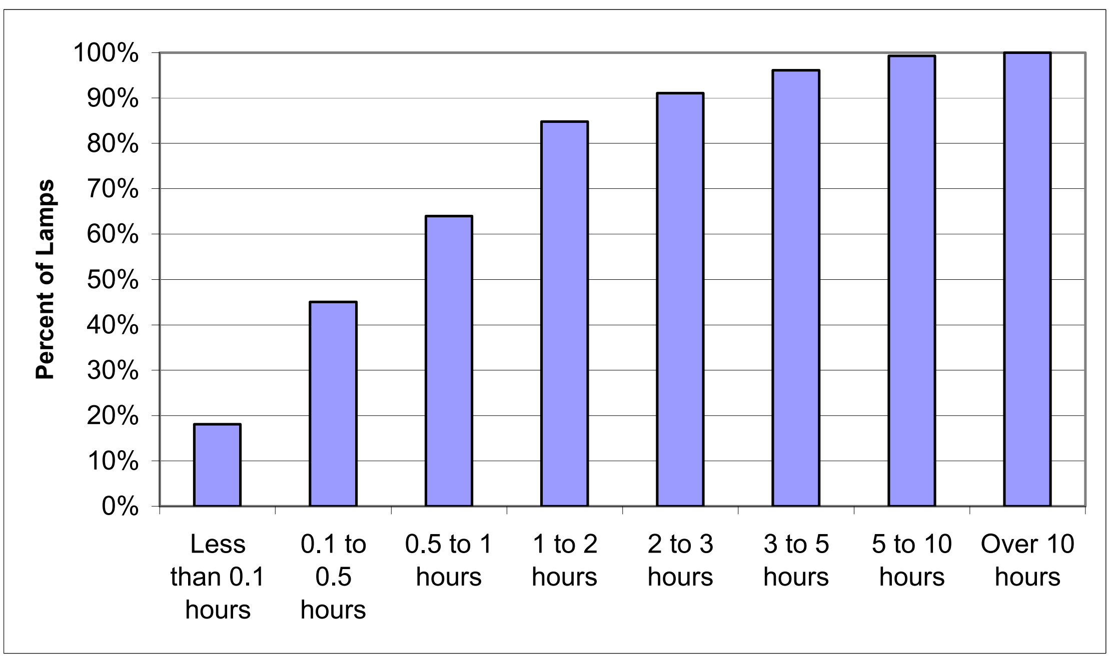


Figure 9-16: Cumulative Lighting Usage by Usage Category



9.4 Conclusions

The lighting usage study in Northwest ENERGY STAR participant homes shows average hours of use per lamp at lower levels than found in previous studies. It is likely that the larger numbers of lamps per home in this study contribute to the lower use per lamp estimates. It is also likely that occupants of ESNHs are more energy conscious than average households, which may also contribute to lower lighting usage estimates.

While the current study provides some insight to lighting usage levels and patterns, it should be kept in mind that the study focused on a particular type of home – the ENERGY STAR New Home. Direct generalization of these results to the average home is not advised, especially since this study was conducted on a relatively small sample of 68 homes.

10. Impact Assessment using Bill Analysis

This section presents the methods and results of a billing analysis that KEMA undertook to estimate energy savings associated with construction of a new home according Northwest ENERGY STAR program requirements. We begin with a brief overview of the kinds of models developed and the data used to estimate them. We next discuss the form of the models in detail and provide the rationale for the modeling approach employed. We also explain how the model results are used to estimate reductions in energy use associated with ENERGY STAR certification for different fuels and sets of end uses. We conclude this section with a discussion of the results of the model and their relationship to findings reported in the New Home Characterization.

10.1 Introduction

10.1.1 Overview

KEMA conducted a billing analysis to compare the annual electricity and gas consumption of homes in the Participant sample to the energy use of homes in the Baseline sample, using regression analysis to account for influences on energy use other than program participation. These influences include differences among individual homes in the two samples in ambient climate conditions, household demographics, home configuration, and complement of heating and cooling equipment. We modeled sites individually as a function of heating and cooling degree days. These models provide site-level estimates of normalized annual consumption (NAC) as well as a decomposition of the overall NAC into baseload and, depending on the optimal model, heating and/or cooling load. We perform a second stage regression with NAC as the dependent variable to estimate the effect of participation controlling for other relevant characteristics such as square footage of the house and number of occupants. We then used the coefficients on those variables to estimate the energy savings associated with building a home that qualifies for Northwest ENERGY STAR Homes certification compared to a reasonably contemporary baseline home.

KEMA developed models of energy consumption for the following fuels and end-uses:

Natural Gas

- Overall consumption
- Space heat
- Base load

Electricity

- Overall consumption
- Cooling
- Space Heat
- Base load

10.1.2 Data Resources Used in the Model

Data sources for the models included the following:

- Monthly electric billing records provided by the electric utilities serving the sample homes.
- Monthly natural gas billing records provided by the gas utilities serving the sample homes.
- On-site survey data as described in the new home characterization survey summarized earlier in this report.
- Ten years of weather data from the National Oceanic and Atmospheric Administration (NOAA).

As part of the recruitment process for both the Participant and Baseline samples, the recruiters and field engineers requested billing information releases from the respondents. We needed to approach respondents to the Baseline survey who had provided consent at the time of the original study again, since those consent forms had expired by the time of the current study. Not all respondents to the Baseline and Participant surveys provided billing information releases.

KEMA collected the billing information releases from the respondents and routed them to the appropriate gas and electric utilities. In all, we received billing records from 26 electric distribution companies and coops and from 7 gas distribution companies.

Table 10-1 displays the names of the utilities that provided electric and gas billing data for use in this study.

Table 10-1. Sources of Billing Data for this Study

Utility	Accounts			
	Electric		Gas	
	Baseline	Participant	Baseline	Participant
Avista Utilities	4		9	4
Benton County PUD	1			
Big Bend Electric Coop		4		
Blachly-Lane Electric	1			
Cascade Natural Gas				1
Central Electric Coop	3	4		
City of Centralia	2			
Central Lincoln PUD	1			
Clark PUD	8	14		
Columbia River PUD		1		
Cowlitz County PUD	1			
Energy West				3
Emerald PUD		5		
Forest Grove Light & Power		1		
Franklin County PUD	3			
Idaho Power	52	63		
InterMountain Gas			63	64
Kootenai Electric Cooperative	2	2		
Lane Electric Cooperative	1			
Lewis County PUD	2			
Mason County PUD	1			
Midstate Electric Coop	1			
Montana-Dakota Utilities			2	2
Monthouth Power & Light	2			
NorthWestern Energy	8	10	7	
NW Natural Gas			60	131
Pacific Power	17	57		
Portland General Electric	43	70		
Puget Sound Energy	33	58		67
City of Richland		3		
Rocky Mountain Power	3			
Salem Electric	1			
Seattle City Light	10	12		
Snohomish County PUD	13	4		
Springfield Utility Board	1			
Tacoma Power	11	1		
Yellowstone Valley Electric Coop		1		
Total	225	310	141	272

Table 10-2 summarizes the billing analysis samples of Participant and Baseline households. Some of the key points to be derived from this table are as follows.

- We were able to obtain 310 electricity billing records and 272 gas billing records for the 341 homes in the Participant sample. We obtained 225 electricity billing records and 141 gas billing records from the 248 homes in the Baseline sample. The number of sites included in the billing analysis falls below the total in the on-site sample for a number of reasons, including:
    - Some customers who originally agreed to sign billing releases decided not to do so in the course of the home visit.
    - Some of the homes included in the in the participant sample had not been occupied long enough to provide a sufficient number of monthly billing observations to support the first-stage billing analysis described below.
- The composition of the billing analysis samples closely resembles the larger on-site samples and populations of new homes. Specifically:
    - Among the 310 Participant homes for which electric bills were obtained, 277 or 89.3 percent had gas space heating equipment. Among the 225 Baseline homes for which electric bills were obtained, 192 or 85.3 percent had gas space heating. In the full on-site samples, 90.0 percent of Participant homes and 86.7 percent of Baseline homes had gas space heat. Eighty-nine percent of the full population of Participant homes had natural gas heating equipment installed.
    - In the full Participant sample, 87.6 percent of the homes had gas hot water heaters versus 85.6 percent in the billing analysis sample. Among baseline homes, 81.8 percent of the full sample had gas water heating versus 85.2 percent in the billing analysis sample.
    - The billing analysis samples closely resembled the full on-site samples in terms of house size and number of occupants. For the participant sample, average home size was 2,276 square feet and average number of occupants was 2.86. For the baseline sample, average home size was 2,355 square feet and average number of occupants was 2.93.

  The billing analysis models used in this study control explicitly for differences among individual homes in terms of size, number of occupants, heating fuels, and hot water fuels. Nonetheless, the close correspondence of the samples along these dimensions reinforces the notion of their comparability.

- On average, each customer in the billing sample had over 22 monthly records for the applicable fuels on which to base the consumption analysis.

Table 10-2. Details of Billing Analysis Sample

	Participant Sample		Baseline Sample	
Characteristic	Electricity Billing Records	Gas Billing Records	Electricity Billing Records	Gas Billing Records
Total number	310	272	225	141
With Gas Space Heat	277	257	192	141
With Electric Space Heat (Heat Pumps)	23	11	26	0
With Gas DHW	264	248	188	138
With Electric DHW	25	10	27	3
Mean number of occupants	2.70	2.68	2.81	2.81
Mean square feet	2,228	2,206	2,303	2,285
Full Sample: Mean Occ'pts	2.86		2.93	
Full Sample: Mean sf	2,276		2,355	
Minimum bill periods	5	3	5	11
Maximum bill periods	39	38	38	39
Mean bill periods	24.7	22.7	27.8	30.2

10.1.3 Normal Temperatures

We produced 10 year normal weather data series for each weather region using NOAA weather data. We calculated degree days across the full range of possible degree day bases for all ten years for each weather region. Then the degree days associated with each base were averaged over the ten years. This provided normalized annual degree day values for each weather station. Each site uses normalized annual degree day values that match the observed weather used to perform the site level modeling.

10.2 Modeling Approach

KEMA used a two-stage approach to develop the gas and electric models. In the first stage, we developed site-level models of temperature-related end uses: heating for gas bills; heating and cooling for electric. This model disaggregates electric and gas consumption into baseload and temperature correlated loads for each home in the sample. The primary purpose of this modeling is to develop an overall estimate of normalized annual consumption. Secondarily, the model results can be left in disaggregate form, providing separate estimates of baseload, heating and cooling.

Using the normalized results from the site level modeling, we estimated a second stage regression equation to capture the effect of program participation on overall NAC as well as baseload, heating and cooling use. The regressions are a function of household characteristics: square footage and number of occupants (in logarithmic form). Outliers are detected by the DFFITS statistic and then removed based on overall NAC regression. Only those households with the relevant end use present, as indicated by the survey, were included in the second stage regression for each disaggregated consumption type. These regressions provide estimates of baseload consumption for non-participants and participants and the difference between the two groups.

10.3 Gas Impacts

10.3.1 Site-Level Gas Heating Usage Billing Regression

In the first step of the analysis, we use the model shown in Equation 1 to disaggregate gas consumption for space heating from base load consumption for each site. The heating usage billing regression uses linear regression to model daily average usage as a function of heating degree days. The equation is:

$$E_{im} = \mu_i + \beta_H H_{im}(\tau_H) + \varepsilon_{im} \quad \text{Equation 1}$$

where

E_{im}	=	Therms used per day during month *m* for customer *i*;
$H_{im}(\tau_H)$	=	Average heating degree-days at the heating base temperature τ_H during month m, based on daily average temperatures, for customer i's meter reading period;
μ_i	=	Baseload usage estimate for customer i;
β_H	=	Heating coefficient, determined by the regression;

τ_H	=	Heating degree-day base temperature, determined by choice of the optimal regression; and
ε_{im}	=	Regression residual.

In this equation, gas usage is a function of an intercept which represents baseload (μ_i) and average daily HDD, $H_{mi}(\tau_H)$, which correlates with heating usage. Monthly bill readings divided by the number of days in the billing period provide the daily therm usage, represented by E_{im}. Average daily degree days for the billing period are calculated by dividing the sum of daily HDD in the billing period by the number of days in the billing period. Because we obtained monthly usage data by bill period, and not all customers are on the same bill cycle, heating degree-days for a given month vary among customers.

The intercept μ_i can be understood as base load consumption. This variable captures household-specific, non-degree day correlated gas usage that occurs across all time periods. Non-heating gas usage can include water heat, cooking and other gas appliances.

In order to identify the best fit for the weather adjustment components of the model, we tested the specification above using a range of potential degree day bases. This approach effectively estimates the average outdoor temperature at which the heating system turns on for each included household. We selected the degree day base that yielded the highest R^2 value. If the optimal model included a heating parameter estimate that was not statistically significant, we removed the heating term and re-optimized. For the gas model, if the heating trend is not found to be statistically significant, household load is characterized by the average daily load across the available bills.

Using the site-level degree day regression parameters, we developed an estimate of normalized consumption using normalized annual degree days based on the site-specific, optimal degree day base. The results include overall normalized annual consumption (NAC) as well as normalized annual heat (NAH) and baseload which represent a decomposition of the NAC estimate.

$$NAC_i = \mu_i * 365 + \hat{\beta}_H \tilde{H}_i(\tau_H)$$ **Equation 2**

where

NAC_i	=	Normalized annual electric consumption for customer *i*;

$\tilde{H}_i(\tau_H)$	=	Normal annual heating degree-days calculated at the heating base temperature τ_H of customer i;
$\hat{\beta}_H$	=	Heating parameter estimate from the site level models.

10.3.2 Second Stage Gas Billing Regression

The second stage regressions model the normalized consumption as a function of square footage, occupancy and participation. We estimate identical model for overall NAC, baseload and normalized annual heating.

Equation 3 provides the specification for the NAC model.

$$NAC_i = \lambda_1 + \lambda_2 SQFT_i + \lambda_3 OCC_i + \delta_1 P_i + \delta_2 SQFT_i * P_i + \delta_3 OCC_i * P + \varepsilon_{im} \quad \text{Equation 3}$$

where

NAC_i	=	Normalized annual consumption for customer *i*
$SQFT_i$	=	House area in square feet for customer i;
OCC_i	=	Log of Occupancy for customer I;
P_i	=	An indicator variable equal to zero for non-participants and one for participants
λ_1, λ_2, λ_3	=	Non-participant coefficients, determined by the regression;
δ_1, δ_2, δ_3	=	Participant difference coefficients, determined by the regression;
ε_{im}	=	Regression residual.

The baseload and normalized heating consumption equations are identical except the dependent variable in each is replaced with the relevant consumption value.

The second stage regression results are fit with the average values from participants. Baseline consumption is then consumption for the participant population had they not participated in the program. The participant effect is the difference in consumption caused by participation in the program. The equation is

$$BC_i = \hat{\lambda}_1 + \hat{\lambda}_2 \bar{S}QFT_i + \hat{\lambda}_3 \bar{O}CC_i + \hat{\delta}_1 P_i + \hat{\delta}_2 \bar{S}QFT_i * P_i + \hat{\delta}_3 \bar{O}CC_{ii} * P$$

Equation 4

where

BC_i	=	Normalized annual baseline consumption;
$\bar{S}QFT$	=	Average square footage for participants;
$\bar{O}CC$	=	Average of Log of Occupancy for participant;

10.3.3 Gas Regression Results

After removing 19 outlier customers, the results of all three second stage regressions are provided in Table 10-3.

