September 18, 2012

2011 RESIDENTIAL BUILDING STOCK ASSESSMENT: SINGLE-FAMILY CHARACTERISTICS AND ENERGY USE

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Acknowledgements

Ecotope would like to thank Anu Teja, Northwest Energy Efficiency Alliance (NEEA) evaluation project manager, for coordinating the Residential Building Stock Assessment (RBSA) advisory group and providing support and direction to this research. We appreciate the contributions of the RBSA advisory group to the design and implementation of study. We also thank Virginia Ulrich and Michael Budds of Ecova™ and their team for their contributions to the field data collection. Virginia Ulrich led the regional field survey implementation, which included more than 1,800 field surveys over a seven-month period. Bruce Manclark of Delta-T, Inc. played a critical role providing training and in-field quality control for the surveyors. Finally, we would like to acknowledge the outstanding cooperation from the Northwest utilities in providing nearly 100% of the billing data required for the energy use analysis.

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Glossary of Acronyms and Abbreviations

AC	air conditioning
ACH	air changes per hour
ACH50	air changes per hour at 50 Pascals of pressure
ACS	American Community Survey (U.S. Census)
AFUE	Annual Fuel Utilization Efficiency
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
BPA	Bonneville Power Administration
Btu	British thermal unit
Btu/hr	British thermal units per hour
CFL	compact fluorescent lamp
CFM	cubic feet per minute
Council	Northwest Power and Conservation Council
CRT	cathode ray tube
cu.ft.	cubic feet
DEI	Distribution Efficiency Initiative
DHP	ductless heat pump
DHW	domestic hot water
DVD	digital video disc
DVR	digital video recorder
EB	error bound
ECM	electronically commutated motor
EISA	Energy Independence and Security Act
EUI	energy use index
FERC	Federal Energy Regulatory Commission
GAMA	Gas Appliance Manufacturers Association
GPM	gallons per minute
HPWH	heat pump water heater

HSPF	heating seasonal performance factor
HVAC	heating, ventilation, and air conditioning
IECC	International Energy Conservation Code
IOU	investor-owned utility
IRES	Idaho Residential Energy Standard
kBtu	kilo British thermal unit
kBtu/sq.ft.	kilo British thermal units per square foot
kW	kilowatt
kWh	kilowatt hours
kWh/sq.ft.	kilowatt hours per square foot
LCD	liquid crystal display
LED	light-emitting diode
Low-E	Low-emissivity (refers to coatings on glazing or glass to control heat transfer through windows)[1]
LPD	lighting power density
n	number of observations
NEEA	Northwest Energy Efficiency Alliance
NOAA	National Oceanic and Atmospheric Administration
Pa	Pascals
PC	personal computer
PRISM	PRInceton Scorekeeping Method
PSC	permanent split capacitor
PTAC	Packaged Terminal Air Conditioner
PTCS	Performance Tested Comfort Systems
PUD	Public Utility District
QC	quality control
RBSA	Residential Building Stock Assessment

[1] http://www.energysavers.gov/your_home/windows_doors_skylights/index.cfm/mytopic=13430

RDD	random digit dial
RTF	Regional Technical Forum
R-value	thermal resistance value
SEER	Seasonal Energy Efficiency Ratio
sq.ft.	square feet
TV	television
UA	The sum of the thermal transfer coefficient (U) times the area (A) of the components of the building. Also includes convective losses from infiltration.
U-value	thermal conductivity
VBDD	variable base degree day
W	Watts
W/sq.ft.	Watts per square foot
WSEC	Washington State Energy Code
ZCTA	Zip Code Tabulation Area

Executive Summary

This report is the first in a series of reports summarizing the results of the Residential Building Stock Assessment (RBSA). The RBSA is sponsored by the Northwest Energy Efficiency Alliance (NEEA) and is being conducted by Ecotope, Inc. with support by Ecova™, Delta-T, Inc., and ORC International. The primary objective of the RBSA is to develop an inventory and profile of existing residential building stock in the Northwest based on field data from a representative, random sample of existing homes. The RBSA establishes the 2011 regional baseline for housing stock for three categories of residences: single-family homes, manufactured homes, and multifamily homes. The results will guide future planning efforts and provide a solid base for assessing energy savings on residential programs throughout the Northwest.

The Northwest has no precedent for a residential field study of the size and representative nature of the RBSA. In this sense, the RBSA is not an update of an existing study or dataset, but rather a new standard for residential characterization studies in the Northwest. Ecotope designed the RBSA sample to include all public and investor-owned utilities in Washington, Oregon, Idaho, and western Montana. The final RBSA sample includes 99 utilities: 89 public utilities, seven investor-owned utilities, and three natural gas-only utilities. Field surveys were conducted on more than 1,850 sites across the Northwest, including more than 1,400 single-family homes.

The current report summarizes the characteristics observed onsite and energy use data for the single-family home component of the RBSA. Subsequent reports will summarize the results for manufactured and multifamily homes. Data collected during the field surveys included general demographic information, occupant attitudes and participation in efficiency programs, a detailed lighting inventory, building envelope characteristics, and end-use characteristics for electronics, major appliances, and heating, ventilation, and air conditioning (HVAC) equipment. As part of a parallel study, 101 sites from the RBSA single-family home sample were metered with a full set of instruments designed to assess electric and other energy uses across a variety of residential end uses.

Background

For more than 30 years, the Northwest has relied heavily on increased efficiency to reduce demand for energy (especially electricity). This effort has resulted in a substantial reduction in the growth of energy demand and obviated the need to expand or build additional power plants across the region. A critical input to this process is the predictability of the savings from efficiency measures. The engineering of most efficiency measures is reasonably straightforward but it is important to establish the “base case” efficiency and energy use so that savings take account of current use patterns and efficiency levels. The base case represents the existing conditions in the residential sector that efficiency programs seek to modify. Savings for these programs are calculated from this base to establish the goals and accomplishments of the efficiency programs. Although data on the overall energy use can be developed from utility bills, program and measure development depend on a more detailed understanding of the current conditions and practices among the utility customers in the region.

The quest to deliver energy efficiency as a resource has driven the region to embark on studies over the years that seek to characterize these base case conditions and provide a basis for conservation measure design and comprehensive resource planning. This style of conservation program design, in which individual savings estimates are less important than aggregate changes in efficiency across all the customers in the region, allows a more simplified approach to program evaluation but also requires more detailed information on existing efficiency patterns.

Since 1978, the region has used a combination of phone surveys and targeted field surveys to piece together a picture of the residential sector. For the most part, the characteristics have been established by self-reported assessment of insulation and appliance use. Although this combination proved effective, the region has not conducted a large-scale residential survey of this magnitude since 1992. Until the RBSA, the knowledge accumulated in the 1980s and early 1990s, coupled with smaller more focused studies, has served as the basis for conservation program design for nearly 20 years.

The RBSA was implemented to update and expand the current knowledge and assumptions in the residential sector. As the planning and program needs of the region have expanded to include many aspects of residential energy use (e.g., lighting, electronics, etc.) over the last 20 years, the goals of a regional review have expanded.

The RBSA was designed to develop a characterization of the residential sector that takes into account the diverse climates, building practices, and fuel choices across the region. The characterization includes both the principal characteristics of the homes (size, insulation level, and heating systems) and the principal characteristics of the occupants and their energy use patterns (e.g., lighting, appliances, electronics, and water heating). Finally, the large scale residential sample allows the benchmarking of energy use with the region’s residences with sufficient detail to assess the progress on improved energy efficiency over the next several years.

As energy efficiency is a primary energy resource in the Northwest, the baseline information generated by the RBSA is an essential element in developing efficiency resources that can meet the region’s future energy requirements and growth.

Study Objectives

The single-family RBSA includes four major objectives:

- Develop a statistically representative sample frame
- Develop a statistically representative field sample of single-family homes
- Analyze and summarize building and energy-use characteristics
- Provide utilities with an opportunity to augment the RBSA sample in their territories

In addition to these objectives, an implicit goal of the RBSA was to set a standard for the design and implementation of future RBSA studies. Particular emphasis was placed on the development of the data collection protocols, a representative and reliable sample, a robust and multifaceted quality management approach, and transparent, flexible datasets and documentation. To help achieve this goal, NEEA established an advisory group for the RBSA to obtain feedback and advice on critical research activities such as development of the sample design, protocols, characteristics and energy benchmarking reports, and the final databases. For example, the final field survey protocol reflects the input of regional organizations such as the Bonneville Power Administration (BPA) and the Northwest Power and Conservation Council (the Council) as well as a number of utilities. This process resulted in a comprehensive protocol aligned with regional data requirements and potential measures of interest to regional stakeholders.

Methodology

Ecotope designed the sample to be representative of single-family homes from four geographic perspectives: by whole region, by state, by whole BPA service territory; and by BPA subregion. The sample design reflects a substantial oversample by BPA in order to achieve a statistically significant number of sample points in BPA's overall service territory as well as in five BPA subregions. The sample was designed to achieve a 90%/10% confidence/precision interval for each of the geographic perspectives. The RBSA sample was also enhanced by seven utility oversamples. Case weights were developed for each home in the sample, and these weights were used to create the characteristics and energy use summaries included in this report. These probability weights were generated based on the final sample size and total population in each stratum.

The Ecotope team implemented a large, region-wide phone survey to develop a representative sample frame (recruiting list) for the field surveys. 6,172 single-family phone surveys were completed using a combination of random digit dial (RDD) and utility customer phone lists. About 2,000 additional surveys were completed that covered the manufactured homes and multifamily strata. Each housing type and stratum was assigned a quota according to the sample design. The initial screening in the phone survey allowed the completed surveys to be assigned to the appropriate strata. The phone survey was implemented in April and May 2011 and covered the following broad topic areas: electrical utility, gas utility, dwelling type, home characteristics, home appliances, demographics, and contact information.

Approximately five phone surveys were completed for each field survey. The field sample was recruited from this sample frame of completed phone surveys. The recruiters were instructed to recruit at random in each individual stratum and to fill the sampling quotas as specified in the sample design. In general, this process resulted in a complete sample in each stratum, and in some cases slightly more homes than were in the original targets. Field surveyors were then deployed to collect the energy survey information on each home recruited. Field surveyors participated in an intensive four-day training workshop and conducted 1,404 single-family field surveys between June 2011 and January 2012. While onsite, the surveyors obtained a participant-signed billing history release and conducted an occupant interview to obtain general demographic information and background information on energy-use behavior and home characteristics. Surveyors created freehand sketches of the floor plan of each residence surveyed and performed a room-by-room inventory of lighting and electronics characteristics. Surveyors also collected detailed data on the building envelope, HVAC system, major appliances, and large and unusual loads. Surveyors used tablet personal computers (PCs) for offline data collection and then uploaded completed surveys to the RBSA working database.