Table 10-3. Gas Second Stage Regression Results with 90 Percent Confidence interval

End Use	Baseline			Participants w/ Program Effects			Difference		
Heating	505.5	+/-	24.5	446.8	+/-	17.6	58.7	+/-	30.2
Baseload	210.3	+/-	19.8	197.1	+/-	14.2	13.2	+/-	24.4
Total	715.8	+/-	26.2	643.9	+/-	18.8	71.9	+/-	32.2

The results from the Heating load regression indicate savings of 58.7 therms. This result is statistically significant at the 90 percent confidence level. The baseload results indicate savings of 13.2 therms, but this result is not statistically significant. The overall normalized consumption regression result indicates a combined savings of 71.9 therms and the result is statistically significant.

In general, the overall normalized annual consumption from site-level degree day regressions is very stable, while the decomposition to baseload, heating and cooling, are more variable. The site-level decomposition depends on the choice of the optimal degree day base for heating and/or cooling. Outliers, and variability in general, will have an effect on the choice of degree day base and thus the level of baseload. The heating and cooling slopes in the models will adjust to the chosen degree day base. The heating and/or cooling load breakouts reflect the observed heating and cooling trends in the data but may have a higher degree of variability than the overall result.

10.4 Electric Impacts

10.4.1 Site-Level Electric Heating Usage Billing Regression

We used the same process for normalizing site-level usage as was applied in the electricity billing analysis. The same site-level model, with the addition of cooling degree day terms, is used to disaggregate electric consumption into heating, cooling and baseload consumption for each site. The electric usage billing regression uses linear regression to model daily average usage as a function of heating degree days and cooling degree days. The equation is:

$$E_{im} = \mu_i + \beta_H H_{im}(\tau_H) + \beta_C C_{im}(\tau_C) + \varepsilon_{im} \qquad \text{Equation 5}$$

where

E_{im}	=	Therms used per day during month *m* for customer *i*;
$H_{im}(\tau_H)$	=	Average heating degree-days at the heating base temperature τ_H during month m, based on daily average temperatures, for customer i's meter reading period;
$C_{im}(\tau_c)$	=	Average cooling degree-days at the cooling base temperature τ_C during month m, based on daily average temperatures, for customer i's meter reading period;
μ_i	=	Baseload usage estimate for customer i;
β_H, β_C	=	Heating and cooling coefficients, determined by the regression;
τ_H, τ_C	=	Heating and cooling degree-day base temperatures, determined by choice of the optimal regression; and
ε_{im}	=	Regression residual.

In this equation, electric usage is a function of an intercept which represents baseload (μ_i), average daily HDD, $H_{mi}(\tau_H)$, which correlates with heating usage and average daily CDD, $C_{mi}(\tau_C)$, which correlates with cooling usage. Monthly bill readings divided by the number of days in the billing period provide the daily electric usage, represented by E_{im}. Average daily degree days for the billing period are calculated by dividing the sum of daily HDD by the number of days in the billing period. Because we obtained monthly usage data by bill period, and not all customers are on the same bill cycle, heating or cooling degree-days for a given month vary among customers.

We estimate the equation across a range of heating and cooling degree day bases. We also fit the model with only a heating or cooling term. This is also done across a range of bases. Finally, we fit the intercept alone. We choose the best heating and cooling degree base combination for each model specification and use an F-test to determine whether the specification including either heating or cooling or both in the model is superior.

The site level modeling process produces a set of parameter estimates for the optimal model, including the degree day bases for heating and cooling. We fit these equations with annual degrees derived from the normal temperatures discussed in section 10.1.3. If both heating and cooling terms are present, the equation is

$$NAC_i = \mu_i * 365 + \hat{\beta}_H \tilde{H}_i(\tau_H) + \hat{\beta}_C \tilde{C}_i(\tau_C)$$ **Equation 6**

where

NAC_i	=	Normalized annual electric consumption for customer *i*;
$\tilde{H}_i(\tau_H)$	=	Normal annual heating degree-days calculated at the heating base temperature τ_H of customer i;
$\tilde{C}_i(\tau_C)$	=	Normal annual cooling degree-days calculated at the cooling base temperature τ_C of customer i;
$\hat{\beta}_H, \hat{\beta}_C$	=	Heating cooling parameter estimates from the site level models.

Each piece of this equation represents a piece of the decomposed overall NAC. The first term, the intercept term, is the baseload. The two degree day oriented terms are heating a cooling load, respectively.

10.4.2 Electric Second Stage Regressions

The second stage of the electric heating and cooling usage billing regression is similar in form to the gas heating model discussed above but with the addition of cooling load. The challenging aspect of electric load disaggregation is the combination of the potential for substantial electric heating and water heating load for a subset of the population that is challenging to reliably identify. Survey respondents do not necessarily properly identify themselves as electric heat or water heat users. On the other hand, the apparent heating load identified by the site level models indicate whether there is heating degree day correlated load, but these regressions will pick up secondary electric heat as well primary gas heat. Finally, unlike gas heat which is ubiquitous in houses with gas service, a much smaller proportion of households have electric heat making it more challenging to get reasonable mean estimates for participants and non-participants and the associated differences.

There are four second stage equations for electric usage: base, heating, cooling and overall. The results from these equations inform estimates of base, heating, cooling and overall savings for the average program participant. These results reflect the difference between participant usage and non participant usage if the non-participants were like participants with respect to square-footage of their home. The results can be expressed as the average participant where electric heat and AC are unknown; that is, heating and cooling consumption are averages across all participants whether they have either end use or not. In addition, savings are expressed for those with cooling and those with electric heat. The distinction between electric heat and electric water heat (in the baseload) was impossible make with the small numbers of sites with one or both of these end uses. As a result, those with only one of these end uses were dropped from the analysis, and electric heat and electric water heat are either both present or not present.

The overall NAC version of the second stage equation is:

$$\begin{aligned} NAC_i = \gamma_1 \quad &+ \gamma_2 SQFT_i + \\ &\delta_1 P_i + \delta_2 SQFT_i * P_i + \varepsilon_i \end{aligned} \qquad \textbf{Equation 7}$$

where

NAC_i	=	Normal Annual Consumption for customer *i*;
$SQFT_i$	=	Square footage for customer i;
$\gamma_1, \gamma_2, \delta_1, \delta_2$	=	Parameters estimated by the regression;

ε_{im} = Regression residual.

The same model is fit for baseload, heating and cooling. The dependent variable in each of these models is the relevant piece of normalized consumption. The latter two models are only fit for those household identified in the survey as having that end use.

The parameter estimates from the second stage model are fit with the average square footage of the participants included in the regression.

$$BU_i = \hat{\gamma}_1 + \hat{\gamma}_2 \bar{S}QFT_i + \hat{\delta}_1 P_i + \hat{\delta}_2 \bar{S}QFT_i * P_i$$

Equation 8

where

BU_i = Baseline usage;

$\bar{S}QFT_i$ = Average square footage for participants;

10.4.3 **Electric Second Stage Regression Results**

Table 10-4 summarizes the results of the enumeration of four electric models: baseload, heating, cooling and overall after removing 31 outlier customers. These results are for the average participant; that is, for all participants regardless of whether survey results indicated cooling or electric heat was present. Each row shows first the baseline level of consumption for the specified combination of end uses, then usage level associated with participation in the Northwest ENERGY STAR program, then the difference between the two. The table also shows the 90 percent confidence interval for the point estimate. The findings shown in Table 10-6 can be summarized as follows.

Table 10-4
Electric Model Results, Average Participant

End Use	Baseline			Participants w/ Program Effects			Difference		
Base	7,926	+/-	384	7,133	+/-	310	-793	+/-	493
Heat	970	+/-	175	767	+/-	136	-203	+/-	221
Cool	522	+/-	75	293	+/-	62	-229	+/-	97
Total	9,417	+/-	411	8,193	+/-	332	-1,224	+/-	528

- **Overall Usage and Participant Savings.** The billing analysis indicates savings of 1,224 kWh +/- 528 kWh for each participant in the program. This estimate of savings is statistically significant. The savings represent a 13 percent difference in consumption from baseline levels. The overall electric results have relatively wide confidence intervals. This is explained by a number of factors:
  - Numerous possible combinations of the presence of AC, electric space heat and electric water heat combined with a relatively small sample;
  - The variable, but potentially substantial, amounts of consumption each end use may represent;
  - Presence of the end use is based on the self-reported survey which in many cases does not line up with the apparent usage levels identified by the site-level modeling.

  Despite this variability and potential errors introduced by misclassification of sample homes by end-use combination, the estimate of reduction in NAC for total consumption is statistically significant

- **Baseline Cooling Use and Participant Savings.** The models estimate average electric use for cooling among all participants, regardless of the reported presence of cooling, at 522 kWh per year, with a 90 percent confidence interval of +/- 75 kWh per year. The savings in cooling energy associated with ENERGY STAR Homes certification is 229 kWh per year +/- 97 kWh per year or 43.8 percent of mean cooling use among the Baseline homes. This result is statistically significant.
- **Baseline Space Heating Use and Participant Savings.** The models estimate average electric use for heating among all participants, regardless of the survey indicated presence of heating, at 970 kWh per year, with a 90 percent confidence interval of +/- 175 kWh per year. The savings in heating energy associated with ENERGY STAR Homes certification are not statistically significant.

The models were unable to produce statistically-significant estimates of heating savings because there were only a small number of participant homes with electric heat and the confounding effects of electric water heat in a subset of these household led us to focus on only those houses with electric space and water heat, further reducing the number. Even for this group, both baseload and heating usage were slightly higher for participants than non-participants.

Effect of ENERGY STAR certification on Base Load. The models estimate average baseload electric use among all participants at 7,926 kWh per year, with a 90 percent confidence interval of +/- 384 kWh per year. The savings in baseload usage associated with ENERGY STAR Homes certification is 793 kWh. This result is statistically significant.

10.5 Discussion of Billing Analysis Results

In this section we discuss the gas and electric savings estimated through the modeling procedures described above, focusing on their consistency with findings from the new home characterization and lighting hours of use studies.

10.5.1 Gas Savings

As discussed in Section 10.3.3, the billing analysis produced statistically significant estimates of reductions in gas used for heating associated with ENERGY STAR Homes certification. The mean savings for all homes with gas heat was 58.7 Therms per year, +/- 30 Therms per year. This amounted to 11.6 percent of annual gas consumption for heat among the baseline homes. The billing analysis provided no statistically reductions in gas base load use associated with ENERGY STAR Homes certification.

Expansion of billing analysis results to the population. In 2006 and 2007, 3,550 gas heated homes received ENERGY STAR Homes certification. This is 89.2 percent of the total population of homes certified by the program during those two years.[19] We estimate total gas savings for the 2006-2007 at 255,245 Therms per year, ± 114,310 Therms per year.

[19] Gas heated homes constituted 90.0 percent of the homes (weighted) in the Participant on-site sample and 85.3 percent of the Participant homes in the billing analysis sample.

Table 10-5. Expansion of Gas Savings Results to the Population of Participant Homes: 2006 - 2007

		90% Confidence Interval	
	Estimate from Billing Analysis	Lower Bound	Upper Bound
Gas heating use savings/home	58.7 Th/Yr	28.7 Th/Yr	88.8 Th/Yr
Total Program Savings: Heat	208,385 Th/Yr	101,885Th/Yr	315,240Th/Yr
Gas Savings/Home: All end uses	71.9 Th/Yr	39.7 Th/Yr	104.1 Th/Yr
Total Program Savings: All end uses	255,245 Th/Yr	140,935 Th/Yr	369,555 Th/Yr

Consistency of billing analysis results with new home characterization findings. The results of the billing analysis of gas savings are highly consistent with the findings of the new home characterization. Recall that we found very little difference between the Participant and Baseline homes in structural characteristics that may affect heating energy use: levels of insulation, window to wall area ratios, average window U-values, and saturation of low-e glazing. Moreover, there was only a small difference between the samples in infiltration levels, as measured by average number of air changes per hour. The Participant and Baseline samples did, however, differ significantly in the saturation of high-efficiency furnaces. Over 96 percent of the furnaces in gas heated Participant homes met the program standard of AFUE 90, and 38.8 percent had AFUEs of 92.5 and above. By contrast 74 percent of the furnaces installed in the Baseline homes barely exceeded Federal minimum standards (AFUE 78). The average AFUE for furnaces installed in Participant homes was 91.9 versus 84.3 in the Baseline homes – a difference in efficiency of 9 percent. The participant homes were also more efficient than the baseline sample in terms of duct leakage. The average duct leakage rate among participant homes was only one-half of that in the baseline homes. Taken together, we believe the higher furnace efficiency and lower duct leakage rates account for much of the estimated difference between the participant and baseline samples in heating-related gas usage.

10.5.2 Electricity Savings

As discussed in section 10.4.3, the billing analysis produced statistically significant estimates of reductions in cooling and overall electrical consumption associated with ENERGY STAR Homes certification. The mean overall savings for all homes 1,224 kWh +/-869 kWh per year. This amounted to 13 percent of annual electric consumption among the baseline homes. The billing analysis results for cooling were also statistically significant with mean savings of 229+/-97kWh. The billing analysis did not provided statistically significant reductions in electric base load or heating use associated with ENERGY STAR Homes certification.

Expansion of billing analysis results to the population. Table 10-6 shows the overall electricity and cooling savings expanded to the program population.

Table 10-6. Expansion of Electric Savings Results to the Population of Participant Homes: 2006 – 2007

		90% Confidence Interval	
	Estimate from Billing Analysis	Lower Bound	Upper Bound
Cooling Savings per Home (kWh/Yr)	229	97	326
Total Cooling Savings (kWh/Yr)	553,205	234,670	788,920
Overall Electric Savings per Home (kWh/Yr)	1,224	696	1,752
Total Electric Savings (kWh/Yr)	4,873,603	2,771,264	6,976,464

Consistency of billing analysis results with New Home Characteristics study findings. The results of the electric billing analyses are highly consistent with relevant findings from the new home characterization study. The following paragraphs address the different sets of end-uses identified in

- **Cooling use.** The modeled difference associated with ENERGY STAR certification in electricity use for cooling is 229 kWh per year, or 44 percent of the baseline level. Energy use simulation models suggest that the tighter duct systems discussed above were the most important factor contributing to the estimated savings. Also, the average SEER rating of central air conditioning systems installed in the Participant homes was 13.6 versus 10.4 in the Baseline homes – a difference of 31.2 percent.
- **Heating use.** The billing analysis did not identify statistically significant savings for electric heating. As discussed earlier, there were no major differences between the Participant and Baseline samples in the thermal features or infiltration rate. There were some differences between the samples that could have caused difference in heating consumption including:
    - Higher saturation of efficient geothermal heat pumps in the Participant sample.
    - Presence of baseboard heating in a few of the Baseline homes, versus none in the Participant homes.
    - Higher levels of duct leakage in the Baseline homes.

Since there were only 49 electrically-heated homes in the combined billing analysis sample, it is difficult to make conclusions about patterns of influence.

- **Base load use.** The modeled difference associated with ENERGY STAR certification in electricity base load use in homes without electric water heating is 793 kWh per year, or 10 percent of the baseline level. This result was statistically significant at the 90 percent confidence level. Findings from the new home characterization study suggest that the following differences between equipment in the Participant and Baseline samples may be contributing to this difference.
  - Higher saturation of compact fluorescent lamps (CFLs). The average Participant home contained 22 more CFLs than the average Baseline home. The average operating hours for the CFLs installed was determined to be 1.21 per day or 442 hours per year. Assuming an average wattage reduction of 47 watts, energy savings per CFL installed is 20.8 kWh per year or 457 kWh per year per Participant home.[20]
  - Higher saturation of ENERGY STAR Appliances. Based on unit savings factors contained in the RTF and differences in saturation of ENERGY STAR refrigerators and clothes washers recorded in the new home characterization study may contribute 50 to 100 kWh per year to the difference between the Participant and Baseline homes in base load consumption.
  - Other potential factors. Other potential influences on the difference in base load electric consumption include the higher saturation of efficient outdoor fixtures in the Participant sample, more frequent use of clothes dryers in the Baseline sample, and higher saturation of dryers with moisture sensors in the Participant sample.

10.5.3 Consistency of Billing Analysis Results with Planning Assumptions

Introduction. It is useful to compare the results of the billing analysis, which provide an empirical estimate of energy use reductions associated with participation in and certification by the Northwest ENERGY STAR Homes program, to assumptions concerning whole house and

[20] There is also a higher number of sockets on average in the Baseline homes, but this difference should be accounted for by the inclusion of square footage-related variables in the base load model.

end-use savings that the Alliance uses for program planning. The Alliance uses a building energy use simulation model to develop unit energy savings at the end-use level for homes with the four heating/cooling configurations that structured our sampling. For each principal end-use the model developers have developed baseline and program specifications. The baseline specifications correspond for the most part to building code requirements; the program specifications correspond primarily to the BOPs. The analysis then sums the end-use savings estimates generated by the simulation model to estimate whole-house savings for each fuel.

To estimate program-level savings, analysts estimate energy savings for individual home prototypes of various sizes, heating/cooling configurations, and ambient climate. They then weight the results according to the representation of the prototypes in the stream of new single-family housing permits. These results are then combined with cost data to assess cost effectiveness. This modeling framework is referred to as the Alliance Cost Effectiveness model or ACE.

In comparing the results of the billing analysis to ACE, we must take into account a number of elements beyond the fundamental difference between measurement and statistical estimation on the one hand and simulation modeling on the other. The other key differences are as follows.

- **Baseline specification.** ACE primarily uses building codes and minimum equipment standards for baseline specification of those elements such as insulation levels and heating and cooling equipment efficiencies that are addressed by codes and standards. For other important characteristics, ACE uses assumptions based on market studies of efficient equipment saturation. For example, ACE incorporates an assumption of a 50 percent reduction in lighting power density associated with Northwest ENERGY STAR Homes participation. The baseline for the billing analysis is defined by the observed characteristics of homes in the baseline sample. In some cases, such as insulation levels, average efficiency among the baseline homes exceeded code levels. In other cases, such as central air conditioner efficiency ratings, the baseline sample was significantly less efficient than code due to recent changes in federal minimum efficiency standards. These differences in baselines likely influenced the relative results of the two methods, as discussed below.

- **Sample design/weighting schemes.** We designed the sample and case weighting system for the participant survey to represent the population of Northwest ENERGY STAR Homes completed during the 2006 – 2007 period. The geographic/climate zone weighting scheme applied in ACE references the distribution of *all* new homes completed in the region. Table 10-7 shows the differences between these two weighting systems.

Table 10-7. Geographic Weighting of the Participant Sample and ACE Model

Region/Climate Zone	Participant Sample Weights	ACE Weights
Puget Sound	24%	44%
SW WA / NW OR / SW OR	35%	20%
Central WA	6%	
E. WA / N. ID / C. OR	14%	15%
S. ID / E. OR	15%	15%
Montana	6%	6%
Total	100%	100%

- **Build-up of results by end-use v. disaggregation of observed whole-house consumption.** The building simulation model builds up total consumption from submodels of end-uses. Thus, for given heating/cooling system configuration, such as “Gas [Heat] w/ AC”, the model produces an estimate of cooling system use which can be aggregated to with other model results to produce an estimate of mean cooling system use for the region. The billing analysis model produces the most accurate results at the aggregated level by estimating average cooling system use, including use by homes that do not report having central cooling. Thus, it is most appropriate to compare the billing analysis results to the “weighted average” results of the ACE simulation models at the end-use and whole-house levels.

Summary of Results: Billing Analysis v. ACE Planning Projections. Table 10-8 summarizes savings estimates generated by the billing analysis versus the ACE planning projections for quantities that can be appropriately compared, given the methodological factors discussed above. The savings figures represent average per home savings for the full populations in questions, and do not refer to homes with specific heating, cooling, or water heating fuels. We provide the saturation of various end uses by fuel in the participant sample to provide perspective on the results for the average home.

Table 10-8. Comparison of Estimates of Annual Energy Savings per Home: Billing Analysis and ACE Model Energy Savings Results

FUEL/End Uses	Saturation in NW ESNH	Billing Analysis Savings Results	ACE Model Savings Results
ELECTRICITY		KWH/YEAR PER HOME	KWH/YEAR PER HOME
Heating	7%	203	392
Cooling (Central AC)	60%	229*	47
Hot Water	10%		21
Dishwasher	100%	793*	3
Lighting & Other Base Load	100%		924**
Electric Total		1,224*	1,449***
NATURAL GAS		THERMS/YEAR PER HOME	THERMS/YEAR PER HOME
Heating	90%	58.7*	116.3
Hot Water	88%	13.2	14.9
Natural Gas Total		71.9*	131.9

* Billing analysis result statistically significant at the 90 percent confidence level. Column does not add due to rounding.
** Does not include savings from "Plus" package lighting and appliance measures.
*** End use consumption estimates do not sum to total consumption in the ACE modeling framework.

The results summarized in Table 10-8 are consistent with differences in baseline assumptions discussed above, as well as with specific findings in regard to the characteristics of the participant and baseline samples. The following paragraphs highlight important findings from this comparison.

Electricity Savings. The billing analysis produced an estimate of average electricity savings per home associated with Northwest ENERGY STAR certification of 1,224 +/- 528 kWh per year – 225 kWh per year less than the ACE model results. The key components of this difference were as follows.

- **Baseload use reductions.** The ACE model yielded average baseload electricity savings of 948 kWh per year, of which 924 kWh per year was due to lighting energy reductions. The billing analysis estimated average baseline savings of 793 kWh kWh per year – 131 kWh per year less than the ACE model. This difference was largely due to differences in assumed versus observed reductions in baseline lighting power density associated with Northwest ENERGY STAR certification. The home characteristics survey found a that LPDs in the baseline sample averaged 30 percent higher than those in the participant homes. The ACE model assumed a 50 percent difference. The fact that the participant homes were somewhat smaller than the baseline sample and contained slightly fewer lighting fixtures may also have contributed to this result.
- **Heating use reductions.** Average reductions in heating use were estimated at 392 kWh per year by the ACE models versus 203 kWh per year by the billing analysis. The billing analysis estimate was not statistically significant. The lower result for the billing analysis is likely related to one or more of the following factors:
    - The assumed saturation of electric heat in the ACE model is over 14 percent, versus 7 percent in the participant sample.
    - The ACE model assumes that duct leakage in participating homes complies with the program standards, whereas it was found to be considerably higher.
    - The ACE model assumes the presence of "code" levels of insulation in the baseline whereas actual levels were observed to be higher.
- **Cooling use reductions.** The billing analysis produced estimates of average savings in cooling energy of 229 kWh per year versus ACE model estimates of 47 kWh per year. This difference is largely explained by differences in baseline. The average SEER of central air conditioners observed in the baseline sample was 10.45 whereas ACE incorporates an assumption that central air conditioners will meet the current 13 SEER federal standard.

Natural Gas Savings. The billing analysis produced an estimate of natural gas savings per home associated with Northwest ENERGY STAR certification of 71.9 +/- 32.2 Therms per year – 60.0 therms per year less than the ACE model results. Nearly all of this difference is attributable to the disparity in the estimates of heating use reductions. These differences are most likely related to differences in observed versus assumed levels of insulation and in the baseline homes and in observed versus assumed levels of duct leakage in the baseline sample.

Appendix A - New Home Characterization Tables

Appendix B - Details of Billing Analysis

Introduction

KEMA conducted a billing analysis to compare the annual electricity and gas consumption of homes in the Participant sample to the energy use of homes in the Baseline sample, using regression analysis to account for influences on energy use other than program participation. These influences include differences in ambient climate conditions among homes in the combined Participant and Baseline sample, as well as differences in household and housing conditions related to energy use. These latter include home size, number of occupants, and complement of heating and cooling equipment. After taking weather, household formation, and home configuration into account, the regression coefficient for the variable indicating program participation provides an estimate of the energy savings associated with receiving Northwest ENERGY STAR Homes certification.

KEMA developed models of energy consumption for the following fuels and end-uses:

- Gas: heating-related uses;
- Gas: baseload uses (hot water & cooking);
- Electric: heating and cooling-related end uses; and,
- Electric: baseload.

The body of this report includes the basic methodology of the approach used for this analysis as well as the results. This appendix focuses on the development of results from the second-stage regressions. The second stage regressions compare the first stage regression results (Normalized annual consumption, and the disaggregations) with variables indicating participation and other factors.

Participant Gas Savings Estimates

According to survey results, almost all households with gas had gas space and water heat. All households with gas were included in the second stage regressions. The results of all three second stage regression equations are reported in **Error! Reference source not found.** and here in Table B-1.

Table B-1. Gas Second Stage Regression Results with 90 Percent Confidence interval

End Use	Baseline	Participants w/ Program	Difference
Heating	505.5 +/- 24.5	446.8 +/- 17.6	58.7 +/- 30.2
Baseload	210.3 +/- 19.8	197.1 +/- 14.2	13.2 +/- 24.4
Total	715.8 +/- 26.2	643.9 +/- 18.8	71.9 +/- 32.2

Participant Electricity Savings Estimates

The distribution of electric end uses is substantially more complicated than for gas end uses. All households have electric usage but only subsets report electric space heat, water heat and/or cooling. To complicate the matter, the presence of heating and cooling as indicated by the first-stage regressions, does not necessarily line up with the reported end uses from the survey. This is quite common for these kinds of analyses. There are two common explanations. There might not be enough observed usage for the first-stage regressions to pick up the presence of a particular end use (particularly the case with AC) or survey respondents may be mistaken about the source of primary heat in their house (not uncommon with electric heat).

To generate results for the average electric customer, as indicated by survey results, the second-stage regression were performed separately for four subsets of households as indicated by the survey results: Households with neither electric heat nor cooling; Households with electric heat but no cooling; households with cooling but not electric heat and households with both electric heat and cooling.

Based on survey data, about 9% customers had electricity heating, 62% customers had air conditioning, and 10% had electricity water heater. The distinction between electric heat and electric water heat (in the baseload) was impossible to make with the small numbers of sites with one or both of these end uses. As a result, those with only one of these end uses were dropped from the analysis, and electric heat and electric water heat are either both present or not present. Thus, all customers are divided into 4 groups, with or without AC, with or without electric heat. The estimates of base, heating, cooling and overall savings for the average program participant in each of the 4 groups are shown in Table B-2 through Table B-5.

The overall estimates for different end uses, the weighted average of corresponding survey-determined end uses in each of the 4 subgroups tables, are provided in Table B-6. These are the results reported in the body of the report. Heating and cooling consumption are averages across all participants whether according to the survey they have either end use or not. Table B-6 and B-8 are presented for the purpose of overall estimation of baseload, heating, cooling, and total electricity consumption for the average participant. The results in these two tables are counter-intuitive but represent a small number of households.

Table B-2
Participant versus. Baseline Electricity Usage (Kwhs)

End Use	Baseline			Participants w/ Program			Difference		
Base	6,967	+/-	591	5,493	+/-	476	1,474	+/-	759
Heat	1,534	+/-	347	764	+/-	280	770	+/-	446
Cool	16	+/-	30	21	+/-	24	-5	+/-	39
Total	8,517	+/-	629	6,277	+/-	507	2,239	+/-	808

For the customers with no AC and no electric heating, the billing analysis indicates savings of 1,474 kWh +/- 759 kWh in baseload and 2,239 kWh +/- 808 kWh in total usage for each participant in the program. The savings are statistically significant. The apparent heating load savings is statistically significant, which is 770 kWh. Cooling load was not statistically significant.

Table B-3
Participant versus. Baseline Electricity Usage (Kwhs)
for customers with electric heating and no AC at Premise Level

End Use	Baseline			Participants w/ Program			Difference		
Base	8,218	+/-	1,558	9,163	+/-	2,695	945	+/-	3,113
Heat	5,729	+/-	704	5,361	+/-	1,217	-368	+/-	1,406
Cool	0	+/-	0	0	+/-	0	0	+/-	0
Total	13,947	+/-	1,934	14,524	+/-	3,345	-577	+/-	3,864

For customers with electric heating and no AC, cooling load is 0. Heating and total load savings are negative. But since there are 3 participant customers in this category, the estimates are not reliable because of the small number of sites.

Table B-4
Participant versus. Baseline Electricity Usage (Kwhs)
for customers with AC and no electric heating at Premise Level

End Use	Baseline			Participants w/ Program			Difference		
Base	8,575	+/-	491	8,045	+/-	411	530	+/-	640
Heat	547	+/-	151	501	+/-	126	46	+/-	196
Cool	869	+/-	125	462	+/-	104	407	+/-	162
Total	9,991	+/-	527	9,008	+/-	441	983	+/-	687

For customers with AC and no electric heaing, cooling load savings is 407 kWh +/- 162 kWh, and the apparent heating load saving is 46kWh, which is not statistically significant. Although the baseload savings is not significant, the total usage savings is significant, which is 983 kWh.

Table B-5
Participant versus. Baseline Electricity Usage (Kwhs)
for customers with both AC and electric heating at Premise Level

End Use	Baseline			Participants w/ Program			Difference		
Base	6,790	+/-	4,703	9,162	+/-	2,686	-2,371	+/-	5,416
Heat	465	+/-	2,993	5,027	+/-	1,709	-4,562	+/-	3,446
Cool	104	+/-	300	501	+/-	171	-397	+/-	345
Total	7,360	+/-	5,063	14,690	+/-	2,891	-7,330	+/-	5,830

For customers with both AC and electric heating, the models were unable to produce statistically-significant estimates of baseload savings because there were only 7 participant homes in this group. When taking the weighted average to estimate the overall consumption for each end use, this group contributes little because of its small size. The overall estimation is dominated by the two group electricity customers with no electricity heating, and with or without AC.

Table B-6 summarizes the results after taking the weighted average of the above 4 tables for baseload, heating, cooling and overall. These results are for the average participant; that is, for all participants regardless of whether survey results indicated cooling or electric heat was present. Each row shows first the baseline level of consumption for the specified combination of end uses, then usage level associated with participation in the Northwest ENERGY STAR program, then the difference between the two. The table also shows the 90 percent confidence interval for the point estimate. These results are presented **Error! Reference source not found.** in the body of the report.