The Ecotope team implemented a comprehensive, multilevel quality management plan. Key aspects of the plan included in-depth surveyor training and feedback loops, in-field quality control (QC), onsite QC via real-time data validation by the tablet computers, weekly aggregate data checks for missing values and outliers, and follow-up site visits to collect missing data.

The survey data was cleaned, assembled, and analyzed in order to develop the report summaries. The summary tables were generated based on the probability weights and summarized for each state. The sample design allows many other summaries based on geographic and population divisions. For this report, the populations of each state in the region were separately summarized as well as the region as a whole. The sample design would allow each of the tables shown in this report to be recast to BPA utilities or in some cases to larger specific utilities.

Findings and Observations

The purpose of a characteristics study is to establish base case conditions in a wide variety of components that can provide the basis for program planning, resource planning, and program evaluation.

There are a few salient findings that can be drawn out of the analysis presented in this single-family home report:

- Characteristics of Northwest housing have a distinct east/west divide. The use of basements, for example, is common in eastern climates and uncommon in western climates. However, new construction is fairly similar across the region, due to the development of more common codes and standards.
- The review of overall conductive heat loss rates for each home shows surprisingly small differences between the states and climates. When reviewing the overall heat loss rate by vintage, the development of the codes in Oregon and Washington offer some clear insights in the short-term impacts of energy codes on construction practice and insulation levels. Overall a 20% decrease in conductive heat loss was observed across the time frame when energy codes were introduced *and* enforced in these states.
- The lighting audit allowed us to develop an estimate of the impacts of Energy Independence and Security Act (EISA) on the region's residential lighting programs. Approximately 27% of all lamps are exempt from these standards and could be the basis for utility programs aimed at these types of lamps and fixtures. About 36% of all lamps are EISA compliant today. The remaining lamps are non-compliant (but not exempt) and will be brought into compliance as the current lamps are replaced with lamps meeting federal standards.
- The overall lighting power density (LPD) for the single-family homes across the region is about 1.4 Watts/sq.ft. About 36% of all lamps are compact fluorescent lamps (CFL) or other types of fluorescent lamps.
- About 57% of homes use natural gas for space heating. About 49% of homes surveyed report use gas heat as their primary heating fuel; the balance report gas as a secondary heating fuel. The largest saturation of gas usage is in Montana.

- Wood heat is used throughout the region. About 25% of all households report either wood or pellet use for space heating. About one-third of this group reports wood heat as their primary heating source.
- Oil or propane fuel represents about 6.5% of the primary heating systems.
- Domestic hot water (DHW) fuel source is dominated by electric with approximately 55% of the water heating use supplied by electric DHW tanks.
- Across the region, homes have about 2.3 TVs and 1.5 set-top boxes. Nearly 30% of the set-top boxes have digital video recorder (DVR) capability.
- Although half of all televisions are cathode ray tube (CRT) types, only 5% of televisions purchased after 2009 are CRTs; the rest are flat screens.
- About one-third of all homes have an electronic gaming system. The average number of gaming systems in those homes is 1.5.
- About 90% of all homes surveyed have at least one computer.
- The average weather normalized, electric and gas energy use index (EUI) is 43.7 kBtu/sq.ft. per home for the region. Occupants report supplemental fuel use (wood, propane, oil, etc.) of about 15,200 kBtu/home or about an 18% increase in the energy use beyond the metered electric and natural gas usage.
- The use of horizontal axis clothes washers has increased significantly. Overall, these more efficient clothes washers account for about one-third of all clothes washers and more than two-thirds of the washers purchased in the last three years.
- An average of 1.3 refrigerators were observed in each home. About 58% of those refrigerators were manufactured since 2000.

1. Introduction

This report is the first in a series of reports summarizing the results of the Residential Building Stock Assessment (RBSA) sponsored by the Northwest Energy Efficiency Alliance (NEEA). NEEA is a non-profit organization working to maximize energy efficiency to meet future energy needs in the Northwest. NEEA is supported by, and works in collaboration with, the Bonneville Power Administration (BPA), Energy Trust of Oregon, and more than 100 Northwest utilities on behalf of more than 12 million energy consumers.[2]

The RBSA is being conducted by Ecotope, Inc., with support by Ecova™, Delta-T, Inc., and ORC International. The primary objective of the RBSA is to develop an inventory and profile of existing residential building stock in the Northwest, based on field data from a representative, random sample of existing homes. The RBSA establishes the 2011 regional baseline for housing stock for three categories of residences: single-family homes, manufactured homes, and multifamily homes. The results will guide future planning efforts and provide a solid base for assessing energy savings on residential programs throughout the Northwest.

The current report summarizes the characteristics observed onsite and energy use data for the single-family home component of the RBSA. Subsequent reports will summarize the results for manufactured and multifamily homes. Data collected during the field surveys included general demographic information, occupant attitudes and participation in efficiency programs, a detailed lighting inventory, building envelope characteristics, and end-use characteristics for electronics, major appliances, and heating, ventilation, and air conditioning (HVAC) equipment.

1.1. Background

For more than 30 years, the Northwest has relied heavily on increased efficiency to reduce demand for energy (especially electricity). This effort has resulted in a substantial reduction in the growth of energy demand and obviated the need to expand or build additional power plants across the region. A critical input to this process is the predictability of the savings from efficiency measures. The engineering of most efficiency measures is reasonably straightforward, but it is important to establish the "base case" efficiency and energy use so that savings take account of current use patterns and efficiency levels. Although data on the overall energy use can be developed from utility bills, program and measure development depend on a more detailed understanding of the current conditions and practices among the utility customers in the region.

The quest to deliver energy efficiency as a resource has driven the region to embark on studies over the years that seek to characterize these base case conditions and provide a basis for conservation measure design and comprehensive resource planning. This style of conservation program design, in which individual savings estimates are less important than aggregate changes in efficiency across all the customers in the region, allows a more simplified approach to program evaluation but also requires more detailed information on existing efficiency patterns.

[2] See the website at www.neea.org.

Since 1978, the region has used a combination of phone surveys and targeted field surveys to piece together a picture of the residential sector. For the most part, the characteristics have been established by self-reported assessment of insulation and appliance use. Although this combination proved effective, the region has not conducted a large-scale residential survey of any sort since 1992 and, except for some small assessments, few detailed characteristic assessments have been conducted during that same period. Until the RBSA, the knowledge accumulated in the 1980s and early 1990s has served as the basis for conservation program design for nearly 20 years.

The RBSA is intended to provide an up-to-date and comprehensive understanding of the regional characteristics for two reasons: (1) to reflect current construction practices as they have evolved over the last two decades; and (2) to assess the suite of appliances and lighting that have been the basis for substantial conservation initiatives in the region. The overall impact of these programs and changes in modern technology on the base case consumption and has not been comprehensively reviewed.

There is no precedent in the Northwest for a residential field study of the size and representative nature of the RBSA. In this sense, the RBSA is not an update of an existing study or dataset, but rather a new standard for residential characterization studies in the Northwest. Ecotope designed the RBSA sample to include all public and investor-owned utilities in Washington, Oregon, Idaho, and western Montana. The final RBSA sample includes 99 utilities: 89 public power utilities, seven investor-owned utilities (including three dual-fuel utilities that supply gas and electric service to their territories), and three gas-only utilities. Table 1 illustrates the total number of utilities included in the final RBSA sample relative to the total number of Northwest utilities. Field surveys were conducted on more than 1,850 sites for three residence types across the Northwest, including more than 1,400 single-family homes.

Table 1: Total Sampled Utilities by Region

Region	Total Utilities	Sampled Utilities	% of Total
Idaho	27	19	70%
Western Montana	10	8	80%
Western Oregon	25	20	84%
Eastern Oregon	14	13	93%
Puget Sound, Washington	18	9	50%
Western Washington (not Puget Sound)	13	10	77%
Eastern Washington	25	20	80%
Total	132	99	75%

1.2. Previous Studies

Although the RBSA is the first large-scale field survey of Northwest homes, it was preceded by two relevant residential characterization studies: the 2007 Single-Family Residential Existing Construction Stock Assessment and the 1992 Pacific Northwest Residential Energy Survey.

The 2007 Single-Family Residential Existing Construction Stock Assessment (RLW 2007a)[3] was the most recent regional residential characterization study. The report and databases were based on a field sample completed between 2004 and 2006 involving 489 single-family homes. The main differences between the 2007 study and the RBSA are the sample design and sample size. The sample design for the 2007 study was based on a load research sample designed for another study, NEEA's Distribution Efficiency Initiative (DEI). The main goal of the DEI sample design was to select an efficient sample for estimating voltage across Northwest climate zones. The sample frame for the 2007 study was composed of a subset of customers from specific utilities that were successfully recruited into the DEI study. The final sample included 11 utilities in Washington, Oregon, and Idaho. As a result of the small number of utilities, all field surveys in the sample were concentrated mainly along the Interstate-5 corridor in Washington and Oregon, the Tri-Cities and mid-Columbia areas of Washington, and the cities of Boise and Idaho Falls in Idaho. In contrast, the final RBSA sample is broadly distributed across the entire Northwest and is representative of large, small, urban, and rural utilities.

The 1992 Pacific Northwest Residential Energy Survey (PNWRES92) (BPA 1993) was the last in a series of four phone-survey-based residential characterization studies conducted by BPA. Similar surveys were conducted in 1979, 1983, and 1985. The PNWRES92 survey included approximately 20,000 total phone surveys across the Northwest, 16,000 of which were surveys of single-family homes. This was the most comprehensive residential characteristics survey conducted prior to the RBSA. However, the data are now 20 years old and were collected using phone surveys, which are less comprehensive than onsite surveys and provide self-reported data rather than data collected and verified onsite. In addition, the PNWRES92 was a clustered, random sample and as such was not directly representative of all utility service territories.

In addition to these comprehensive efforts aimed at existing residential buildings, several efforts to assess the new construction characteristics have been conducted dating back to the mid 1980s. These efforts taken together provide a view of the construction in the region, but they do not provide an overview of the characteristics across all housing types and all vintages. On the whole, the level of effort and extent of the RBSA sample provide a unique summary of the single-family residential construction and occupancy in the Northwest region.