Table B-6
Electric Model Results, Average Participant

End Use	Baseline			Participants w/ Program			Difference		
Base	7,926	+/-	384	7,133	+/-	310	-793	+/-	493
Heat	970	+/-	175	767	+/-	136	-203	+/-	221
Cool	522	+/-	75	293	+/-	62	-229	+/-	97
Total	9,417	+/-	411	8,193	+/-	332	-1,224	+/-	528

A.1. Household Characteristics

Table 1
Average per Home Occupancy

Average per Home Occupancy	ESNH Average, n=336	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
Overall	2.90	0.10	2.90	0.10	

Table 2
Distribution of per Home Occupancy

Distribution of per Home Occupancy	ESNH Proportions, n=336	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
1	9.3%	2.6%	9.8%	2.0%	
2	44.2%	4.5%	40.6%	3.3%	
3	19.6%	3.6%	17.3%	2.5%	
4	15.2%	3.2%	20.0%	2.7%	
5	6.4%	2.2%	7.1%	1.7%	
8	3.6%	1.7%	4.2%	1.3%	
7	0.7%	0.8%	0.7%	0.6%	
8	0.4%	0.6%	0.3%	0.3%	
9	0.3%	0.5%	0.1%	0.2%	
≥ 9	0.3%	0.5%			

A.2. Number and age of occupants

Table 3
Proportions of Occupancy Age Ranger per Homes

Proportions of Occupancy Age Ranger per Homes	ESNH Proportions, n=652	ESNH EB_{90}'s	Baseline Proportions, n=1,133	Baseline EB_{90}'s	Significant Difference
Under 1 Year	4.7%	1.4%	3.4%	0.9%	
2 to 5 Years	10.4%	2.0%	11.2%	1.5%	
6 to 18 Years	14.4%	2.3%	17.1%	1.8%	
18 to 29 Years	10.6%	2.0%	12.2%	1.6%	
30 to 49 Years	33.8%	3.0%	32.1%	2.3%	
50 to 64 Years	19.4%	2.5%	15.9%	1.8%	
65 or older	6.6%	1.6%	8.1%	1.3%	

Table 4
Proportions of Occupancy Adults per Home

Proportions of Occupancy Adults per Home	ESNH Proportions, n=336	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
0	0.4%	0.6%			
1	12.5%	3.0%	13.0%	2.2%	
2	76.3%	3.8%	78.3%	2.8%	
3	8.0%	2.4%	5.7%	1.6%	
4	2.0%	1.2%	2.6%	1.1%	
5	0.7%	0.7%	0.3%	0.4%	
6+	0.3%	0.5%	0.1%	0.2%	

A.3. Number of Occupants Employed Inside/Outside of the Home

Table 5
Proportion of Occupants Employed Outside of Home

Proportion of Occupants Employed Outside of Home	ESNH Proportions, n=345	ESNH EB_{90}'s	Baseline Proportions, n=260	Baseline EB_{90}'s	Significant Difference
0	20.7%	3.6%	23.9%	4.3%	
1	40.3%	4.3%	35.5%	4.9%	
2	33.3%	4.2%	36.8%	4.9%	
3	4.5%	1.8%	3.0%	1.7%	
4	1.2%	0.9%	0.8%	0.9%	

A.4. House Type

Table 6
Proportion of Homes Types Surveyed

Proportion of Homes Types Surveyed	ESNH Proportions, n=345	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
Single Family, Detached, 1 story	22.4%	3.7%	35.7%	3.2%	*
Single Family, Detached, 2 story	57.8%	4.4%	60.0%	3.3%	
Single Family, Detached, ≥ 3 story	6.5%	2.2%	3.1%	1.2%	*
Duplex, Triplex or Quadplex	0.3%	0.5%			
Townhouse / Rowhouse	13.0%	3.0%	1.1%	0.7%	*

A.5. House Size

Table 7
Average Home Area by Sqft

Average Home Area by Sqft	ESNH Average, n=345	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
ID	2,556.3	132.1	2,165.2	93.5	*
MT	1,983.5	476.7	2,508.6	403.5	
OR	2,085.2	86.7	2,435.5	123.7	*
WA	2,384.7	138.8	2,374.8	90.9	
Overall	2,275.7	67.9	2,355.5	59.2	

Table 8
Proportions of Homes Size in Sqft

Proportions of Homes Size in Sqft	ESNH Proportions, n=345	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
< 600 sq.ft.					
600 to 999 sq.ft.	1.5%	3.7%	0.3%	0.4%	
1,000 to 1,599 sq.ft.	20.0%	12.2%	18.9%	2.6%	
1,600 to 1,999 sq.ft.	22.3%	12.7%	21.6%	2.8%	
2,000 to 2,399 sq.ft.	17.5%	11.6%	16.7%	2.5%	
2,400 to 2,999 sq.ft.	20.8%	12.4%	21.5%	2.8%	
3,000 or more sq.ft.	17.9%	11.7%	20.9%	2.7%	

A.6. Home Characteristics

Table 9
Proportions of Homes by BOP Classification

Proportions of Homes by BOP Classification	ESNH Proportions, n=344	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
BOP-1	99.1%	0.8%	92.2%	1.8%	*
BOP-2	0.9%	0.8%	7.8%	1.8%	*

A.7. Infiltration Rates

Table 10
Average Infiltration Rates, ACH50

Average Infiltration Rates, ACH50	ESNH Average, n=340	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
BOP1	4.95	0.16	5.90	0.19	*
BOP2	3.99	1.23	4.91	0.79	
Overall	4.94	0.16	5.83	0.19	*

Table 11
Infiltration Rates in BOP1 Homes, ACH50

Infiltration Rates in BOP1 Homes, ACH50	ESNH Proportions, n=334	ESNH EB_{90}'s	Baseline Proportions, n=239	Baseline EB_{90}'s	Significant Difference
1 to 2	1.8%	1.6%			
2.1 to 3.0	11.1%	3.8%	1.5%	2.8%	*
3.1 to 4.0	18.9%	4.7%	9.5%	6.7%	
4.1 to 5.0	24.3%	5.2%	26.2%	10.1%	
5.1 to 6.0	20.5%	4.9%	20.5%	9.3%	
6.1 to 7.0	11.9%	3.9%	13.4%	7.9%	
7.1 to 8.0	3.9%	2.4%	17.9%	8.8%	*
8.1 to 9.0	5.1%	2.7%	7.3%	6.0%	
9.1 and Over	2.5%	1.9%	3.7%	4.4%	

Table 12
Infiltration Rates in BOP2 Homes, ACH50

Infiltration Rates in BOP2 Homes, ACH50	ESNH Proportions, n=5	ESNH EB_{90}'s	Baseline Proportions, n=8	Baseline EB_{90}'s	Significant Difference
0 to 2.0			9.9%	6.9%	
2.1 to 2.5					
2.6 to 3.0	43.7%	6.0%			
3.1 to 3.5			33.5%	10.9%	
3.6 to 4.0	29.3%	33.0%	5.3%	5.1%	
4.1 and Over	27.0%	34.7%	16.5%	8.5%	

A.8. Windows

Table 13
Average Window Area per Home Sqft

Average Window Area per Home Sqft	ESNH Average, n=338	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
ID	0.102	0.007	0.162	0.032	*
MT	0.066	0.019	0.119	0.012	*
OR	0.094	0.004	0.158	0.017	*
WA	0.092	0.005	0.150	0.018	*
Overall	0.094	0.003	0.153	0.012	*

Table 14
Average Window Sqft by Home

Average Window Sqft by Home	ESNH Average, n=339	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
ID	256.7	20.7	358.8	74.0	*
MT	124.7	44.8	300.8	59.5	*
OR	211.8	40.1	400.7	58.3	*
WA	210.9	15.7	345.2	31.5	*
Overall	218.0	19.4	361.3	28.0	*

A.9. Window-to-floor area ratio

Table 15
Ratio of Window Area to Conditioned Floor Area (sq. ft./sq. ft.)

Ratio of Window Area to Conditioned Floor Area (sq. ft./sq. ft.)	ESNH Proportions, n=338	ESNH EB_{90}'s	Baseline Proportions, n=598	Baseline EB_{90}'s	Significant Difference
0.000 to 0.070	21.9%	11.8%	1.1%	3.1%	*
0.071 to 0.090	26.3%	12.6%	7.6%	8.0%	*
0.091 to 0.110	24.0%	12.2%	15.4%	10.8%	
0.111 to 0.130	15.0%	10.2%	26.5%	13.3%	*
0.131 to 0.150	7.1%	7.4%	19.3%	11.9%	*
0.151 to 0.170	3.0%	4.9%	13.7%	10.3%	
0.171 to 0.190	1.9%	3.9%	9.8%	8.9%	
0.191 to 0.210	0.2%	1.3%	3.2%	5.3%	
0.211 to 0.230	0.2%	1.3%	1.4%	3.6%	
0.231 and Over	0.2%	1.3%	2.0%	4.2%	

A.10. Frame Type

Table 16
Average Window Area by Frame Type (sq. ft.)

Average Window Area by Frame Type (sq. ft.)	ESNH Average, n=362	ESNH EB_{90}'s	Baseline Average, n=613	Baseline EB_{90}'s	Significant Difference
Metal	167.7	63.2	104.5	49.2	
NonMetal	212.2	19.8	354.9	26.7	*
Unknown	24.9	15.0			*
Overall	205.0	18.7	354.1	27.7	*

A.11. Insulation Properties of Windows

Table 17
Average Window U-Value by BOP

Average Infiltration Rates, ACH50	ESNH Average, n=336	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
BOP1	0.340	0.001	0.366	0.005	*
BOP2	0.339	0.007	0.356	0.008	*
Overall	0.340	0.001	0.366	0.005	*

Table 18
BOP1 U-Value Proportions

BOP1 U-Value Proportions	ESNH Proportions, n=338	ESNH EB_{90}'s	Baseline Proportions, n=560	Baseline EB_{90}'s	Significant Difference
0.28	1.2%	17.9%			
0.29	2.2%	17.5%			
0.3	4.6%	16.6%			
0.31	1.2%	17.8%			
0.32	5.2%	16.4%			
0.33	7.6%	15.6%			
0.34	26.1%	10.0%			
0.35	51.9%	4.2%	83.1%	0.5%	*
0.37			0.1%	18.2%	
0.38			0.4%	18.1%	
0.39			0.3%	18.2%	
0.4			1.2%	17.8%	
0.5			13.7%	13.6%	
0.51			0.1%	18.2%	
0.53			0.1%	18.2%	
0.56			0.1%	18.2%	
0.59			0.2%	18.2%	
0.6			0.1%	18.2%	
0.61			0.3%	18.2%	
0.62			0.2%	18.2%	
0.64			0.1%	18.3%	

BOP2 U-Value Proportions

BOP2 U-Value Proportions	ESNH Proportions, n=4	ESNH EB_{90}'s	Baseline Proportions, n=42	Baseline EB_{90}'s	Significant Difference
0.33	25.2%	35.7%	93.2%	6.4%	*
0.34	46.2%	41.0%			
0.35	28.5%	37.1%			
0.5			6.8%	6.4%	

A.12. Glazing Coating

Table 19
Presence of LowE in WA Homes

Presence of LowE in WA Homes	ESNH Proportions, n=1,703	ESNH EB_{90}'s	Baseline Proportions, n=916	Baseline EB_{90}'s	Significant Difference
LowE	97.5%	0.6%	92.7%	1.4%	*
Not LowE	2.4%	1.1%	7.3%	1.4%	*
DK	0.1%	0.1%			

Table 20
Presence of LowE in OR Homes

Presence of LowE in OR Homes	ESNH Proportions, n=2,285	ESNH EB_{90}'s	Baseline Proportions, n=712	Baseline EB_{90}'s	Significant Difference
LowE	96.3%	0.7%	86.0%	2.1%	*
Not LowE	3.6%	1.0%	13.8%	2.1%	*
DK	0.2%	0.1%	0.2%	0.3%	

Table 21
Presence of LowE in MT Homes

Presence of LowE in MT Homes	ESNH Proportions, n=153	ESNH EB_{90}'s	Baseline Proportions, n=72	Baseline EB_{90}'s	Significant Difference
LowE	98.5%	1.6%	94.7%	4.3%	
Not LowE	1.0%	1.3%	5.3%	4.3%	
DK	0.5%	0.9%			

Table 22
Presence of LowE in ID Homes

Presence of LowE in ID Homes	ESNH Proportions, n=1,533	ESNH EB_{90}'s	Baseline Proportions, n=716	Baseline EB_{90}'s	Significant Difference
LowE	94.9%	0.9%	69.1%	2.8%	*
Not LowE	4.8%	1.4%	30.6%	2.8%	*
DK	0.3%	0.3%	0.3%	0.3%	

A.13. Wall Characteristics

Table 23
Proportions of Wall Construction Types

Proportions of Wall Construction Types	ESNH Proportions, n=307	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
Wood Studs, 2" x 6"	89.8%	2.7%			
Wood Studs, 2" x 4"	8.2%	2.4%	19.3%	2.6%	*
Concrete/Masonry	0.5%	0.6%			
Metal Studs, 2" x 6"	0.3%	0.5%			
Other	0.3%	0.5%			
Don''t Know	1.0%	0.9%	1.0%	0.7%	

A.14. Roof/Attic Assemblies

Table 24
ESNH Roof/Attic Type Observed

ESNH Roof/Attic Type Observed	ESNH Total Sq Ft	ESNH Percent
Attic	461,884	89%
Vault	35,510	7%
Roof/Deck	967	0%
Other	10,653	2%
Overall	518,590	

A.15. Attic Insulation

Table 25
Mean Attic Insulation R-Values

Mean Attic Insulation R-Values	ESNH Average	ESNH EB_{90}'s	ESNH n	Baseline Average	Baseline EB_{90}'s	Baseline n	Significant Difference
ID	42.5	0.9	70	37.8	0.4	173	*
MT	44.7	4.5	9	39.4	1.6	17	*
OR	40.6	0.9	132	38.1	0.4	178	*
WA	39.7	0.9	87	38.2	0.3	211	*
Overall	40.7	0.5	298	38.1	0.2	579	*

Table 26
ESNH Type of Insulation

ESNH Type of Insulation	ESNH Total Sq Ft	ESNH Percent
Batt	27,030.0	6%
Loose	396,785.5	90%
Rigid	3,293.8	1%
Other	9,027.7	2%
None	3,166.0	1%
Overall	523,179.8	

A.16. Floor and Basement Configuration and Insulation

Table 27
Proportions of Homes with Basements

Proportions of Homes with Basements	ESNH Proportions, n=345	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
No	93.2%	2.2%	87.2%	2.2%	*
Yes	6.8%	2.2%	12.8%	2.2%	*

Table 28
Types of Floors Observed

Types of Floors Observed	ESNH Proportions, n=344	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
Crawl Space w/Floor Insulation	71.3%	4.0%	72.0%	3.0%	
Crawl Space w/o Floor Insulation	1.3%	1.0%	0.9%	0.6%	
Open Area (>4 ft. high)	0.6%	0.7%	11.2%	2.1%	*
Garage	7.8%	2.4%			
Unconditioned Basement	0.7%	0.7%			
Slab, on Grade	13.7%	3.0%	15.9%	2.4%	
Other	2.7%	1.4%			
DK	2.0%	1.2%			