[3] See http://neea.org/docs/reports/Single-FamilyResidentialExistingConstructionStockAssessment.pdf?sfvrsn=4

1.3. Study Objectives

The single-family RBSA was designed to provide a base case reference for practices, attitudes, building characteristics, and technologies that will be the basis for future programs in the single-family residential market. The study includes four major objectives:

- **Develop a statistically representative sample frame.** To have a representative sample, all residences must have an equal probability of participating in the final survey. The development of this sample frame must also provide the basis for contacting and recruiting the potential participants into the final survey assessments and into the final energy benchmarking.
- **Develop a geographically representative sample of single-family homes.** The region specified several subregions that would need to be represented at the same level of certainty. The sample was then stratified by geographic area using four geographic perspectives: by whole region; by state; by whole BPA service territory (public power customers of the BPA); and by BPA subregion. In addition, NEEA requested a subsample of heat-loss assessments, including blower door and duct blaster testing for single-family homes. This sample was drawn at random from the samples generated from the main sample recruited for the field surveys.
- **Analyze and summarize building and energy-use characteristics.** Characteristics include building shell, home heating and cooling system characteristics, lighting characteristics, appliance characteristics, and a limited survey of plug loads focusing particularly on electronics and home entertainment. Energy-use characteristics include energy use index (EUI) for each single-family home in the sample.
- **Provide utilities with an opportunity to augment the RBSA sample in their territories.** The RBSA study was designed to allow individual utilities to increase the RBSA samples in their service territories to meet those utilities' particular planning and evaluation needs. Seven utilities requested oversamples, and those added points were weighted into the overall survey results. This process used probability weighting to make sure that no utility was over-represented in the final RBSA characteristic studies regardless of their oversamples.

In addition to these objectives, an implicit goal of the RBSA was to set a standard for the design and implementation of future RBSA studies. Particular emphasis was placed on the development of the data collection protocols, (i.e., what information would be collected), a representative sample, a robust and multifaceted quality management approach, and transparent, flexible datasets and documentation. To help achieve this goal, NEEA established an advisory group for the RBSA to obtain feedback and advice on critical research activities such as development of the sample design, protocols, characteristics and energy benchmarking reports, and the final databases. For example, the final field survey protocol reflects the input of regional organizations such as BPA and the Northwest Power and Conservation Council (the Council) as well as a number of utilities. This process resulted in a comprehensive protocol aligned with regional data requirements and potential measures of interest to regional stakeholders.

1.4. Study Limitations

This RBSA effort included a large number of sites and characteristics as well as a significant number of individual surveyors and analysts. Moreover, the field surveys were completed on residences across the region with the inherent limitations placed on the surveyors by the study participants. Thus, some data could not be collected because a room or area was off-limits to the surveyor, or because the configuration of the home did not allow access. These issues resulted in missing data on a small number of sites in various categories.

The following list describes potential biases that exist in the study:

- The sample frame was developed from a phone survey, which in turn was developed from random digit dial (RDD) lists in most areas. The RDD lists were supplemented by similar lists for cell phones in the same localities. These lists were targeted based on the percentage of homes thought to only use cell phones as their primary household phone. In addition, utility customer lists were made available from ten of the largest utilities. The RDD lists were purchased from reputable providers. Even with all these precautions, the quality of the sample frame depended on people answering the phone, responding to a short questionnaire, and providing sufficient contact information that would allow later recruiting for the field surveys. People can screen calls from an unfamiliar number and can disconnect to avoid talking to a telephone surveyor. For utilities and cell phone lists, similar biases may have been present coupled with the potential underlying limitations of utility customer phone lists and extensive screening requirements for implementing cell-phone-only surveys in specific geographic areas. We have no mechanism for correcting this bias or assessing its impact on the characteristics collected.
- The 2010 U.S. Census changed the relationship between the American Community Survey (ACS) and the overall census. In prior years the ACS was part of the decennial census and was also updated between censuses. In 2010 the ACS became an independent survey. As a result, the summaries used to develop the original RBSA sample based on Zip Code Tabulation Areas (ZCTAs) were not available. The summaries that were available in the 2010 census for housing type, vintage, and other physical characteristics of the home were compiled only by county and state. This change has limited potential comparisons between the RBSA results and the ACS results.
- To recruit field survey participants, recruiters called the individual respondents and offered them a cash incentive for participating in the field survey. This process was fairly successful, but it could have resulted in those respondents with low income being more receptive than respondents with higher incomes. Recruiters were persistent so as to minimize this problem, but there is a potential for this bias in occupancy which might be reflected in the homes recruited into the field study.
- Lighting audits were performed on a room-by-room basis. In some cases, rooms were inaccessible, resulting in a reduced number of lamps and watts in the lighting audit. The quality control (QC) process screened for this result, but relatively minor rooms may not have been identified. This factor could result in recording a lower level of lighting power than was actually in use. This error could introduce a negative bias whenever it occurred. The negative bias could consistently reduce the apparent lighting power across the

sample. The QC process directed efforts toward minimizing this problem, but there remains the possibility of a small downward bias.

- Heat-loss characteristics such as insulation and wall framing are difficult to observe. The surveyors were given some techniques for assessing these components through indirect observation. Nevertheless, many of these assignments remain an educated guess. We believe that this guess was unbiased, but we have no mechanism for verifying this assertion.
- This report summarizes more than 1,400 single-family home field surveys. In addition to non-response during the sample frame development, missing data occurred in the survey itself. The sample design allowed for some loss of data; however, even with these precautions, the missing data can result in an elevated level of uncertainty in assessing the distribution of specific characteristics.

On the whole, we are confident about the quality of this data collection effort in spite of the known limitations of this type of survey. Most of the data were readily obtainable to the surveyors and the sample bias has been minimized. The resulting dataset is robust, exhibits reasonable error bounds, and provides detailed data for a number of important measures.

2. Methodology

2.1. Sample Design

2.1.1. Sampling Objectives and Approach

Ecotope designed the sample to be representative of single-family homes from four geographic perspectives: by whole region, by state, by whole BPA service territory, and by BPA subregion. The sample design reflects a substantial oversample by BPA in order to achieve a statistically significant number of sample points in BPA's overall service territory as well as in five BPA subregions. Table 2 presents the single-family home sampling requirements, including the regional sampling domains and the BPA oversample domains.

Table 2: Sample Stratification Requirements

	Regional Sampling Domains with 90%/10% Confidence/Precision
NWR	All residential utility customers in Washington, Oregon, Idaho, and western Montana (BPA region with NorthWestern Energy)
WA	All residential utility customers in Washington
OR	All residential utility customers in Oregon
ID	All residential utility customers in Idaho
MT	All residential utility customers in western Montana (BPA region with NorthWestern Energy)
	BPA Public Power Sampling Domains
NWP	All BPA public (cooperative, Public Utility District [PUD], municipal, federal) residential utility customers in the Northwest
WWA	All BPA public utility residential customers in western Washington, excluding Puget Sound
PS	All BPA public utility residential customers in Puget Sound
WOR	All BPA public utility residential customers in western Oregon
EOW	All BPA public utility residential customers in eastern Oregon and eastern Washington
ID/MT	All BPA public utility residential customers in Idaho and western Montana (BPA region only)

In order to address the sampling requirements for these overlapping domains, Ecotope defined the minimum set of non-overlapping geographic cells which could be combined to form each of the defined domains. Ecotope defined the following seven non-overlapping geographic cells:

1. Idaho
2. Western Montana
3. Western Oregon
4. Eastern Oregon
5. Puget Sound, Washington
6. Western Washington (excluding Puget Sound)
7. Eastern Washington

Each cell was further partitioned into the portion served by BPA public utilities (BPA Public), and the portion served by investor-owned and other non-BPA public utilities (IOU/Other), resulting in a total of fourteen non-overlapping geographic cells that collectively partition the entire region.

Subsequent to the original sample design, seven utilities contracted for oversamples in their service territories. These utilities became separate sampling strata since they required expanded samples to meet their oversample requirements. The final sampling strata were developed by combining the 14 geographic cells with the seven oversample utilities and removing any overlap. For example, the western Washington not Puget Sound cell is only served by BPA customers hence the sample did not include a stratum for non-BPA customers. In the case of Puget Sound, an oversample utility (Puget Sound Energy) was the only utility in the Puget Sound cell for IOU/Other utilities. As a result, the Puget Sound Energy stratum was used in place of a Puget Sound IOU/Other cell. Including these two revisions, a total of 19 strata were defined in the final RBSA single-family sample. Ecotope calculated the sample sizes for each stratum based on the original sampling criteria and the utility oversample specifications.

2.1.2. Sample Frame Development

The key to developing a representative sample is that the selection of sample points must be random and unbiased. Within a defined stratum, any home should have an equal chance to be contacted and recruited as any other home. Ecotope implemented a rigorous, multiphase sampling process in order to ensure the random distribution and representativeness of the final field surveys sample.

Phase 1 included the development of the initial population sample frame. The population sample frame was developed using census data, detailed utility information for all the utilities in the region based on a regional database of utilities and their loads, and 861 certification filings with the Federal Energy Regulatory Commission (FERC) from 2009[4] that each utility makes to the U.S. Department of Energy as part of their licensing requirements. This information includes total residential customers and total residential energy loads for each utility broken down by each state where it operates. Because the utilities include both public and investor-owned entities, this data source allowed a common level of information to be developed for each utility and allowed utility customers to be assigned to the 19 sampling strata. Once assigned, the sum of the residential customers became the overall population assumed in each of the sampling strata.

The ratio among single-family homes, manufactured homes, and multifamily units was established by using 2000 U.S. Census data sorted by Census zip code tabulation areas, so that the sample for each of the three RBSA residence types could be designed and sampled separately.

For Phase 2 of the sampling process, Ecotope used a large, region-wide phone survey to develop a representative sample frame (recruiting list) for the field surveys. 6,172 single-family phone surveys were completed using a combination of RDD and utility customer phone lists. Each housing type and sampling stratum was assigned a quota according to the sample design. The initial screening in the phone survey allowed the completed surveys to be assigned to the appropriate strata.

The phone survey was conducted in April and May 2011 Each survey call averaged eight minutes and covered the following broad topic areas:

- Screening questions to determine electrical utility and dwelling type
- Home characteristics
- Demographics
- Contact information

[4] FERC is an independent agency that regulates the interstate transmission of electricity, natural gas, and oil. When the RBSA sample was designed, 2009 data were the latest available FERC data.

Table 3 presents the final distribution of the sample frame for the field survey.

Table 3: Field Survey Sample Frame

Geographic Cell	Total Single-Family Customers	IOU/Other Sample Frame	BPA Public Sample Frame	Total Sample Frame
Idaho	524,022	522	286	808
Western Montana	288,127	411	294	705
Western Oregon	1,005,334	526	620	1,146
Eastern Oregon	186,553	44	194	238
Puget Sound	1,278,211	639	1512	2,151
Western Washington	288,064	0	621	621
Eastern Washington	453,626	122	381	503
Total	**4,023,937**	**2,264**	**3,908**	**6,172**

2.1.3. Sample Distribution

Phase 3 of the sampling process included recruitment of the field survey sample. Upon completion of the phone survey, the resulting list of contacts was assembled into the recruiting lists for the field surveys. A target was assigned to each of the 19 strata in the sample design.

Table 4 summarizes the distribution of the RBSA single-family home field survey sample prior to the addition of utility oversamples. The table shows the split in each geographic cell based on the proportion of that region that is in IOU/Other service territories or BPA Public service territories.

Table 4: Initial Single-Family Sample Distribution

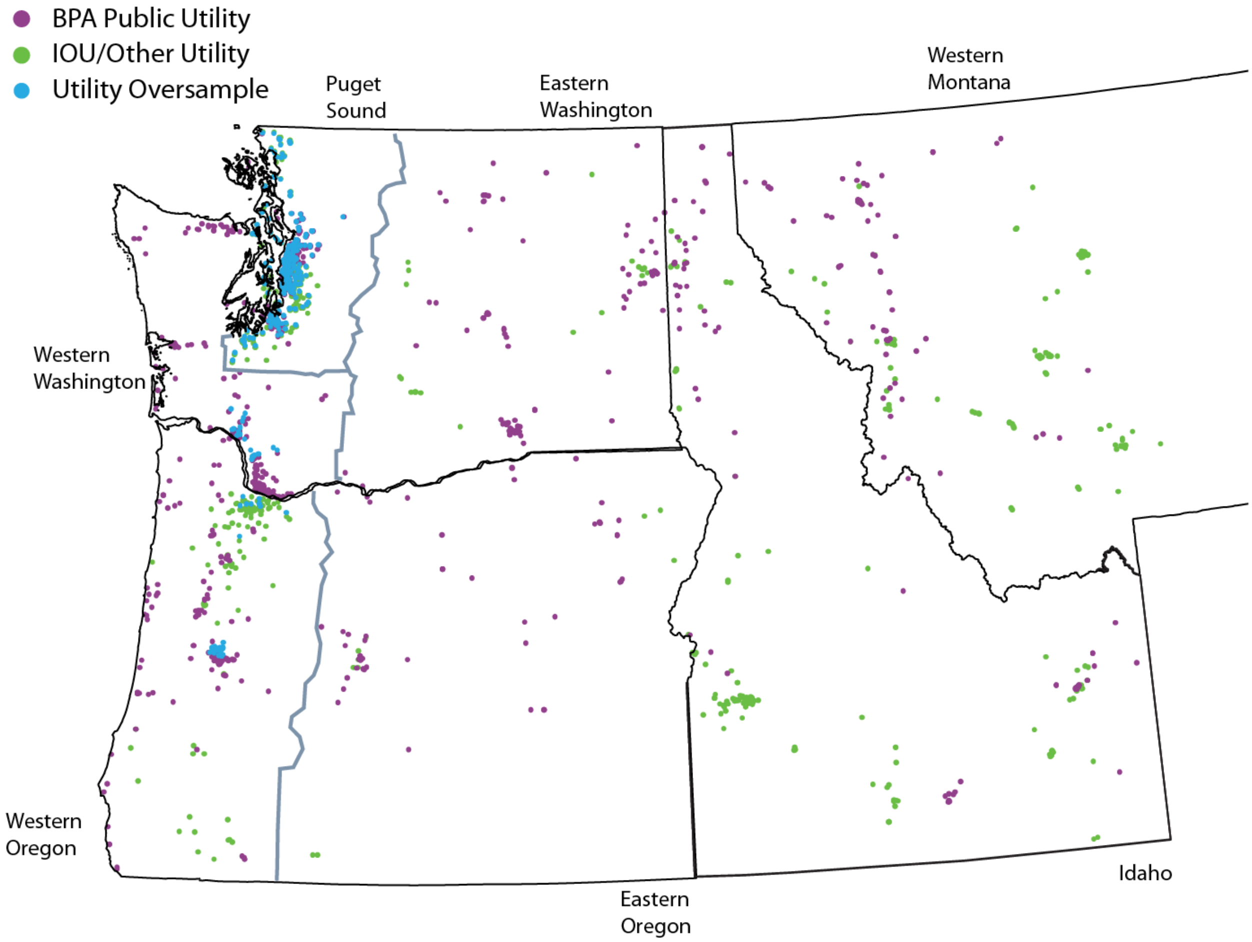
Geographic Cell	IOU/Other Sample	BPA Public Sample	Total Initial Sample
Idaho	117	68	185
Western Montana	96	73	169
Western Oregon	98	138	236
Eastern Oregon	11	48	59
Puget Sound	51	141	192
Western Washington	N/A	139	139
Eastern Washington	23	90	113
Total	**396**	**697**	**1,093**

Field survey targets for each oversample utility stratum included not only the utility's commissioned oversample points, but also an allocation of RBSA sample points. The utility oversamples significantly enhanced the final sample, increasing the total field surveys by nearly 30%. Table 5 shows the total, final sample distribution, including utility oversamples. Figure 1 is a map of the final sample distribution. The BPA Public, IOU/Other, and utility oversamples are included in different colors. The widely distributed nature of the sample dots in Figure 1 demonstrates the broadly representative nature of the sample.

Table 5: Final Single-Family Sample Distribution (Including Utility Oversamples)

Geographic Cell	Total Sample	Utility Oversamples	Final Sample
Idaho	185	0	185
Western Montana	169	0	169
Western Oregon	236	19	255
Eastern Oregon	59	0	59
Puget Sound	192	280	472
Western Washington	139	12	151
Eastern Washington	113	0	113
Total	**1,093**	**311**	**1,404**

Figure 1: Map of Final Sample Distribution of Single-Family Field Surveys



2.1.4. Heat-Loss Assessment Sample

In addition to the overall conductive heat-loss assessment developed for each home, NEEA requested a heat-loss assessment based on air leakage on a subsample of the RBSA field surveys. The main strategies for performing the heat-loss assessment included blower door, duct leakage, and central heating/cooling system airflow tests at a randomly selected subset of homes participating in the RBSA. The heat-loss sample was designed to deliver data at a confidence/precision interval of 90%/10%, by state and for the whole region. These criteria cut across the sampling strata, and targets were assigned for these tests that were proportional to the population in each of those strata. The heat-loss assessment was also performed on 94 additional sites as part of a parallel RBSA effort focused on metering the whole home energy use of 101 RBSA single-family homes.

Table 6 presents the final heat-loss assessment sample distribution. The heat-loss assessment targeted and tested 358 single-family home field surveys across the region in order to achieve statistical significance in the four Northwest states. However, as shown in Table 6, the final heat-loss sample includes an additional 94 homes. All RBSA metered sites included a heat-loss assessment. In 94 of the 101 cases, the metering and heat-loss assessments were conducted on homes that were not included in the original heat-loss assessment sample of 358. These sites were subsequently weighted into the heat-loss sample to enhance the precision of the sample.

Table 6: Final Distribution of Heat-Loss Assessment Sample

State	Sample from RBSA Field Survey	Sample from RBSA Metering Study	Final Sample
Idaho	55	12	67
Western Montana	55	5	60
Oregon	92	30	122
Washington	156	47	203
Total	358	94	452

2.1.5. Sample Weighting

Each survey record in the database contains a sampling weight. Sampling weights are inversely proportional to the probability of a home's inclusion in the sample given the particular sampling stratum in which it occurs. For example, if there are 3,000 homes in one stratum and 30 of them are sampled, the sampling probability is 1% and the weight is 100 for each sample point. If in the same sample, another stratum included 200 homes with a sample of 30, the sampling probability is 15% and each case has a weight of 6.6. The weights can be thought of as the number of (unsampled) homes that each completed survey represents. Weighting strategies are employed to ensure that an unbiased estimate is produced as the data gathered at the individual home is combined to characterize the region or any particular subregion of interest. Because the population varies dramatically between each stratum, while the target sample sizes vary much less, an un-weighted combination of surveys would result in biases. Thus, weights were developed to reflect the population of each stratum divided by the total sample size recruited in that stratum. For each characteristic, these weights were used throughout in the calculation of all reported means and error bounds in the report.

2.2. Onsite Data Collection

The Ecotope team conducted 1,404 single-family home field surveys between June 2011 and January 2012. Field survey participants were recruited from the completed phone surveys, which included contact information on potential participants. The recruiters were instructed to contact these participants in a random order and recruit them into the field sample using a quota established for each stratum. Approximately five times as many homes required were available to recruiters in each stratum. Field survey participants were recruited from these phone surveys by randomly assigning the completed phone interviews and recruiting according to that random assignment. Recruiters mailed information to potential participants, describing the survey process and incentives. Participant mailings were conducted in batches, according to the needs of the sample distribution, and included a request that participants call the program's toll-free phone number to register their desire to participate. Recruiters followed up the introductory letters with a phone recruitment effort to secure participation and schedule site visits. Ecotope monitored field survey sample dispositions weekly to ensure progress for each sample stratum.

Field surveyors participated in a four-day training seminar, with subsequent on-the-job training and coaching through quality assurance activities. Surveyor training focused on the data collection requirements of the study, and on situations that require judgment and interpretation by the surveyors. These situations include the identification of heating equipment type and instruction on how to reflect exceptional circumstances in a prescribed set of database fields.

While onsite, the surveyors obtained a participant-signed billing history release form and conducted an occupant interview to obtain general demographic information as well as background information on energy-use behavior and home characteristics. Surveyors created freehand sketches of the floor plan of each residence surveyed and performed a room-by-room inventory of lighting and electronics characteristics. Surveyors also collected detailed data on the building envelope, HVAC system, major appliances, and large and unusual loads. Surveyors used tablet personal computers (PCs) for offline data collection. Surveyors entered field survey data using a form interface, and at the end of each day synced the data to the RBSA working database. Appendix A includes the single-family onsite data collection protocol.