Table 29
Average R-Values at Floors of Surveyed Homes

Average R-Values at Floors of Surveyed Homes	ESNH Average, n=223	ESNH EB_{90}'s	Baseline Average, n=493	Baseline EB_{90}'s	Significant Difference
Crawl Space w/Floor Insulation	27.0	0.7	25.2	0.4	*
Crawl Space w/o Floor Insulation	7.0	NA			
Open Area (>4 ft. high)	27.5	4.1	24.6	1.4	
Garage	32.2	3.9			
Unconditioned Basement	35.6	12.3			
Slab, on Grade	21.0	4.3			*
Other	17.4	10.6			
Overall	26.7	0.8	22.7	0.7	*
DK	32.5	10.7			

A.17. Heating

Table 30
Proportion of Primary Heating System Type

Proportion of Primary Heating System Type	ESNH Proportions, n=345	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
Baseboards	0.1%	0.3%	1.0%	0.7%	
DK	0.3%	0.5%			
Fireplace	0.6%	0.7%	0.7%	0.5%	
Floor			0.5%	0.5%	
Forced Air Furnace	83.5%	3.3%	85.2%	2.4%	
Heat Pump	7.0%	2.3%	8.4%	1.9%	
Hydronic System	8.5%	2.5%	1.7%	0.9%	*
Pellet Stove			0.1%	0.2%	
Wall Unit			2.6%	1.1%	

Table 31
Proportion of Hydronic Systems Fuel Types

Proportion of Hydronic Systems Fuel Types	ESNH Proportions, n=23	ESNH EB_{90}'s	Baseline Proportions, n=8	Baseline EB_{90}'s	Significant Difference
Electricity	16.2%	12.6%			
Gas	71.1%	15.6%	84.0%	21.3%	
Propane	4.7%	7.3%	16.0%	21.3%	
Solar	8.0%	9.3%			
Geothermal					
DK					

Table 32
Proportion of Heat Pump Fuel Types

Proportion of Heat Pump Fuel Types	ESNH Proportions, n=22	ESNH EB_{90}'s	Baseline Proportions, n=43	Baseline EB_{90}'s	Significant Difference
Electricity	81.9%	13.5%	92.9%	6.5%	
Gas	6.9%	8.9%	7.1%	6.5%	
Geothermal	11.2%	11.0%			
Propane					
Solar					
DK					

Table 33
Proportion of Forced Air Furnace Fuel Types

Proportion of Forced Air Furnace Fuel Types	ESNH Proportions, n=294	ESNH EB_{90}'s	Baseline Proportions, n=526	Baseline EB_{90}'s	Significant Difference
Electricity			2.2%	1.1%	
Gas	99.0%	0.9%	93.1%	1.8%	*
Propane	1.0%	0.9%	4.7%	1.5%	*
Geothermal					
Solar					
DK					

Table 34
Average AFUE Value

Average AFUE Value	ESNH Average, n=275	ESNH EB_{90}'s	Baseline Average, n=525	Baseline EB_{90}'s	Significant Difference
BOP1	91.9	0.2	83.3	0.4	*
BOP2	89.2	6.2	90.3	2.5	
Overall	91.9	0.2	83.8	0.5	*

Table 35
Proportions of Capacity Ranges, kBTUh

Proportions of Capacity Ranges, kBTUh	ESNH Proportions, n=281	ESNH EB_{90}'s	Baseline Proportions, n=501	Baseline EB_{90}'s	Significant Difference
0 to 25	1.5%	3.6%	3.1%	5.8%	
26 to 40	11.1%	9.3%	11.6%	10.7%	
41 to 55	12.3%	9.7%	16.1%	12.3%	
56 to 70	38.6%	14.4%	27.4%	15.0%	*
71 to 85	19.3%	11.7%	24.9%	14.5%	
86 to 100	10.4%	9.0%	11.6%	10.7%	
101 and Over	6.8%	7.5%	5.4%	7.6%	

Table 36
Heating FAF Mean Capacity

Heating FAF Mean Capacity	ESNH Average, n=281	ESNH EB_{90}'s	Baseline Average, n=501	Baseline EB_{90}'s	Significant Difference
Solar		NA			
Propane	68.3	18.0	76.5	10.2	
Pellets				NA	
Overall	63.9	2.0	65.2	1.7	
Geothermal	24.5	NA			
Gas	64.4	2.0	66.9	1.5	
Electricity	14.0	7.8	11.9	5.5	
DK		NA			

Table 37
Average Normalized Primary Heating System Capacities, kBTUh per Sqft

Average Normalized Primary Heating System Capacities, kBTUh per Sqft	ESNH Average, n=280	ESNH EB_{90}'s	Baseline Average, n=	Baseline EB_{90}'s	Significant Difference
Solar		NA			
Propane	0.000038	0.005858	0.000071	0.003098	
Pellets				NA	
Overall	0.000140	0.001160	0.000098	0.000728	
Geothermal	NA	NA			
Gas	0.000136	0.001157	0.000078	0.000673	

Table 38
Proportions of Normalized Primary Heating System Capacities, kBTUh per Sqft

Proportions of Normalized Primary Heating System Capacities, kBTUh per Sqft	ESNH Proportions, n=281	ESNH EB_{90}'s	Baseline Proportions, n=501	Baseline EB_{90}'s	Significant Difference
0.00 to 0.015	3.6%	4.0%	5.7%	5.5%	
0.016 to 0.020	12.0%	7.0%	8.2%	6.5%	
0.021 to 0.025	20.7%	8.8%	18.6%	9.2%	
0.026 to 0.030	20.9%	8.8%	17.8%	9.1%	
0.031 to 0.035	21.8%	8.9%	24.8%	10.3%	
0.036 to 0.040	14.3%	7.6%	14.1%	8.3%	
0.041 and Over	6.7%	5.4%	10.7%	7.4%	

Table 39
Proportions of Homes in Category

Proportions of Homes in Category	ESNH Proportions, n=344	ESNH EB_{90}'s	Baseline Proportions, n=587	Baseline EB_{90}'s	Significant Difference
Baseboard					
Electricity	100.0%		100.0%		
Fireplace					
Gas	100.0%		100.0%		
Forced Air Furnace					
Electricity			2.2%	1.1%	
Gas	99.0%	0.9%	93.1%	1.8%	*
Propane	1.0%	0.9%	4.7%	1.5%	*
Heat Pump					
Electricity	81.9%	13.5%	92.9%	6.5%	
Gas	6.9%	8.9%	7.1%	6.5%	
Geothermal	11.2%	11.0%			
Pellets					
Hydronic					
Electricity	16.2%	12.6%			
Gas	71.1%	15.6%	84.0%	21.3%	
Propane	4.7%	7.3%	16.0%	21.3%	
Solar	8.0%	9.3%			

Table 40
Average AFUE by System Type

Average AFUE by System Type	ESNH Average, n=275	ESNH EB_{90}'s	Baseline Average, n=514	Baseline EB_{90}'s	Significant Difference
Forced Air Furnace	92.0	0.2	82.9	0.4	*
Heat pump w/o electric supplement			94.3	12.8	
Hydronic System	86.7	2.7	85.6	3.4	
Overall	91.9	0.2	83.8	0.5	*

Table 41
Percent of Homes with Heating Systems

Percent of Homes with Heating Systems	ESNH Proportions	ESNH Number of Homes	Baseline Proportions	Baseline Number of Homes
Primary System	100.0%	345.00	100.0%	604.00
Secondary Heating System	8.2%	28.31	56.1%	338.61

Table 42
Heating System AFUE, BOP1

Heating System AFUE, BOP1	ESNH Proportions, n=272	ESNH EB_{90}'s	Baseline Proportions, n=493	Baseline EB_{90}'s	Significant Difference
77.5 to 79.9			0.3%	1.7%	
80.0 to 82.4	2.6%	4.5%	74.1%	13.9%	*
82.5 to 84.9			0.3%	1.8%	
85.0 to 87.4	1.0%	2.8%			
87.5 to 89.9					
90.0 to 92.4	58.0%	13.9%	14.0%	11.0%	*
92.5 to 94.9	36.4%	13.6%	7.6%	8.4%	*
95.0 to 97.4	2.1%	4.0%	0.2%	1.3%	
97.5 and Over			3.6%	5.9%	

Table 43
Heating System AFUE, BOP2

Heating System AFUE, BOP2	ESNH Proportions, n=3	ESNH EB_{90}'s	Baseline Proportions, n=32	Baseline EB_{90}'s	Significant Difference
77.5 to 79.9	24.1%	12.1%	35.8%	15.2%	
80.0 to 82.4			4.6%	6.7%	
82.5 to 84.9					
85.0 to 87.4					
87.5 to 89.9	75.9%	12.1%	10.0%	9.5%	*
90.0 to 92.4			15.2%	11.4%	
92.5 to 94.9					
95.0 to 97.4			34.4%	15.0%	
97.5 and Over					

A.18. Cooling

Table 44
Air Conditioning System Types

Air Conditioning System Types	ESNH Proportions, n=345	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
Heat Pump	10.6%	2.7%	7.8%	1.8%	
Heat Pump, Mini Split	0.6%	0.7%			
Packaged AC	0.2%	0.4%	3.1%	1.2%	*
Stand-Alone/Portable	1.1%	0.9%	0.2%	0.3%	
PTAC	0.3%	0.5%	0.7%	0.6%	
Split System AC	47.6%	4.4%	46.1%	3.3%	
None	39.4%	4.3%	42.0%	3.3%	
Don't Know	0.2%	0.4%			

Table 45
Heat Pump SEER Ratings

Heat Pump SEER Ratings	ESNH Proportions, n=24	ESNH EB_{90}'s	Baseline Proportions, n=16	Baseline EB_{90}'s	Significant Difference
< 10 SEER	2.0%	4.6%			
≥ 10 SEER			39.5%	20.1%	
≥ 11 SEER					
≥ 12 SEER			41.0%	20.2%	
≥ 13 SEER	21.8%	13.9%	19.5%	16.3%	
≥ 14 SEER	38.7%	16.4%			
≥ 15 SEER	37.6%	16.3%			

Table 46
Packaged AC Systems SEER Ratings

Packaged AC Systems SEER Ratings	ESNH Proportions, n=1	ESNH EB_{90}'s	Baseline Proportions, n=14	Baseline EB_{90}'s	Significant Difference
< 10 SEER					
≥ 10 SEER			94.5%	10.0%	
≥ 11 SEER					
≥ 12 SEER			5.5%	10.0%	
≥ 13 SEER	100.0%				
≥ 14 SEER					
≥ 15 SEER					

Table 47
Split Systems SEER Ratings

Split Systems SEER Ratings	ESNH Proportions, n=163	ESNH EB_{90}'s	Baseline Proportions, n=278	Baseline EB_{90}'s	Significant Difference
< 10 SEER			1.4%	1.2%	
≥ 10 SEER	1.5%	1.6%	83.6%	3.7%	*
≥ 11 SEER	2.9%	2.2%	2.9%	1.7%	
≥ 12 SEER	3.3%	2.3%	7.2%	2.5%	
≥ 13 SEER	76.8%	5.4%	2.0%	1.4%	*
≥ 14 SEER	10.5%	4.0%	2.8%	1.6%	*
≥ 15 SEER	4.9%	2.8%			

Table 48
Combined SEER Ratings

Combined SEER Ratings	ESNH Proportions, n=198	ESNH EB_{90}'s	Baseline Proportions, n=324	Baseline EB_{90}'s	Significant Difference
< 10 SEER	0.3%	0.6%	1.2%	1.0%	
≥ 10 SEER	9.8%	3.5%	82.1%	3.5%	*
≥ 11 SEER	1.6%	1.5%	2.5%	1.4%	
≥ 12 SEER	2.3%	1.8%	8.9%	2.6%	*
≥ 13 SEER	2.6%	1.9%	2.9%	1.5%	
≥ 14 SEER	69.0%	5.4%	2.4%	1.4%	*
≥ 15 SEER	14.4%	4.1%			

Table 49
SEER Ratings of Cooling Systems by Size: Heat Pumps

SEER Ratings of Cooling Systems by Size: Heat Pumps	ESNH Average, n=24	ESNH EB_{90}'s	Baseline Average, n=16	Baseline EB_{90}'s	Significant Difference
0.51 to 1.0 tons		NA		NA	
1.01 to 1.5 tons	14.0	NA		NA	
1.51 to 2.0 tons	14.4	0.7	10.0		*
2.01 to 2.5 tons	13.0		12.1	2.1	
2.51 to 3.0 tons	14.6	0.8	12.4	0.6	*
3.01 to 3.5 tons	14.0	0.6	10.0	NA	
3.51 to 4.0 tons	15.1	2.2	12.2	1.5	
4.01 to 4.5 tons		NA		NA	
4.51 to 5.0 tons		NA	12.6	0.7	
5.01 to 5.5 tons		NA		NA	
5.51 to 6.0 tons		NA		NA	
Overall	14.4	0.5	11.5	0.6	*

Table 50
SEER Ratings of Cooling Systems by Size: Split Systems

SEER Ratings of Cooling Systems by Size: Split Systems	ESNH Average, n=163	ESNH EB_{90}'s	Baseline Average, n=278	Baseline EB_{90}'s	Significant Difference
0.51 to 1.0 tons		NA		NA	
1.01 to 1.5 tons	15.3	NA		NA	
1.51 to 2.0 tons	13.1	0.2	10.1	0.1	*
2.01 to 2.5 tons	13.2	0.2	10.1	0.1	*
2.51 to 3.0 tons	13.2	0.2	10.3	0.1	*
3.01 to 3.5 tons	13.3	0.2	10.6	0.3	*
3.51 to 4.0 tons	13.3	0.3	10.9	0.3	*
4.01 to 4.5 tons	12.3	0.6		NA	
4.51 to 5.0 tons	13.1	0.7	10.3	0.2	*
5.01 to 5.5 tons		NA		NA	
5.51 to 6.0 tons		NA		NA	
Overall	13.2	0.1	10.4	0.1	*

Table 51
Size Distribution: Heat Pumps

Size Distribution: Heat Pumps	ESNH Average, n=30	ESNH EB_{90}'s	Baseline Average, n=40	Baseline EB_{90}'s	Significant Difference
0.51 to 1.0 tons					
1.01 to 1.5 tons	7.0%	7.6%			
1.51 to 2.0 tons	21.4%	12.3%	7.7%	6.9%	
2.01 to 2.5 tons	7.0%	7.6%	17.9%	10.0%	
2.51 to 3.0 tons	27.6%	13.4%	28.9%	11.8%	
3.01 to 3.5 tons	10.5%	9.2%	11.0%	8.1%	
3.51 to 4.0 tons	16.5%	11.1%	23.9%	11.1%	
4.01 to 4.5 tons					
4.51 to 5.0 tons	8.5%	8.4%	10.6%	8.0%	
5.01 to 5.5 tons	1.5%	3.7%			
5.51 to 6.0 tons					

Table 52
Size Distribution: Mini Split Heat Pump

Size Distribution: Mini Split Heat Pump	ESNH Average, n=1	ESNH EB_{90}'s	Baseline Average, n=	Baseline EB_{90}'s	Significant Difference
3.51 to 4.0 tons	100.0%				