Data collected onsite included, but was not limited to:

- **Building envelope**
  - Windows
    - Area (square feet [sq.ft.] per room)
    - South-facing
    - Frame type
    - Glazing type
    - Low-E coating
    - Skylights
  - Walls
    - Frame type
    - Insulation type and R-value
    - Area
  - Masonry and basement walls
    - Wall type
    - Insulation type and R-value
    - Area
  - Roof/attic
    - Attic type
    - Area
    - Insulation type and R-value
    - Insulation condition
    - Estimate of possible R-value improvement

    - Floors
        - Floor type
        - Insulation type and R-value
        - Area
        - Insulation condition

- **Ducts**
    - Presence of ducts
    - Duct type
    - Lineal feet
    - Insulation type
    - Insulation condition
    - Insulation R-value
    - Duct location

- **Lighting (by Room)**
    - Fixture type
    - Fixture quantity
    - Lamps per fixture
    - Lamp technology by fixture
    - Lamp wattage
    - Control type (e.g., manual, dimmer, motion-sensor, timer, etc.)
    - Area of the room

- **Heating, Cooling, and Ventilation Equipment**
    - Heating system
        - System type
        - Fuel type
        - Input/output British thermal unit (Btu)
        - Fan type
        - Thermostat type
        - Manufacture year
        - Distribution type
    - Cooling system
        - System type
        - Brand/model
        - Capacity
        - Fan type
    - Ventilation system
        - Type
        - Controls
        - Functioning/non-functioning

- **Water heater**
  - Fuel type
  - System type (e.g., storage, instantaneous)
  - Equipment type (e.g., tank, condensing)
  - Tank size
  - Tank wrap
  - Input capacity
  - Manufacture date
  - Solar water heating
  - Location (e.g., garage, basement, main house, crawlspace, etc.)
- **Showerheads**
  - Number
  - Measured flow rate of primary
- **Refrigerator/freezers**
  - System type/style (e.g., side-by-side, bottom freezer, etc.)
  - Brand/Model
  - Manufacture year
  - Volume
  - Icemaker type
  - Icemaker functioning/not functioning
  - Usage
  - Location (e.g., conditioned, unconditioned space)
- **Clothes washers**
  - System type (e.g., vertical/horizontal axis, stacked, combined, etc.)
  - Brand
  - Manufacture year
  - Usage
- **Clothes dryers**
  - Fuel type
  - Manufacture year
  - Usage
- **Dishwashers**
  - Manufacture year
  - Usage
- **Cooking**
  - Oven fuel
  - Cook top fuel

- **Large and Unusual Loads**
  - Equipment type (e.g., heated pool, hot tub, kiln, irrigation pump, chicken heat lamp, etc.)
- **Electronics, General**
  - Number of electronics chargers plugged in
  - Number of audio equipment components
  - Presence and type of subwoofers
- **Televisions**
  - Number of televisions (TVs)
  - Type (e.g., cathode ray tube [CRT], flat screen)
  - Brand/model
  - Size
  - Manufacture year
  - Primary vs. secondary
  - Primary television (TV) wattage (measured)
  - Number of plugged-in auxiliary items associated with TV
  - Cable/satellite set-top box provider
  - Year set-top box issued
  - Set-top box size (full size or small)
  - Set-top box ability to record
- **Gaming Systems**
  - Number of gaming systems
  - Brand and release
  - Ability to play digital video discs (DVDs) or Blu-ray movies
  - Ability to access the Internet (e.g., email, Netflix, video chat, etc.)
- **Computers**
  - Number of computers/laptops
  - Type
  - Number of screens
  - Screen size
  - Number of plugged in peripherals (all items plugged into single strip)

2.2.1. Data Quality Management

The Ecotope team implemented a comprehensive quality management plan focused on the quality assurance and quality control steps required across the full spectrum of the data collection process, starting with the protocol development and surveyor training and continuing through survey implementation and the final data cleaning and analysis phase. The quality management plan was designed to ensure accurate, consistent, and actionable data.

Key steps in the RBSA data quality management process included:

- **Protocol development.** In addition to completeness and correctness, a primary metric for data quality is alignment with study objectives. The data identified in the RBSA protocol were developed with input from numerous regional stakeholders and were designed to provide the level of detail necessary for developing energy efficiency measures in the Northwest. The protocol was developed by senior staff with extensive experience designing and evaluating Northwest measures.
- **Surveyor training and feedback loops.** The Ecotope team provided clear work instructions for surveyors and established feedback loops, utilizing tools such as conference calls, digital pictures, webinars, and regular feedback of data reported by each surveyor to illuminate and resolve common problems.
- **In-field QC.** Ecotope team members with specialized experience implementing residential characteristics surveys and heat-loss testing conducted in-field QC inspections of at least 6% of surveys to ensure that the surveys met project standards. In-field QC staff informed surveyors of inspection results and provided retraining as needed.
- **Onsite QC via tablet PC**. The tablet PC software included validation parameters to verify the accuracy, completeness, and consistency of data prior to being uploaded to the RBSA database.
- **Weekly data reviews.** During the field survey implementation, the Ecotope team performed weekly aggregate reviews of all uploaded surveys. The weekly QC reviews included checks for missing values and outliers. Particular emphasis was placed on the input variables for critical calculations such as lighting power density and heat-loss rate. The Ecotope team also analyzed data trends to reveal QC concerns related to specific surveyors and/or companies. For example, Ecotope checked the frequency of times a surveyor selected a type of bulb and wattage in order to assess the legitimacy of the surveyor's data.
- **Follow-up site visits.** Surveyors made return visits as needed to gather missing or incorrect data identified in the data QC process. When homeowners were unable to accommodate a follow-up site visit, the site was replaced following the same recruiting process as the original site.
- **Final data cleaning.** Once the surveys and the various QC steps were complete, Ecotope and Ecova cleaned and analyzed the data. This process involved several distinct activities:
  - Conduct overall checks on the data that identified outliers and allowed correction to be made when these were data collection or typographical errors.
  - Evaluate inconsistent data entries using surveyor notes or engineering judgments.
  - Assess missing data from surveyor notes, or secondary information collected during the survey (e.g., occupant interviews).
  - Where no alternatives were available, arrange a revisit of the site to collect missing or ambiguous data.

2.3. Characteristics Analysis

The RBSA single-family home sample design was based on a geographically stratified population for the entire region. Thus, case weights were developed based on all the completed surveys to account for the sampling probability in each geographic and utility stratum in the final database. This process was based on the actual surveys received. As a result of various scheduling overlaps, a few extra surveys were received but the case weights were developed for all 1,404 valid survey points. In the case of the blower door and duct leakage tests, a separate sample design was used based on the individual states. Ecotope developed separate weights for those tests that allowed generalized inference.

The second phase of the analysis was to assess and combine the data collected into meaningful summaries and to construct variables that would be useful in characterizing the single-family residential sector. At the outset, the output from the electronic tablet PC software was disaggregated into 75 database tables that each included the data for an individual subsurvey. For example, a single database table was constructed that included all the data collected for water heaters. This table included the information that related the water heater data back to the particular home and to the case weights for subsequent analysis. These tables were approached individually and later combined into analytic tables that were used to construct the report summaries used in this report.

The summary tables presented in this report were weighted using the case weights associated with each completed survey. These weights were used to compute the mean and the standard error of each variable and combination of variables presented here.

Each table in the report includes weighted mean values and the error bound (EB) on those values. The EB was calculated as a two-sided 90% confidence interval. The tables also generally include the number of sample points used to develop each mean value. The final summaries include all usable data for any particular record or home; as a result, not all summaries include all 1,404 homes.

2.4. Billing Data Collection and Analysis

Field surveyors secured a utility service billing release for each home, in addition to the interviews and physical surveys performed. Ecotope collected and assembled the billing data to summarize total energy use for each home by population group, by state, and for the region as a whole. In addition to enumerating the appliances in each home, field surveyors interviewed the participants about thermostats, setbacks, and other energy use behaviors. Surveyors also asked participants to estimate the amount of wood, oil, or propane burned or purchased. Ecotope used the billing data and interview data to estimate overall EUIs and space heating energy use.

Ecotope reviewed billing releases to verify accuracy and completeness, and provided them to participating utilities, along with a summary spreadsheet request outlining the site addresses, participants, and their account information at each utility. All personal identifying customer data were transferred between Ecotope and the utilities using a secure, password-protected website.

The billing data request included all electric and natural gas utility service records for the field survey sites. Ecotope requested billing records from January 2009 to March 2012 for each home, and where possible, all occupants' billing data for the site was collected, with the period of occupancy of the participant noted in the complete billing set. Utilities submitting data were able to provide at a minimum the last two years of billing data for their participant sites.

Utility response rates were high relative to other regional characterization studies. Table 7 shows the utility response rate by utility and the site data submission rate (99% of sites received out of total sites requested). Ninety-five percent of utilities solicited provided data for the study. Utilities submitted 99% of the requested billing data.

Table 7: Utility Billing Solicitation Response Rate

Utility Service	Utility Response Rate	Site Data Submission Rate
Electric Service	93%	99%
Natural Gas Service	100%	98%
Total	95%	99%

Ambiguities in participant understanding of what constituted natural gas and their gas provider influenced the number of gas sites obtained, though every effort was made to identify a probable natural gas provider and request bills from them in each ambiguous case. Most of this confusion revolved around the use of propane. In some cases, occupants were confused about the difference between propane and natural gas and, as a result, reported natural gas utilities that did not serve the home. In consequence, some homes with no natural gas service were requested, and utility analysts were most generous in assisting Ecotope to clarify when no natural gas service was provided to the residence.

Billing data submitted by each utility was audited as it was received to verify that it was as complete as possible, and that every site had been submitted. Ecotope followed up with utilities to clarify missing or ambiguous records. Checks were performed to verify that data submitted matched the residence and accounts requested. Kilowatt hours (kWh) and therm readings were checked for duplicates and anomalous readings, and these were resolved or removed from the analysis.

The billing analysis was based on a PRISM[5]-type variable base degree day (VBDD) billing analysis. Billing data were compared against quality controlled daily weather files provided by the National Oceanic and Atmospheric Administration (NOAA). This method allows disaggregation of other energy use from space heating. Ecotope developed a home EUI based on kilo British thermal units per square foot (kBtu/sq.ft.) for each home in the sample. Overall energy use was summarized by state. Specific end use information was summarized when

[5] PRInceton Scorekeeping Method. See Fels, 1986.

possible. The billing analysis used the case weights arrived at for the overall RBSA single-family sample design.

2.5. Final Database

The RBSA single-family home field survey generally collected about 750 pieces of information on each home. These variables included observed characteristics, occupant interviews, and utility bills. In addition, some composite analytical variables were constructed and will be included with the final data.[6] The summaries included in this report present a subset of the overall data collected in the study. A relational database is being developed that documents the 1,404 individual surveys and provides a data dictionary for the variables and calculated fields. The final single-family home database will be in a Microsoft Access format later in 2012.

[6] The most significant of these would be home heat loss rate (UA) (see Glossary of Acronyms and Abbreviations for definition of UA), lighting power density (LPD), and energy use index (EUI, total energy normalized by conditioned floor area).

3. Building Components

The Council defines single-family homes as buildings with fewer than five residential units in a single structure. Buildings with five or more units are classified as multifamily buildings. Factory-built homes built under the Federal Manufactured Home Standards are classified as manufactured homes. For the purposes of this report, manufactured homes were not considered single-family homes. This report is limited to single-family homes throughout the region.

Home configuration is another area in which the overall characteristics of the homes in the states can be compared. Several dimensions are important, but the most significant is the nature of the foundation. In addition, residence type (see Section 3.1), vintage (see Section 3.2), ground contact (see Section 3.3), conditioned area (see Section 3.4), building height (see Section 3.5), and room types (see Section 3.6) are all part of the overall home configuration.

Appendix B includes an auxiliary set of breakout tables for the electrically heated homes in the sample. This appendix is focused on the physical characteristics of the homes surveyed. In some cases this class of homes is significantly different than the entire population of single-family homes.

3.1. Type of Residence

The homes surveyed and reported here are distributed across the region as a geographically stratified random sample as discussed in Section 2.1. The regional sampling requirements coupled with oversamples specified by individual utilities have resulted in 1,404 single-family home surveys that are the basis of this summary.

Table 8 shows the percentage of homes by residence type across all states and the region. Townhouses are single-family attached homes. These homes are built with some common walls with adjacent units, but the floor and ceiling are not constructed as common or adiabatic components shared with other units. The duplex, triplex, and fourplex designations imply that some of these components could be shared with adjacent units. Although a townhouse could be part of a large number of units with shared common walls, the duplex, triplex and fourplex will not have more than two, three, or four units respectively. In all these cases, the unit recruited in the sample was surveyed and the adjacent units were generally ignored.

Table 8 shows that about 93% of the surveys across the entire region are single-family detached homes. Approximately 4% are in the duplex, triplex, and fourplex category, and another 2% are townhouses or rowhouses. These distinctions, for the most part, are not important to any of the subsequent summaries in this report.

Table 8: Distribution of Homes by Type and State

Home Type		Percentage of Homes					
		ID	MT	OR	WA	Region	n
Single Family, Detached	**%**	91.1%	88.9%	95.0%	93.5%	93.3%	1,321
	EB	3.9%	4.3%	2.5%	2.1%	1.4%	
Duplex, Triplex, or Fourplex	**%**	5.1%	7.4%	2.6%	4.6%	4.3%	52
	EB	3.1%	3.7%	1.8%	1.8%	1.1%	
Townhouse or Rowhouse	**%**	3.8%	3.8%	2.4%	1.9%	2.4%	30
	EB	2.6%	2.6%	1.9%	1.2%	0.9%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,403

3.2. Vintage

As Table 9 and Figure 2 show, about 24% of the region's housing was built prior to 1951. Thereafter, the percent additions in each decade are reasonably consistent across states. A notable exception is home construction in Idaho where almost 23% of the homes were constructed in the post-2000 time period. This level of growth is fairly striking even when compared to other larger states such as Washington with large population growths in this time period. In Idaho, however, there has been almost a 40% growth of total homes in the state since 1990. None of the other states have approached this level of expansion over a comparable time period.

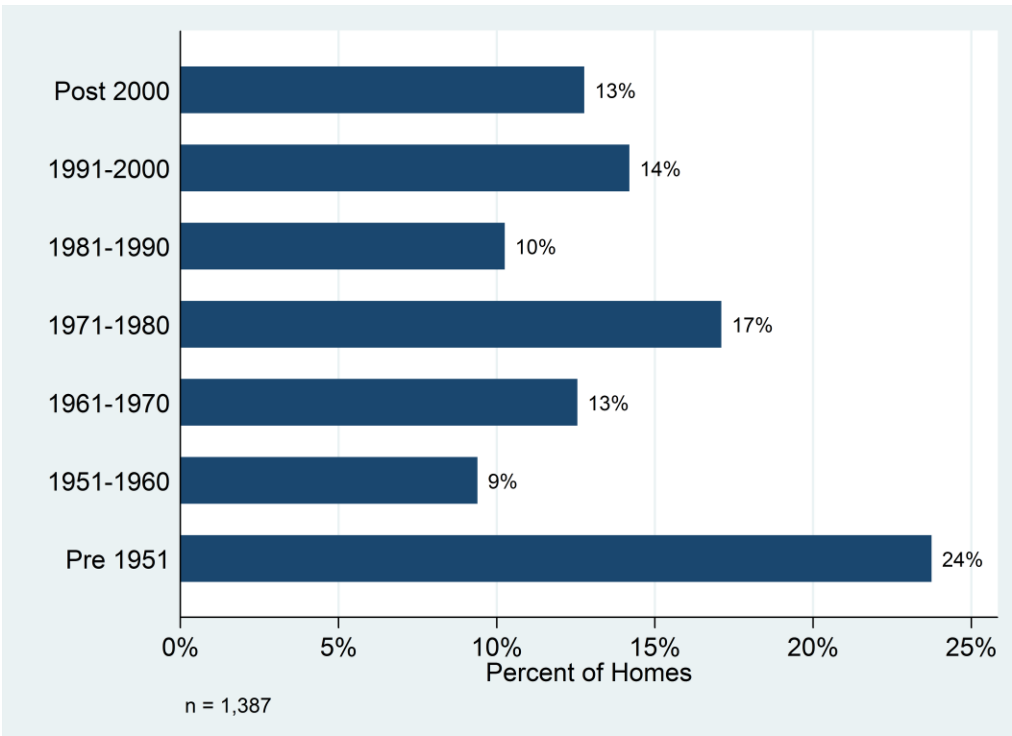
Overall about 37% of the region's housing stock has been added since 1981; after which energy codes, conservation, and other efficiency considerations have influenced construction.

Table 9: Distribution of Homes by Vintage and State

Vintage		Percentage of Homes					
		ID	MT	OR	WA	Region	n
Pre 1951	**%**	19.6%	21.9%	26.4%	23.5%	23.7%	378
	EB	5.4%	5.6%	5.2%	2.7%	2.2%	
1951-1960	**%**	7.8%	8.8%	10.3%	9.3%	9.4%	132
	EB	3.6%	3.8%	3.6%	2.3%	1.7%	
1961-1970	**%**	8.5%	10.4%	15.1%	12.4%	12.5%	166
	EB	3.7%	4.1%	4.1%	2.5%	1.8%	
1971-1980	**%**	17.2%	19.9%	15.3%	17.7%	17.1%	223
	EB	5.2%	5.4%	4.0%	3.2%	2.1%	
1981-1990	**%**	8.8%	10.5%	9.2%	11.2%	10.3%	123
	EB	3.7%	4.0%	3.4%	2.5%	1.7%	
1991-2000	**%**	15.4%	17.6%	13.2%	14.0%	14.2%	189
	EB	4.9%	4.9%	4.0%	2.9%	2.0%	
Post 2000	**%**	22.7%	10.9%	10.4%	11.9%	12.8%	176
	EB	5.6%	4.1%	3.5%	2.4%	1.8%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,387

The vintage data from the RBSA survey suggests that the comparison with the U.S. Census American Community Survey (ACS) is relatively close on a state-by-state basis. In no case are the ACS estimates outside the error bounds of the RBSA survey. When these estimates are combined, however, some differences do emerge. The ACS, for example, estimates the percentage of the regional housing stock added since 1981 to be 44%. This regional estimate is significantly different from the RBSA estimate for the same period.[7]

Figure 2: Distribution of Homes by Vintage



3.3. Ground Contact

In colder parts of the region, the use of a basement is commonplace. Table 10 and Figure 3 show the distribution of basements, crawlspaces, and other foundation configurations across the sample. In Montana, more than half of the homes have basements. In Oregon, about 22% of the homes have basements and over 80% of the homes have crawlspaces. Surveyors were instructed to classify basements as unconditioned if the floor above is insulated from the main home and there are no heating systems and/or major appliances providing either direct or incidental conditioning to the basement rooms. The surveyors were instructed to classify basements as

[7] The ACS summary used here includes all of Montana, not just the western portion, and includes 1980 in the summary. These differences probably would reduce the difference but they would not eliminate it.

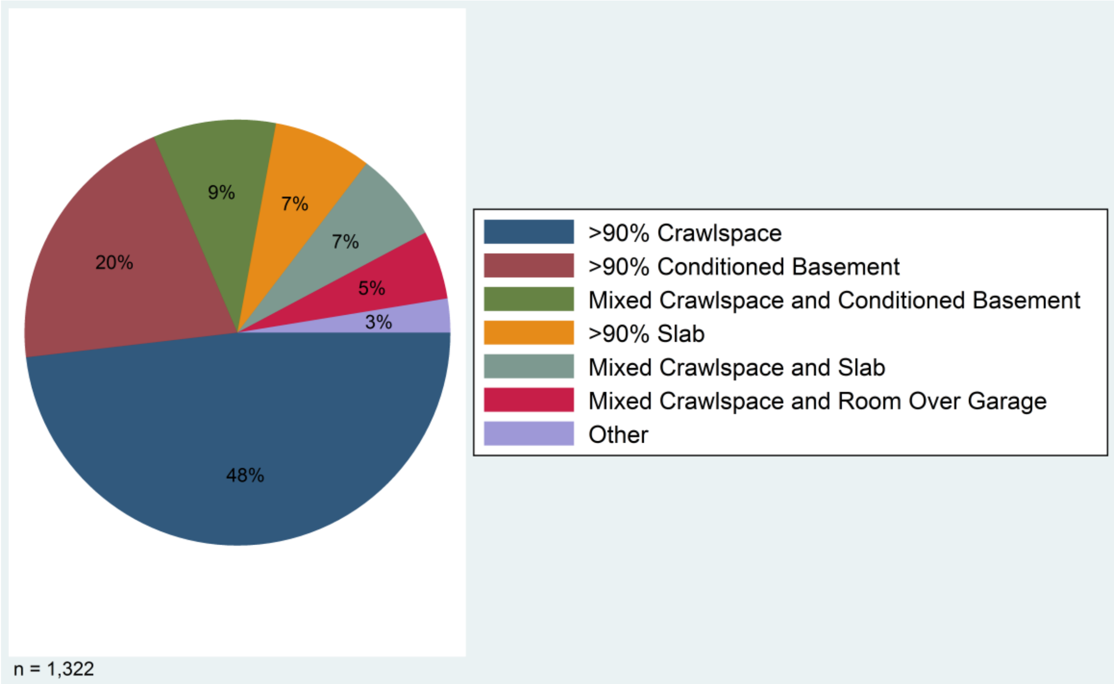
conditioned space if the basements include major pieces of equipment such as the furnace, water heater, laundry appliances, etc., even if the floor between the basement and the home is insulated. This approach is largely based on the fact that given those functions, the basement will be conditioned and the heat loss from the basement will be part of the overall efficiency of the home. The level of finish in the basement was not taken into account when making this decision.