Table 53
Size Distribution: Packaged System AC

Size Distribution: Packaged System AC	ESNH Average, n=1	ESNH EB_{90}'s	Baseline Average, n=17	Baseline EB_{90}'s	Significant Difference
0.51 to 1.0 tons					
1.01 to 1.5 tons					
1.51 to 2.0 tons			13.8%	13.7%	
2.01 to 2.5 tons	100.0%		22.9%	16.8%	
2.51 to 3.0 tons			15.3%	14.4%	
3.01 to 3.5 tons			22.5%	16.7%	
3.51 to 4.0 tons			13.8%	13.7%	
4.01 to 4.5 tons					
4.51 to 5.0 tons			11.8%	12.9%	
5.01 to 5.5 tons					
5.51 to 6.0 tons					

Table 54
Size Distribution: Portable Stand Alone

Size Distribution: Portable Stand Alone	ESNH Average, n=1	ESNH EB_{90}'s	Baseline Average, n=2	Baseline EB_{90}'s	Significant Difference
0.51 to 1.0 tons	100.0%		100.0%		

Table 55
Size Distribution: PTAC

Size Distribution: PTAC	ESNH Average, n=	ESNH EB_{90}'s	Baseline Average, n=2	Baseline EB_{90}'s	Significant Difference
0.51 to 1.0 tons	NA	NA	48.7%	58.1%	
1.01 to 1.5 tons	NA	NA	51.3%	58.1%	

Table 56
Size Distribution: Split System AC

Size Distribution: Split System AC	ESNH Average, n=178	ESNH EB_{90}'s	Baseline Average, n=297	Baseline EB_{90}'s	Significant Difference
0.51 to 1.0 tons					
1.01 to 1.5 tons	0.6%	1.0%			
1.51 to 2.0 tons	17.4%	4.7%	10.2%	2.9%	
2.01 to 2.5 tons	18.2%	4.8%	20.0%	3.8%	
2.51 to 3.0 tons	30.1%	5.7%	27.2%	4.2%	
3.01 to 3.5 tons	12.2%	4.0%	14.4%	3.4%	
3.51 to 4.0 tons	10.8%	3.8%	19.6%	3.8%	
4.01 to 4.5 tons	5.1%	2.7%			
4.51 to 5.0 tons	5.6%	2.8%	8.6%	2.7%	
5.01 to 5.5 tons					
5.51 to 6.0 tons					

Table 57
Proportion of Homes with Air Conditioning by State

Proportion of Homes with Air Conditioning by State	ESNH Proportion, n=223	ESNH EB_{90}'s	Baseline Proportion, n=375	Baseline EB_{90}'s	Significant Difference	ESNH Tracking, n=132	Tracking EB_{90}'s
ID	97.0%	3.3%	86.5%	4.2%	*	98.2%	6.7%
MT	78.3%	20.4%	61.4%	18.9%		42.1%	24.5%
OR	71.1%	5.9%	65.4%	5.9%		28.8%	4.7%
WA	31.1%	7.6%	41.4%	5.4%		14.5%	4.4%
Overall	60.8%	4.3%	58.0%	3.3%		35.6%	3.9%

Table 58
Average Airflow for Cooling Systems

Average Airflow for Cooling Systems	ESNH Average, n=182	ESNH EB_{90}'s	Baseline Average, n=101	Baseline EB_{90}'s	Significant Difference
Central Systems	339.6	22.4	307.5	16.3	*

Table 59
Ratio of Cooling System Airflow Rate to Cooling Capacity, CFM/Tons

Ratio of Cooling System Airflow Rate to Cooling Capacity, CFM/Tons	ESNH Proportions, n=183	ESNH EB_{90}'s	Baseline Proportions, n=103	Baseline EB_{90}'s	Significant Difference
≤ 200	11.1%	21.1%	9.1%	5.5%	
201 to 225	2.1%	9.7%	6.5%	4.7%	
226 to 250	6.7%	16.8%	3.8%	3.7%	
251 to 275	9.1%	19.3%	19.3%	7.5%	
276 to 300	15.5%	24.3%	10.4%	5.8%	
301 to 325	8.4%	18.6%	11.6%	6.1%	
326 to 350	11.0%	21.0%	13.2%	6.5%	
351 to 375	10.3%	20.4%	11.3%	6.1%	
376 to 400	5.3%	15.0%	5.6%	4.4%	
401 to 425	8.3%	18.6%	5.4%	4.3%	
426 to 450	3.9%	12.9%	3.7%	3.6%	
> 450	8.4%	18.6%			

A.19. Duct Leakage

Table 60
Average Duct Leakage to Outside, Q50/sq.ft.

Average Duct Leakage to Outside, Q50/sq.ft.	ESNH Average, n=289	ESNH EB_{90}'s	Baseline Average, n=226	Baseline EB_{90}'s	Significant Difference
Ducts in Conditioned Spaces, Only	0.064	0.014	0.088	0.026	
Ducts in Unconditioned Spaces	0.071	0.005	0.143	0.008	*
Overall	0.070	0.004	0.139	0.008	*

Table 61
Duct Leakage Rate per Conditioned Square Footage, Q50/sq. ft.

Duct Leakage Rate per Conditioned Square Footage, Q50/sq. ft.	ESNH Proportions, n=289	ESNH EB_{90}'s	Baseline Proportions, n=226	Baseline EB_{90}'s	Significant Difference
0.000 to 0.020	8.8%	3.1%	0.8%	1.6%	*
0.021 to 0.040	22.8%	4.6%	2.5%	2.9%	*
0.041 to 0.060	24.0%	4.7%	4.2%	3.8%	*
0.061 to 0.080	16.3%	4.1%	10.1%	5.7%	
0.081 to 0.100	11.1%	3.5%	13.3%	6.4%	
0.101 to 0.120	5.3%	2.5%	15.9%	6.9%	*
0.121 to 0.140	4.1%	2.2%	14.7%	6.7%	*
0.141 to 0.160	3.3%	2.0%	7.3%	4.9%	
0.161 to 0.180	1.8%	1.5%	8.7%	5.3%	*
0.181 to 0.200	1.1%	1.2%	7.0%	4.8%	
0.201 to 1.000	1.4%	1.3%	15.5%	6.8%	*

Table 62
Average Total Duct Leakage Rate, Q50 in CFM

Average Total Duct Leakage Rate, Q50 in CFM	ESNH Average, n=143	ESNH EB_{90}'s	Baseline Average, n=113	Baseline EB_{90}'s	Significant Difference
Overall	172.5	238.6	311.6	18.7	*

Table 63
Total Duct Leakage Rate, Q50 in CFM

Total Duct Leakage Rate, Q50 in CFM	ESNH Proportions, n=293	ESNH EB_{90}'s	Baseline Proportions, n=225	Baseline EB_{90}'s	Significant Difference
0 to 25	2.2%	1.6%			
25 to 50	1.0%	1.1%	1.2%	4.1%	
51 to 75	14.0%	3.8%	1.6%	4.7%	*
76 to 100	10.2%	3.3%	1.8%	5.1%	
101 to 125	14.9%	3.9%	4.4%	7.7%	
126 to 150	13.3%	3.8%	4.6%	7.9%	
151 to 175	9.8%	3.3%	5.7%	8.7%	
176 to 200	6.9%	2.8%	8.6%	10.6%	
201 to 225	5.6%	2.5%	4.6%	7.9%	
226 to 250	5.7%	2.6%	12.3%	12.4%	
251 to 275	4.5%	2.3%	6.7%	9.4%	
271 to 300	2.6%	1.8%	5.5%	8.6%	
301 and Over	9.4%	3.2%	43.1%	18.7%	*

Table 64
Average Ratio of Duct Leakage Rate to TrueFlow System Airflow, CFM/CFM

Average Ratio of Duct Leakage Rate to TrueFlow System Airflow, CFM/CFM	ESNH Average, n=255	ESNH EB_{90}'s	Baseline Average, n=173	Baseline EB_{90}'s	Significant Difference
Conditioned	0.211	0.059	0.368	0.1	*
Unconditioned	0.192	0.014	0.344	0.0	*
Overall	0.194	0.014	0.346	0.0	*

Table 65
Ratio of Duct Leakage Rate to TrueFlow System Airflow, CFM/CFM

Ratio of Duct Leakage Rate to TrueFlow System Airflow, CFM/CFM	ESNH Proportions, n=253	ESNH EB_{90}'s	Baseline Proportions, n=174	Baseline EB_{90}'s	Significant Difference
0.00 to 0.050	2.4%	1.7%	0.5%	1.4%	
0.05 to 0.100	16.1%	4.1%	2.1%	2.7%	*
0.10 to 0.15	25.2%	4.8%	6.6%	4.7%	*
0.16 to 0.20	18.8%	4.3%	12.6%	6.3%	
0.21 to 0.25	16.8%	4.2%	12.9%	6.4%	
0.26 to 0.30	6.8%	2.8%	10.7%	5.9%	
0.31 to 0.35	4.8%	2.4%	15.5%	6.9%	*
0.36 to 0.40	3.3%	2.0%	10.9%	5.9%	
0.41 to 0.45	0.9%	1.1%	6.2%	4.6%	
0.46 to 0.50	1.1%	1.1%	8.6%	5.3%	*
0.51 to 0.54	1.7%	1.4%	3.5%	3.5%	
0.55 to 0.60	0.2%	0.5%	1.6%	2.4%	
0.61 to 2.00	1.9%	1.5%	8.3%	5.2%	

A.20. Thermostats

Table 66
Proportions of Thermostat Types

Proportions of Thermostat Types	ESNH Proportions, n=344	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
Digital	89.1%	2.8%	90.3%	2.0%	
Hybrid	9.0%	2.5%	0.7%	0.5%	*
Mechanical	0.8%	0.8%	8.7%	1.9%	*
Don't Know / Other	1.1%	0.9%	0.4%	0.4%	

A.21. Hot Water

Table 67
Capacity of Storage Tank Water Heaters, Gallons

Capacity of Storage Tank Water Heaters, Gallons	ESNH Proportions, n=294	ESNH EB_{90}'s	Baseline Proportions, n=582	Baseline EB_{90}'s	Significant Difference
≤ 40	28.0%	13.1%	27.0%	14.3%	
40.1 to 50	62.9%	14.0%	57.9%	15.9%	
50.1 to 60	0.8%	2.5%	0.6%	2.5%	
60.1 to 70	3.6%	5.4%	4.3%	6.5%	
70.1 to 80	4.7%	6.2%	10.3%	9.8%	

Table 68
Average Energy Factor by BOPs

Average Energy Factor by BOPs	ESNH Average, n=262	ESNH EB_{90}'s	Baseline Average, n=393	Baseline EB_{90}'s	Significant Difference
BOP1Over60NG	0.62	NA	0.54	0.01	
BOP1Over70Ele	0.86	0.01	0.89	0.02	
BOP1Under60NG	0.62	0.00	0.39	0.39	
BOP1Under70Ele	0.93	0.01	0.90	0.01	*
BOP2Elec	0.95		0.90	0.02	*
Overall	0.65	0.01	0.44	0.34	

Table 69
Water Heater Energy Factors by System Size and Fuel Type

Water Heater Energy Factors by System Size and Fuel Type	ESNH Average, n=262	ESNH EB_{90}'s	Baseline Average, n=393	Baseline EB_{90}'s	Significant Difference
BOP1Over60NG	0.62	NA	0.54	0.01	
BOP1Over70Ele	0.86	0.01	0.89	0.02	
BOP1Under60NG	0.62	0.00	0.39	0.39	
BOP1Under70Ele	0.93	0.01	0.90	0.01	*
BOP2Elec	0.95		0.90	0.02	*
Overall	0.65	0.01	0.44	0.34	

Table 70
Energy Factors by Water Heater Type

Energy Factors by Water Heater Type	ESNH Average, n=289	ESNH EB_{90}'s	Baseline Average, n=409	Baseline EB_{90}'s	Significant Difference
Heat Pump (Electric)	0.9	0.04			
Standard Storage (Electric)	0.9	0.01	0.9	0.01	
Instantaneous Tankless (Natural Gas)	0.8	0.00	0.8	0.01	
Standard Storage (Natural Gas)	0.6	0.00	0.4	0.37	*
Instantaneous Tankless (Propane LPG	0.8	0.01			
Standard Storage (Propane LPG)			0.6	0.01	
Heat Pump (Solar)	0.9	NA			
Standard Storage (Solar w/back-up)	1.0	NA			

Table 71
Percent of Water Heaters with Blankets

Percent of Water Heaters with Blankets	ESNH Proportions, n=332	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
No Blanket	97.3%	1.5%	97.6%	1.0%	
Blanket	2.7%	1.5%	2.4%	1.0%	

Table 72
Distribution of Lamps per Home

Distribution of Lamps per Home	ESNH Proportions, n=344	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
20 to 40	5.2%	16.3%	6.8%	18.5%	
41 to 60	34.4%	34.9%	30.2%	33.8%	
61 to 80	27.9%	33.0%	27.1%	32.7%	
81 to 100	20.7%	29.8%	16.9%	27.6%	
101 to 120	6.7%	18.3%	10.2%	22.2%	
121 and Over	5.2%	16.4%	8.8%	20.9%	

A.22. Lighting

Table 73
Distribution of Number of Lighting Fixtures per Home

Distribution of Number of Lighting Fixtures per Home	ESNH Proportions, n=344	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
0 to 10	0.4%	1.9%			
11 to 20	2.4%	4.6%			
21 to 30	14.8%	10.7%	0.3%	1.7%	*
31 to 40	26.4%	13.2%	2.3%	4.7%	*
41 to 50	20.8%	12.2%	6.6%	7.8%	*
51 to 60	15.0%	10.7%	12.2%	10.4%	
61 to 70	10.7%	9.3%	13.0%	10.6%	
71 to 80	4.0%	5.9%	11.3%	10.0%	
81 to 90	1.4%	3.6%	11.0%	9.9%	
91 to 100	1.1%	3.1%	6.8%	8.0%	
101 and Over	3.0%	5.1%	36.7%	15.3%	*

Table 74
Distribution of Lighting Sockets per Sqft

Distribution of Lighting Sockets per Sqft	ESNH Proportions, n=344	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
0.0 to 0.020	3.0%	5.0%	3.5%	5.7%	
0.021 to 0.025	9.2%	8.6%	13.1%	10.5%	
0.026 to 0.030	30.8%	13.6%	25.2%	13.5%	
0.031 to 0.035	25.4%	12.9%	22.5%	13.0%	
0.036 to 0.040	14.2%	10.3%	15.4%	11.2%	
0.041 to 0.045	9.9%	8.8%	8.6%	8.7%	
0.046 to 0.050	3.5%	5.5%	5.8%	7.3%	
0.051 and Over	4.0%	5.8%	6.0%	7.4%	

Table 75
Average Lighting Sockets per Sqft by Type of Residence

Average Lighting Sockets per Sqft by Type of Residence	ESNH Average, n=344	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
Single Family, Detached, 1 Story	0.037	0.002	0.036	0.001	
Single Family, Detached, 2 Story	0.031	0.001	0.032	0.001	
Single Family, Detached, 3+ Story	0.030	0.002	0.030	0.003	
Townhouse or Rowhouse	0.032	0.001	0.035	0.007	
Duplex, Triplex, or Quadplex	0.044	NA			
Overall	0.033	0.001	0.033	0.001	