Under some protocols in other studies, the basement has been considered unconditioned even though it houses many of these important functions. In some cases, the insulation is placed in the floor above the basement, in spite of the fact that it is insulating between two spaces that are essentially the same temperature. In this survey, the insulated floor between the conditioned basement and the main living space was considered adiabatic and not included in the heat loss of the home. In the region as a whole, crawlspaces in various configurations dominate with approximately 70% of the homes having some kind of crawlspace, sometimes in combination with partial basements. Only about 30% of the homes have basements (sometimes in combination with crawlspaces). Slab-on-grade floors make up the other floor type, which occurs in about 14% of the houses.

Table 10: Distribution of Homes by Ground Contact Type and State

Ground Contact Type		Percentage of Homes					
		ID	MT	OR	WA	Region	n
> 90% Crawlspace	%	38.5%	28.6%	55.7%	48.9%	48.1%	615
	EB	6.6%	6.0%	5.9%	3.9%	2.8%	
> 90% Conditioned Basement	%	27.8%	39.5%	11.7%	21.0%	20.4%	293
	EB	5.9%	6.6%	4.0%	3.4%	2.2%	
Mixed Crawlspace and Conditioned Basement	%	10.2%	15.4%	9.3%	8.2%	9.4%	127
	EB	4.1%	4.9%	3.6%	2.3%	1.7%	
> 90% Slab	%	13.2%	5.9%	4.8%	7.8%	7.5%	92
	EB	4.6%	3.2%	2.6%	2.3%	1.5%	
Mixed Crawlspace and Slab	%	3.2%	6.0%	9.7%	6.2%	6.8%	92
	EB	2.4%	3.2%	3.5%	1.6%	1.4%	
Mixed Crawlspace and Room Over Garage	%	3.9%	0.8%	7.1%	5.0%	5.2%	58
	EB	2.7%	1.3%	3.0%	1.6%	1.3%	
Mixed Crawlspace and Unconditioned Basement	%	1.4%	0.8%	0.3%	0.9%	0.8%	17
	EB	1.4%	1.0%	0.4%	0.5%	0.3%	
> 90% Unconditioned Basement	%	0.2%	1.2%	1.0%	1.0%	0.9%	15
	EB	0.4%	1.4%	1.2%	0.6%	0.5%	
Adiabatic Space Below	%	1.5%	2.0%	0.4%	0.9%	0.9%	13
	EB	1.7%	1.9%	0.4%	0.7%	0.4%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,322

Figure 3: Distribution of Homes by Ground Contact Type



3.4. Conditioned Floor Area

Throughout this report, some parameters were normalized by conditioned floor area. Conditioned floor area was defined for purposes of heat loss rate calculations, and does not necessarily reflect the living area of the home.[8] Surveyors measured conditioned floor area by combining the outside dimensions of the home with the “conditioned basements” as described in Section 4.1.2.1. Table 11 and Figure 4 show the distribution of conditioned floor area by state. Figure 4 shows the distribution of areas using the median area and the quartiles of the distribution. The overall area of homes across the region is relatively similar. This similarity is somewhat misleading because the largest homes are actually in Idaho and Montana. In Idaho and Montana, about 40–55% of the homes have basements, which accounts for the larger home size in these states (with basements usually counted as part of the conditioned floor area). This difference inflates the size of homes in these states relative to Oregon and Washington, which have much fewer basements but larger above-grade homes.

The surveyors also collected interior areas by room. The interior area was used only when characteristics (e.g., lighting power density) were summarized by room or room type. This area was always reported as the *interior* area of the room.

[8] This is particularly true of homes with unfinished (but conditioned) basements.

Table 11: Average Conditioned Floor Area by State

State	Conditioned Floor Area (sq.ft.)		
	Mean	EB	n
ID	2,109	122	183
MT	2,158	137	167
OR	1,882	98	310
WA	2,030	63	730
Region	2,006	47	1,390

Figure 4: Average Conditioned Floor Area by State

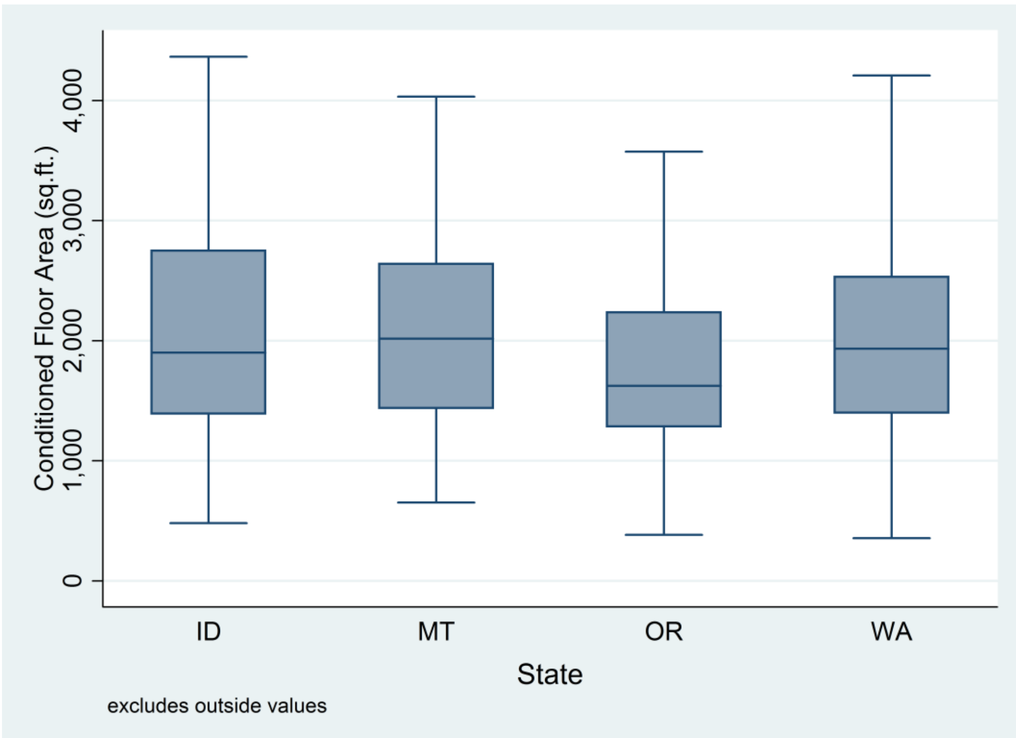


Table 12 shows the distribution of house size by vintage across the region. House sizes have steadily increased over the last 50 years. Overall the conditioned floor area has increased about 20% across the region.

Table 12: Average Conditioned Floor Area by Vintage and State

Vintage		Conditioned Floor Area (sq.ft.)					
		ID	MT	OR	WA	Region	n
Pre 1951	Mean	1,919	1,850	1,968	1,831	1,886	373
	EB	269	202	231	85	92	
1951–1960	Mean	2,416	2,040	1,560	1,809	1,807	130
	EB	485	381	218	189	139	
1961–1970	Mean	1,907	2,348	1,759	2,140	1,996	164
	EB	348	578	196	180	128	
1971–1980	Mean	1,967	2,131	1,711	2,040	1,950	222
	EB	251	279	214	176	118	
1981–1990	Mean	2,151	2,009	2,019	2,039	2,044	122
	EB	448	248	430	176	159	
1991–2000	Mean	2,171	2,623	2,244	2,193	2,242	189
	EB	337	452	280	193	137	
Post 2000	Mean	2,365	2,316	1,937	2,352	2,252	173
	EB	264	362	228	191	127	
All Vintages	Mean	2,109	2,158	1,882	2,030	2,006	1,373
	EB	122	137	98	63	47	

3.5. Building Height

The surveyors were instructed to assess the overall building height in stories. Table 13 summarizes the number of stories observed during the surveys. As noted, the vast majority of homes are either single-story or one-and-one-half stories (i.e., homes with a partial second story).

Table 13: Distribution of Homes by Building Height and State

Building Height		Percentage of Homes					
		ID	MT	OR	WA	Region	n
1 Story	%	63.3%	59.2%	55.5%	50.9%	54.5%	762
	EB	6.3%	6.5%	5.9%	3.9%	2.8%	
1.5 Stories	%	9.5%	16.6%	14.2%	15.7%	14.5%	206
	EB	3.8%	4.9%	4.2%	2.9%	2.0%	
2 Stories	%	22.9%	23.4%	27.3%	30.6%	28.1%	385
	EB	5.5%	5.6%	5.2%	3.6%	2.5%	
2.5 Stories	%	4.1%	0.4%	1.1%	2.1%	2.0%	36
	EB	2.7%	0.7%	1.1%	0.8%	0.6%	
3+ Stories	%	0.2%	0.4%	1.9%	0.6%	0.9%	15
	EB	0.4%	0.7%	1.4%	0.5%	0.5%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,404

3.6. Rooms

The real estate market has consistently used the number of bedrooms and bathrooms to characterize homes. Table 14 shows the average number of bedrooms per home by state. The average number of bedrooms per home for the region is nearly 3.2.