A.23. Fixture Types

Table 76
Proportions of Lamps by Fixture

Proportions of Lamps by Fixture	ESNH Proportions, n=10,277	ESNH EB_{90}'s	Baseline Proportions, n=16,302	Baseline EB_{90}'s	Significant Difference
Architecturally Integrated	0.5%	0.1%	0.7%	0.1%	
Ceiling fixtures	31.2%	0.8%	29.3%	0.6%	*
Ceiling Fan	3.5%	0.3%	4.2%	0.3%	*
Floor Lamp	2.6%	0.3%	1.7%	0.2%	*
Track lighting	0.3%	0.1%	0.7%	0.1%	*
Other	0.4%	0.1%	0.6%	0.1%	*
Recessed can	20.8%	0.7%	23.7%	0.5%	*
Chandelier / Hanging	10.7%	0.5%	12.2%	0.4%	*
Torchiere	0.6%	0.1%	0.4%	0.1%	*
Table lamps	6.0%	0.4%	5.4%	0.3%	
Under Counter	2.8%	0.3%	2.0%	0.2%	*
Wall mount	20.7%	0.7%	19.2%	0.5%	*
DK	0.0%	0.0%			

Table 77
Proportions of Fixture Types

Proportions of Fixture Types	ESNH Proportions, n=2,288	ESNH EB_{90}'s	Baseline Proportions, n=4,010	Baseline EB_{90}'s	Significant Difference
Architecturally Integrated	1.2%	0.4%	2.4%	0.4%	*
Ceiling fixtures	15.1%	1.2%	15.0%	0.9%	
Ceiling Fan	7.4%	0.9%	7.9%	0.7%	
Floor Lamp	9.6%	1.0%	7.7%	0.7%	*
Track lighting	0.5%	0.2%	1.1%	0.3%	*
Other	1.0%	0.3%	1.3%	0.3%	
Recessed can	14.1%	1.2%	14.4%	0.9%	
Chandelier / Hanging	13.3%	1.2%	13.8%	0.9%	
Torchiere	2.6%	0.5%	2.7%	0.4%	
Table lamps	13.0%	1.2%	13.0%	0.9%	
Under Counter	7.2%	0.9%	5.6%	0.6%	*
Wall mount	15.1%	1.2%	14.9%	0.9%	
DK	0.0%	0.1%			

Table 78
Average Lamps per Fixture

Average Lamps per Fixture	ESNH Average, n=10,261	ESNH EB_{90}'s	Baseline Average, n=16,302	Baseline EB_{90}'s	Significant Difference
Architecturally Integrated	3.021	1.101	2.416	0.355	
Ceiling fixtures	2.389	0.048	2.496	0.048	*
Ceiling Fan	2.409	0.112	2.936	0.086	*
Chandelier / Hanging	4.076	0.157	4.372	0.135	*
Floor Lamp	1.486	0.079	1.628	0.095	*
Track lighting	4.372	0.781	3.806	0.500	
Other	3.226	0.991	2.534	0.337	
Recessed can	2.706	0.073	3.489	0.086	*
Torchiere	1.359	0.142	1.185	0.071	*
Table lamps	1.246	0.026	1.438	0.030	*
Under Counter	2.873	0.293	3.479	0.421	*
Wall mount	2.890	0.075	3.254	0.062	*
DK	2.500	2.468			
Overall	2.482	0.031	2.854	0.031	*

Table 79
Proportion of Overall Fixture-Lamp ES Candidates

Proportion of Overall Fixture-Lamp ES Candidates	ESNH Proportions, n=15,568	ESNH EB_{90}'s	Baseline Proportions, n=17,605	Baseline EB_{90}'s	Significant Difference
Control(M)	0.1%	0.0%	0.1%	0.0%	
Control(P)	0.0%	0.0%	0.0%	0.0%	
Control(P/M)	0.0%	0.0%	0.1%	0.0%	*
Fix	1.3%	0.2%	0.2%	0.1%	*
Lamp	51.2%	0.8%	7.6%	0.3%	*
No Qual	47.4%	0.8%	92.0%	0.4%	*
Comb	52.6%	0.8%	8.0%	0.4%	*

Table 80
Proportions of Lighting Fixture Types

Proportions of Lighting Fixture Types	ESNH Proportions	Baseline Proportions
Architecturally Integrated	8.7%	14.6%
Ceiling fixtures	99.7%	99.7%
Ceiling Fan	51.0%	56.1%
Floor Lamp	62.0%	52.0%
Track lighting	3.5%	6.8%
Other	7.5%	10.9%
Recessed can	93.6%	96.0%
Chandelier / Hanging	87.0%	92.1%
Torchiere	17.7%	16.4%
Table lamps	86.1%	87.1%
Under Counter	46.1%	33.6%
Wall mount	99.7%	98.7%
DK	0.3%	

Table 81
Average Number of Fixtures by Type of Residence

Average Number of Fixtures by Type of Residence	ESNH Average, n=344	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
Duplex, Triplex, or Quadplex	29.0	NA			
Single Family, Detached	50.0	2.4	104.3	4.7	*
Single Family, Deatched, Two Story	45.7	4.2	85.5	5.1	*
Single Family, Detached, Three or more	60.9	6.8	130.9	22.0	*
Townhouse or Rowhouse	32.7	2.9	54.9	6.1	*
Overall	47.4	1.9	97.9	3.5	*

Table 82
Average Fixture Types per Home

Average Fixture Types per Home	ESNH Average, n=2,288	ESNH EB_{90}'s	Baseline Average, n=4,010	Baseline EB_{90}'s	Significant Difference
Architecturally Integrated	3.5	0.5	2.4	0.3	*
Ceiling fixtures	13.2	0.6	13.3	0.4	
Ceiling Fan	2.2	0.2	2.2	0.1	
Floor Lamp	2.1	0.2	1.7	0.1	*
Track lighting	2.3	0.9	2.4	0.5	
Other	2.6	0.8	3.1	0.5	
Recessed can	16.0	1.3	19.0	1.4	*
Chandelier / Hanging	2.7	0.2	2.9	0.1	
Torchiere	2.2	0.3	1.4	0.1	*
Table lamps	4.7	0.3	4.3	0.2	*
Under Counter	2.9	0.3	2.6	0.3	
Wall mount	8.0	0.4	7.0	0.3	*
DK	5.0	NA			
Overall	7.1	0.3	7.4	0.3	

Table 83
Proportions of Lighting Fixtures with CFLs

Proportions of Lighting Fixtures with CFLs	ESNH Proportions	Baseline Proportions
Architecturally Integrated	73.8%	11.6%
Ceiling fixtures	80.5%	20.7%
Ceiling Fan	51.8%	6.3%
Floor Lamp	29.5%	18.0%
Garage Door Opener		2.9%
Track lighting	18.2%	1.2%
Other	54.1%	5.4%
Recessed	47.9%	12.7%
Chandelier / Hanging	50.4%	5.8%
Torchiere	33.6%	31.9%
Table lamps	32.3%	11.9%
Under Counter	65.8%	52.0%
Wall mount	54.9%	6.8%

A.24. Lamp Types

Table 84
Average Number of Lamp Types per Home

Average Number of Lamp Types per Home	ESNH Average, n=1,004	ESNH EB_{90}'s	Baseline Average, n=1,383	Baseline EB_{90}'s	Significant Difference
CFL	37.9	1.8	11.7	2.3	*
Fluorescent	6.8	0.9	8.9	1.0	*
Halogen	6.9	1.2	10.3	1.9	*
Inc	28.4	1.9	62.1	1.8	*

Table 85
Proportion of Lamps by Lamp Type per Home

Proportion of Lamps by Lamp Type per Home	ESNH Proportions, n=2,288	ESNH EB_{90}'s	Baseline Proportions, n=4,010	Baseline EB_{90}'s	Significant Difference
Architecturally Integrated	1.2%	0.4%	2.4%	0.4%	*
Ceiling fixtures	15.1%	1.2%	15.0%	0.9%	
Ceiling Fan	7.4%	0.9%	7.9%	0.7%	
Floor Lamp	9.6%	1.0%	7.7%	0.7%	*
Track lighting	0.5%	0.2%	1.1%	0.3%	*
Other	1.0%	0.3%	1.3%	0.3%	
Recessed can	14.1%	1.2%	14.4%	0.9%	
Chandelier / Hanging	13.3%	1.2%	13.8%	0.9%	
Torchiere	2.6%	0.5%	2.7%	0.4%	
Table lamps	13.0%	1.2%	13.0%	0.9%	
Under Counter	7.2%	0.9%	5.6%	0.6%	*
Wall mount	15.1%	1.2%	14.9%	0.9%	
DK	0.0%	0.1%			

Table 86
Average Number of Lamps by Type of Residence

Average Number of Lamps by Type of Residence	ESNH Average, n=344	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
Duplex, Triplex, or Quadplex	53.0	NA			
Single Family, Detached, 2 Story	77.4	3.1	81.8	3.0	*
Single Family, Detached, 1 Story	71.1	6.0	68.4	3.4	
Single Family, Detached, 3+ Story	90.0	8.8	96.9	14.1	
Townhouse or Rowhouse	49.8	3.1	45.5	2.2	*
Overall	73.1	2.5	77.1	2.3	*

Table 87
Proportions of CFLs by Room Type

Proportions of CFLs by Room Type	ESNH Proportions	Baseline Proportions
Basement	71.4%	7.1%
Bathroom	51.2%	5.0%
Breakfast Nook	55.7%	9.4%
Bedroom	58.9%	7.3%
Closet	81.9%	5.8%
Dining Room	44.6%	5.9%
Family Room	53.5%	8.8%
Garage	59.6%	8.4%
Hall	69.5%	6.8%
Kitchen	48.1%	8.3%
Living Room	47.9%	8.4%
Laundry Room	84.2%	7.1%
Other	61.8%	6.1%
Office	56.3%	9.1%
Porch	36.6%	7.2%
Rec Room	68.8%	11.8%
Whole House	54.6%	NA

A.25. Recessed Cans

Table 88
Proportions of Room Types with Recessed Can Fixtures

Proportions of Room Types with Recessed Can Fixtures	ESNH Proportions	Baseline Proportions
Basement	0.2%	
Bathroom	15.1%	59.8%
Breakfast Nook	0.8%	
Bedroom	4.6%	7.1%
Closet	0.7%	1.8%
Dining Room	3.7%	2.4%
Family Room	4.0%	1.8%
Garage	0.4%	
Hall	13.9%	4.7%
Kitchen	25.4%	6.5%
Laundry Room	13.5%	3.0%
Living Room	1.5%	10.7%
Other	1.5%	
Office	2.1%	2.4%
Porch	0.6%	
Rec Room	0.8%	
Outside	11.0%	

Table 89
Proportions of Recessed Cans by Room Type

Proportions of Recessed Cans by Room Type	ESNH Proportions	Baseline Proportions
Basement	0.2%	
Bathroom	15.1%	59.8%
Breakfast Nook	0.8%	
Bedroom	4.6%	7.1%
Closet	0.7%	1.8%
Dining Room	3.7%	2.4%
Family Room	4.0%	1.8%
Garage	0.4%	
Hall	13.9%	4.7%
Kitchen	25.4%	6.5%
Living Room	13.5%	10.7%
Laundry Room	1.5%	3.0%
Other	1.5%	
Office	2.1%	2.4%
Porch	0.6%	
Rec Room	0.8%	
Whole House	11.0%	

Table 90
Average Number of Recessed Cans

Average Number of Rececssed Cans	ESNH Average, n=344	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
Overall	15.0	1.2	0.8	0.2	*

A.26. Ceiling Fans

Table 91
Ceiling Fan Lamp Types

Ceiling Fan Lamp Types	ESNH Number of Fans with this Bulb	ESNH Percentage of Ceiling Fans	Baseline Number of Fans with this Bulb	Baseline Percentage of Ceiling Fans
Compact Fluorescent A Style	8	3.7%	2	0.5%
Compact Fluorescent Capsule	1	0.5%		
Compact Fluorescent Circline	2	0.9%		
Compact Fluorescent Decorative	1	0.5%		
Compact Fluorescent Flood	2	0.9%		
Compact Fluorescent Globe	4	1.8%	1	0.3%
Compact Fluorescent Spring	86	39.3%	16	4.1%
Compact Fluorescent Tube	3	1.4%		
Compact Fluorescent Unknown	8	3.7%	1	0.3%
Compact Fluorescent Mini			3	0.8%
Compact Fluorescent Pin Based			1	0.3%
Total Compact Fluorescent	**115**	**36.5%**	**24**	**3.2%**
Fluorescent Other	1	0.5%	3	0.8%
Fluorescent Circular	4	1.8%		
Total Fluorescent	**5**	**2.3%**	**3**	**0.8%**
Halogen MR-16 pin based	2	0.9%		
Halogen Other	2	0.9%	1	0.3%
Halogen Quartz Tube	2	0.9%		
Halogen Unknown			3	0.8%
Total Halogen	**6**	**2.7%**	**4**	**1.0%**
Incandescent Decorative	11	5.0%	53	13.6%
Incandescent Flood	4	1.8%	4	1.0%
Incandescent Globe	4	1.8%	9	2.3%
Incandescent Other			5	1.3%
Incandescent Standard	60	27.4%	282	72.3%
Incandescent Unkown	6	2.7%	4	1.0%
Incandescent Mini			2	0.5%
Total Incandescent	**85**	**38.8%**	**359**	**92.1%**
LED	1	0.5%		
Don't Know	7	3.2%		

Table 92
Total Number of Ceiling Fixture Lamps by Type

Total Number of Ceiling Fixture Lamps by Type	ESNH Total Number of Ceiling Fixture Lamps	ESNH Proportion of Ceiling Fixture Lamps	Baseline Total Number of Ceiling Fixture Lamps	Baseline Proportion of Ceiling Fixture Lamps
Compact Fluorescent A Style	22	5.6%	4	0.5%
Compact Fluorescent Capsule	1	0.3%		
Compact Fluorescent Circline	3	0.8%		
Compact Fluorescent Decorative	1	0.3%		
Compact Fluorescent Flood	2	0.5%		
Compact Fluorescent Globe	5	1.3%	1	0.1%
Compact Fluorescent Spring	163	41.2%	27	3.6%
Compact Fluorescent Tube	4	1.0%		
Compact Fluorescent Unknown	16	4.0%	1	0.1%
Compact Fluorescent Mini			4	0.5%
Compact Fluorescent Pin Based			1	0.1%
Total Compact Fluorescent	**217**	**54.8%**	**38**	**5.0%**
Fluorescent Other	1	0.3%	17	2.3%
Fluorescent Circular	5	1.3%		
Total Fluorescent	**6**	**1.5%**	**17**	**2.3%**
Halogen MR-16 pin based	2	0.5%		
Halogen Other	2	0.5%	1	0.1%
Halogen Quartz Tube	2	0.5%		
Halogen Unknown			3	0.4%
Total Halogen	**6**	**1.5%**	**4**	**0.5%**
Incandescent Decorative	14	3.5%	93	12.3%
Incandescent Flood	4	1.0%	11	1.5%
Incandescent Globe	8	2.0%	11	1.5%
Incandescent Other			5	0.7%
Incandescent Standard	123	31.1%	569	75.5%
Incandescent Unkown	10	2.5%	4	0.5%
Incandescent Mini			2	0.3%
Total Incandescent	**159**	**40.2%**	**695**	**92.2%**
LED	1	0.3%		
Don't Know	7	1.8%		

Table 93
Number of Ceiling Fans

Number of Ceiling Fans	ESNH Average, n=344	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
Total Number of Fans Installed	376		703		
Average Fans per House with at least one Fan	2.28		2.22		
Average Fans per House over Sample	1.09	0.14	1.16	0.11	

Table 94
Percentage of Homes with Ceiling Fans by Room Type

Percentage of Homes with Ceiling Fans by Room Type	ESNH Proportions, n=304	Baseline Proportions, n=591
(B) Basement	1.0%	0.0%
(BA) Bathroom	2.3%	1.0%
(BN) Breakfast Nook	0.3%	1.5%
(BR) Bedroom	42.8%	38.1%
(CL) Closet	0.0%	0.0%
(D) Dining Room	1.0%	1.2%
(F) Family Room	6.6%	11.3%
(G) Garage	0.0%	0.8%
(H) Hall	1.3%	1.0%
(K) Kitchen	0.0%	0.5%
(L) Living Room	31.3%	32.0%
(LN) Laundry Room	0.0%	0.3%
(O) Other	5.6%	0.7%
(OF) Office	4.9%	6.1%
(P) Indoor Porch	0.3%	1.4%
(RR) Rec Room	2.0%	4.1%
(X) Outside	0.7%	0.0%

Table 95
Proportion of Lamps per Ceiling Fan

Proportion of Lamps per Ceiling Fan	ESNH Proportions, n=391	ESNH EB_{90}'s	Baseline Proportions, n=718	Baseline EB_{90}'s	Significant Difference
0.0 to 1.0	27.9%	11.8%	16.4%	9.9%	*
1.1 to 2.0	32.5%	12.3%	22.8%	11.2%	*
2.1 to 3.0	21.3%	10.8%	24.5%	11.5%	
3.1 to 4.0	15.7%	9.6%	34.1%	12.7%	*
4.1 to 5.0	1.6%	3.3%	1.7%	3.5%	
5.1 and Over	1.1%	2.7%	0.5%	2.5%	

Table 96
Ceiling Fans per Home

Ceiling Fans per Home	ESNH Proportions, n=344	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
None	51.1%	15.0%	47.4%	15.8%	
0 to 1	20.0%	12.0%	22.9%	13.3%	
1.01 to 2	14.5%	10.6%	13.7%	10.9%	
2.01 to 3	6.6%	7.4%	7.4%	8.3%	
3.01 to 4	3.7%	5.7%	4.3%	6.4%	
4.01 to 5	2.0%	4.2%	1.6%	4.0%	
5.01 to 6	0.4%	2.0%	1.1%	3.3%	
Over 6	1.7%	3.9%	1.6%	4.0%	

A.27. Torchiere Lights

Table 97
Lighting Torchieres per Home

Lighting Torchieres per Home	ESNH Proportions, n=61	ESNH EB_{90}'s	Baseline Proportions, n=	Baseline EB_{90}'s	Significant Difference
0 to 1.0	55.5%	14.9%	67.9%	14.8%	
2	12.6%	10.0%	24.2%	13.6%	
3	12.2%	9.8%	6.7%	7.9%	
4	9.0%	8.6%	0.7%	2.7%	
5	4.6%	6.3%	0.6%	2.4%	
6 and Over	6.1%	7.2%			

Table 98
Proportions of Rooms with Torchieres

Proportions of Rooms with Torchieres	ESNH Proportions	Baseline Proportions
Basement		0.8%
Bathroom 1		
Bathroom 2		
Bathroom 3		
Bathroom 4		
Bathroom 5		
Bathroom 6		
Master Bathroom	1.1%	
Breakfast Nook	1.1%	
Bedroom 1	8.6%	8.1%
Bedroom 2	8.6%	6.5%
Bedroom 3	3.2%	3.2%
Bedroom 4		0.8%
Bedroom 5		
Bedroom 6		
Master Bedroom	10.8%	10.5%
Closet		
Closet 2		
Dining Room		0.8%
Family Room	10.8%	21.8%
Garage		
Hall	3.2%	2.4%
Kitchen	1.1%	
Living Room	24.7%	33.9%
Living Room 2		
Living Room 3		
Living Room 4		
Laundry Room		0.8%
Other	3.2%	0.8%
Office	6.5%	8.9%
Office 2		
Indoor Porch		
Rec Room	3.2%	0.8%
Exterior Entry	9.7%	
Exterior Landscape	1.1%	
Exterior Porch	1.1%	
Exterior Walkway	1.1%	
DK	1.1%	

A.28. Lighting Controls

Table 99
Proportions of Exterior Fixtures with Controls

Proportions of Exterior Fixtures with Controls	ESNH Proportions, n=791	ESNH EB_{90}'s	Baseline Proportions, n=939	Baseline EB_{90}'s	Significant Difference
Non-Candidates	42.9%	2.9%	86.7%	1.8%	*
M Control-Qualified Fixture Candidates	1.2%	0.6%	1.8%	0.7%	
P Control-Qualified Fixture Candidates	0.7%	0.5%	0.5%	0.4%	
P/M Control-Qualified Fixture Candidat	0.1%	0.2%	2.3%	0.8%	*
Pin-Based Fixture Candidates	1.2%	0.6%	0.1%	0.2%	*
Screw-based CFL Candidates	53.9%	2.9%	8.6%	1.5%	*

A.29. Lamp Wattages

Table 100
Average Lighting Power Density by Type of Residence

Average Lighting Power Density by Type of Residence	ESNH Average, n=344	ESNH EB_{90}'s	Baseline Average, n=604	Baseline EB_{90}'s	Significant Difference
Single Family, Detached, 1 Story	45.7	37.1	81.1	0.4	*
Single Family, Detached, 2 Story	50.0	33.8	68.4	0.4	*
Single Family, Detached, 3+ Story	60.9	31.7	61.7	0.3	
Townhouse or Rowhouse	32.7	18.3	99.5	0.5	*
Duplex, Triplex, or Quadplex	29.0	NA			
Overall	47.4	34.5	73.0	0.4	*

Table 101
Average Lamp Fixture Wattage

Average Lamp Fixture Wattage	ESNH Average, n=2,215	ESNH EB_{90}'s	Baseline Average, n=4,010	Baseline EB_{90}'s	Significant Difference
Architecturally Integrated	32.4	5.6	38.5	3.8	
Ceiling fixtures	26.4	1.3	59.0	0.9	*
Ceiling Fan	35.0	3.5	57.2	1.9	*
Floor Lamp	74.7	6.3	66.2	4.8	*
Track lighting	57.0	10.9	54.2	3.3	
Other	35.9	7.6	68.7	15.1	*
Recessed can	45.3	2.1	68.5	1.7	*
Chandelier / Hanging	35.9	2.3	57.0	1.1	*
Torchiere	73.5	13.7	144.1	22.5	*
Table lamps	53.0	2.9	53.1	1.3	
Under Counter	31.9	3.3	35.0	1.8	
Wall mount	38.5	1.9	60.1	1.1	*
Overall	42.9	1.1	60.5	0.9	

Table 102
Average Lamp Wattage by Lamp Type

Average Lamp Wattage by Lamp Type	ESNH Average, n=3,139	ESNH EB_{90}'s	Baseline Average, n=1,741	Baseline EB_{90}'s	Significant Difference
Compact Fluorescent A Style	16.3	1.3	15.3	0.7	
Compact Fluorescent Capsule	11.0		11.4	1.2	
Compact Fluorescent Decorative	18.8	6.1	30.0	19.1	
Compact Fluorescent Flood	19.8	1.9	19.2	1.5	
Compact Fluorescent Globe	12.7	1.7	14.7	1.4	
Compact Fluorescent Spring	17.0	0.5	15.7	0.3	*
Compact Fluorescent Tube	20.3	1.4	19.7	2.8	
Compact Fluorescent Unknown	24.3	1.6	18.6	3.2	*
Compact Fluorescent Mini	18.1	1.3			
Compact Fluorescent Pin Based	21.9	3.3			
Fluorescent Tube T-12	39.5	1.2	37.9	8.8	
Fluorescent T-4	15.5	7.4	45.6	8.9	*
Fluorescent Tube T-5	16.5	3.1	21.7	3.4	*
Fluorescent Tube T-8	31.2	1.9	33.1	2.7	
Fluorescent Circuline	25.6	3.1	78.9	8.4	*
Fluorescent Other	30.5	7.4	31.5	14.2	
Fluorescen Tube Unknown	26.7	1.7	31.5	11.9	
PAR	64.7	5.1	60.6	6.1	
Halogen Quartz Tube	172.6	23.7	118.7	36.5	*
Halogen T-3			100.0	NA	
Halogen MR-16 pin based	43.9	5.1	43.2	6.0	
Halogen Flood			57.9	4.4	
Halogen - Other	49.1	8.1	84.5	18.5	*
Halogen - Unknown	65.2	9.6	64.7	13.2	
Incandescent Heat Lamp	204.0	11.2	250.0	35.0	
Incandescent Flood	66.4	0.6	69.3	1.6	*
Incandescent Globe	57.7	1.6	60.7	3.8	
Incandescent - Other	57.0	5.5	51.2	7.6	
Incandescent Standard	64.3	0.6	71.5	1.8	*
Incandescent - Unknown	77.8	20.6	45.5	8.3	*
Incandescent Flood Heat Lamp			250.0	NA	
Incandescent Decorative	48.2	1.5	44.5	3.5	
Incandescent Mini	36.1	2.5			
LED			30.0	NA	
NO BULB				NA	
Don't Know			32.6	30.2	

A.30. Primary Refrigerators

Table 103
Proportions of Refrigerator Configuration

Proportions of Refrigerator Configuration	ESNH Proportions, n=345	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
Bottom Freezer	26.3%	3.9%	14.5%	2.4%	*
DK	0.4%	0.6%			
Side by Side	61.4%	4.3%	69.5%	3.1%	*
Single Door	0.4%	0.6%	0.4%	0.4%	
Standard	11.4%	2.8%	15.6%	2.4%	

Table 104
Distribution of Refrigerator Sizes

Distribution of Refrigerator Sizes	ESNH Proportions, n=345	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
Very Small (<=10 Cubic Feet)	1.8%	1.2%			
Small (11-14 Cubic Feet)	0.4%	0.6%	0.3%	0.4%	
Medium (15-18 Cubic Feet)	3.5%	1.6%	6.0%	1.6%	
Large (19-22 Cubic Feet)	29.4%	4.0%	25.8%	2.9%	
Very Large (>22 Cubic Feet)	64.1%	4.2%	67.9%	3.1%	
Don't Know	0.8%	0.8%			

Table 105
Proportions of Refrigerators with Through the Door Features

Proportions of Refrigerators with Through the Door Features	ESNH Proportions, n=345	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
No	34.4%	4.2%	32.9%	3.1%	
Yes	65.6%	4.2%	67.1%	3.1%	

A.31. Secondary Refrigerators

Table 106
Proportions of Secondary Refrigerator Configuration

Proportions of Secondary Refrigerator Configuration	ESNH Proportions, n=88	ESNH EB_{90}'s	Baseline Proportions, n=124	Baseline EB_{90}'s	Significant Difference
Bottom Freezer	1.7%	2.3%	9.6%	4.3%	*
Compact	24.0%	7.5%	14.4%	5.2%	
DK	0.7%	1.4%			
Side by Side	19.8%	7.0%	18.0%	5.7%	
Single Door	9.5%	5.1%	2.7%	2.4%	
Standard	44.4%	8.7%	55.4%	7.3%	

Table 107
Proportions of Secondary Refrigerators with Through the Door Features

Proportions of Secondary Refrigerators with Through the Door Features	ESNH Proportions, n=88	ESNH EB_{90}'s	Baseline Proportions, n=124	Baseline EB_{90}'s	Significant Difference
No	83.1%	6.6%	84.7%	5.3%	
Yes	16.9%	6.6%	15.3%	5.3%	

A.32. Clothes Washers

Table 108
Proportion of Homes with Washing Machines

Proportion of Homes with Washing Machines	ESNH Proportions, n=345	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
No	1.4%	1.0%	0.2%	0.3%	
Yes	98.6%	1.0%	99.8%	0.3%	*

Table 109
Proportion of Washing Machine Types

Proportion of Washing Machine Types	ESNH Proportions, n=342	ESNH EB_{90}'s	Baseline Proportions, n=595	Baseline EB_{90}'s	Significant Difference
Horizontal axis	55.8%	4.4%	35.6%	3.2%	*
Standard	38.2%	4.3%	59.6%	3.3%	*
Stacked-Horizontal	5.8%	2.1%	2.7%	1.1%	
Stacked-Standard	0.1%	0.2%	0.6%	0.5%	
No Washer			0.2%	0.3%	
DK	0.2%	0.4%			

Table 110
Dryer Moisture Sensor Prevalence

Dryer Moisture Sensor Prevalence	ESNH Proportions, n=342	ESNH EB_{90}'s	Baseline Proportions, n=604	Baseline EB_{90}'s	Significant Difference
Yes	74.4%	3.9%	50.6%	3.3%	*
No	19.8%	3.5%	49.4%	3.3%	*
DK	5.8%	2.1%			

A.33. Clothes Dryers

Table 111
Dryer Fuel Type

Dryer Fuel Type	ESNH Proportions, n=342	ESNH EB_{90}'s	Baseline Proportions, n=602	Baseline EB_{90}'s	Significant Difference
Electric	86.5%	3.0%	88.8%	2.1%	
Gas	13.1%	3.0%	9.5%	2.0%	
Propane			1.8%	0.9%	
DK	0.4%	0.5%			

Table 112
Dryer Usage Frequency

Dryer Usage Frequency	ESNH Proportions, n=342	ESNH EB_{90}'s	Baseline Proportions, n=602	Baseline EB_{90}'s	Significant Difference
Used for all loads	68.1%	4.1%	87.6%	2.2%	*
Used for most loads	24.4%	3.8%	11.8%	2.2%	*
Used for some loads	0.2%	0.4%			
Infrequent use	2.5%	1.4%	0.7%	0.5%	
Unknown	4.8%	1.9%			

A.34. Small Appliances and Plug Loads

Table 113
Average Number of Consumer Products per Home

Average Number of Consumer Products per Home	ESNH Average, n=344	ESNH EB_{90}'s	Baseline Average, n=599	Baseline EB_{90}'s	Significant Difference
Gaming Consoles	0.5	0.1	0.5	0.1	
Computers/workstations/laptops	1.9	0.1	1.6	0.1	*
Printers	1.2	0.1	1.1	0.1	
Portable MP3/CD Players	1.0	0.1	0.8	0.1	*
PDA's	0.3	0.1	0.3	0.1	
Cell phone chargers	1.6	0.1	1.6	0.1	
Answering machines	0.5	0.0	0.7	0.0	*
Stereos	1.1	0.1	1.2	0.1	
Televisions	2.4	0.1	2.6	0.1	