Table 14: Average Number of Bedrooms per Home by State

State	Bedrooms per Home		
	Mean	EB	n
ID	3.37	0.127	185
MT	2.99	0.131	169
OR	3.03	0.098	314
WA	3.21	0.073	736
Region	3.16	0.050	1,404

Table 15 shows the average number of bathrooms per home by state. The average number of bathrooms per home is fairly uniform across all states. The average number for Oregon is 2.14, with slightly more in Washington and Idaho and slightly less in Montana.

Table 15: Average Number of Bathrooms per Home by State

State	Bathrooms per Home		
	Mean	EB	n
ID	2.26	0.109	185
MT	1.99	0.105	169
OR	2.14	0.094	314
WA	2.23	0.065	736
Region	2.19	0.046	1,404

More than 18,500 rooms were surveyed, and areas were measured on virtually all of them. Table 16 shows a distribution of room type and size. These rooms are summarized here without regard for whether they are conditioned or unconditioned.

Table 16: Average Room Areas by Room Type

Room Type	Room Areas (sq.ft.)		
	Mean	EB	n
Bathroom	65	1.34	2,942
Bedroom	158	2.54	3,123
Closet	49	2.36	1,067
Dining Room	149	5.04	894
Family Room	305	9.47	738
Garage	514	16.01	849
Hall	90	3.04	2,315
Kitchen	179	4.37	1,404
Laundry Room	92	4.30	982
Living Room	294	5.74	1,325
Master Bedroom	214	5.54	877
Office	154	5.41	736
Other	255	14.94	1,270
All Room Types	167	2.39	18,522

4. Building Envelope

A major component of all home energy survey protocols is the assessment of building component areas and insulation values for purposes of constructing a picture of the heat-loss rate of each home (the UA). In the RBSA study, the use of the tablet PC software standardized the ranges of insulation the surveyor reported, and this resulted in somewhat more consistent insulation level assessments. These characteristics apply to component areas throughout each home. We summarize insulation values and component characteristics throughout this section using the categories the surveyor used to collect the insulation information. The summaries are always weighted by both the case weights and the areas of the particular components in each home. The weighting enables summaries of the characteristics by the actual area of the component, not just the particular sampling weight of the home. In this section, we use only the sample weight for the house when characterizing the percentage of homes with a particular characteristic.

4.1. Insulation

When assessing building shell components, the surveyors were trained to make informed assessment of the insulation levels. They were instructed in several techniques for assessing inaccessible insulation levels in all cavities—for example, at penetrations such as at electrical and plumbing, and probes at convenient locations near the floor and ceiling, and in attics and crawlspaces. In addition, when all techniques were exhausted, the surveyor made a judgment based on the participant's assessment of insulation levels or other secondary information that might be available at the site, including home vintage.

4.1.1. Walls

Wall assessment typically presents a challenge for surveyors to identify insulation levels and framing types. Quite often these characteristics are fully covered and finished, and there is no straightforward way to observe the insulation cavities or the quality and degree of the insulation. Nevertheless, the surveyors, using the techniques described above, assigned framing and insulation into four general categories, as shown in Table 17.

Table 17: Distribution of Frame Wall Insulation Levels by Framing Type

Wall Framing Type		Frame Wall Insulation Levels						
		R0	R1-R10	R11-R16	R17-R22	>R22	All Insulation Levels	n
2x4	%	18.7%	12.2%	64.2%	4.9%	—	62.6%	987
	EB	2.7%	2.3%	3.4%	1.5%	—	2.9%	
2x6	%	3.0%	—	8.5%	86.2%	2.3%	36.8%	476
	EB	1.5%	—	2.4%	3.0%	1.1%	2.9%	
2x8	%	—	—	24.0%	8.0%	67.9%	0.5%	4
	EB	—	—	27.6%	13.2%	29.5%	0.4%	
Alternative	%	—	—	—	—	—	0.0%	1
	EB	—	—	—	—	—	0.1%	
All Frame Types	%	12.8%	7.6%	43.4%	34.9%	1.2%	100.0%	1,487
	EB	1.8%	1.5%	2.9%	2.9%	0.5%		

Table 18 summarizes the distribution of wall framing types by vintage. As shown in the table, most of the framing observed across the entire sample—approximately 63%—consists of 2x4s with the balance being 2x6 framing. In a few cases, surveyors observed larger framing or alternative wall construction. 2x4 wall construction was used almost exclusively prior to the advent of the energy codes, which effectively mandated 2x6 construction. Energy codes were introduced (and enforced) in Washington and Oregon in the late 1980s and in Idaho and Montana 10 to 15 years later.[9] The homes in the sample that were built prior to these periods are largely 2x4 framed. Approximately 13% of homes have no wall insulation, and could potentially be eligible for utility programs.

[9] The first statewide Washington State Energy Code (WSEC) was introduced in 1980, but for practical purposes the impact of this code on construction practices did not begin until the passage of the 1986 WSEC which was enforced in many jurisdictions beginning in 1987. The Oregon energy code was introduced in 1984, but did not mandate 2x6 construction until the 1993 revision. Idaho had a largely voluntary code, the Idaho Residential Energy Standard (IRES) beginning in 1996. This code did not require 2x6 construction, but did mandate foam sheathing on a portion of all residential walls. In 2001, Idaho adopted and began to enforce the International Energy Conservation Code (IECC), which did require 2x6 construction. The state of Montana requires building permits for only about half of all residential construction. The energy code applies to that group. Montana adopted the IECC in 2004, thus effectively requiring 2x6 construction and modern insulation standards for a portion of the Montana residential building stock.

Table 18: Distribution of Wall Framing Types by Vintage

Vintage		Wall Framing Types				n
		2x4	2x6	2x8	Alternative	
Pre 1981	%	89.0%	10.5%	0.4%	0.1%	983
	EB	2.0%	2.0%	0.4%	0.1%	
1981-1990	%	63.0%	35.5%	1.4%	—	125
	EB	8.7%	8.6%	2.4%	—	
1991-2000	%	15.2%	83.9%	0.9%	—	194
	EB	5.6%	5.7%	1.0%	—	
Post 2000	%	13.2%	86.8%	—	—	177
	EB	4.4%	4.4%	—	—	
All Home Vintages	%	62.6%	36.8%	0.5%	0.0%	1,479
	EB	2.9%	2.9%	0.4%	0.1%	

Table 19 shows the overall distribution of wall insulation by vintage. Virtually all of the uninsulated walls are in homes built before 1981. On the other hand, nearly 60% of these walls have between R11 and R16 insulation, suggesting a substantial penetration of retrofit insulation, especially in homes built with 2x4 walls.

Table 19: Distribution of Wall Insulation Levels by Home Vintage

Vintage		Wall Insulation Levels					n
		R0	R1-R10	R11-R16	R17-R22	>R22	
Pre 1981	%	21.4%	12.7%	57.2%	8.4%	0.3%	978
	EB	2.9%	2.4%	3.5%	1.8%	0.4%	
1981-1990	%	1.5%	3.2%	56.3%	37.6%	1.4%	124
	EB	1.9%	3.1%	9.3%	9.1%	2.4%	
1991-2000	%	1.3%	0.1%	15.0%	81.2%	2.5%	194
	EB	2.1%	0.2%	5.2%	5.7%	1.8%	
Post 2000	%	0.6%	—	12.7%	83.6%	3.2%	177
	EB	0.9%	—	4.7%	5.1%	2.1%	
All Vintages	%	12.8%	7.6%	43.4%	34.9%	1.2%	1,473
	EB	1.8%	1.5%	2.9%	2.9%	0.5%	

Table 20 through Table 23 show the distribution of insulation levels by state. These tables show the consistent migration of building practices toward R20 wall insulation as energy codes were introduced and enforced in each state.

Table 20: Distribution of Wall Insulation Levels by Home Vintage, Idaho

Vintage		Wall Insulation Levels, Idaho					
		R0	R1-R10	R11-R16	R17-R22	>R22	n
Pre 1981	%	28.9%	8.2%	54.8%	8.1%	—	92
	EB	9.4%	5.0%	9.8%	5.1%	—	
1981-1990	%	4.9%	—	68.7%	26.4%	—	18
	EB	8.0%	—	20.0%	18.8%	—	
1991-2000	%	—	—	22.2%	73.5%	4.4%	28
	EB	—	—	15.6%	16.4%	7.1%	
Post 2000	%	—	—	32.5%	67.5%	—	44
	EB	—	—	13.6%	13.6%	—	
All Vintages	%	14.0%	3.9%	45.1%	36.2%	0.7%	182
	EB	5.0%	2.4%	7.0%	6.8%	1.2%	

Table 21: Distribution of Wall Insulation Levels by Home Vintage, Montana

Vintage		Wall Insulation Levels, Montana					
		R0	R1-R10	R11-R16	R17-R22	>R22	n
Pre 1981	%	11.9%	2.9%	56.4%	27.6%	1.3%	99
	EB	6.3%	2.9%	9.5%	8.5%	2.1%	
1981-1990	%	—	—	42.3%	57.7%	—	17
	EB	—	—	25.2%	25.2%	—	
1991-2000	%	—	—	25.4%	58.0%	16.7%	36
	EB	—	—	13.1%	15.9%	14.1%	
Post 2000	%	—	—	3.0%	87.5%	9.5%	19
	EB	—	—	4.9%	12.0%	11.0%	
All Vintages	%	6.2%	1.5%	40.0%	46.4%	5.9%	171
	EB	3.4%	1.5%	7.0%	7.3%	4.1%	

Table 22: Distribution of Wall Insulation Levels by Home Vintage, Oregon

Vintage		Wall Insulation Levels, Oregon					
		R0	R1-R10	R11-R16	R17-R22	>R22	n
Pre 1981	%	25.7%	10.2%	56.1%	7.9%	—	223
	EB	6.8%	4.9%	7.3%	3.7%	—	
1981-1990	%	—	5.4%	55.3%	39.3%	—	28
	EB	—	8.7%	19.7%	19.1%	—	
1991-2000	%	—	—	11.6%	88.1%	0.3%	42
	EB	—	—	11.6%	11.6%	0.5%	
Post 2000	%	2.4%	—	6.7%	89.1%	1.8%	36
	EB	4.0%	—	10.6%	11.4%	2.8%	
All Vintages	%	16.1%	6.8%	42.7%	34.1%	0.3%	329
	EB	4.6%	3.2%	5.9%	5.9%	0.3%	

Table 23: Distribution of Wall Insulation Levels by Home Vintage, Washington

Vintage		Wall Insulation Levels, Washington					
		R0	R1-R10	R11-R16	R17-R22	>R22	n
Pre 1981	%	18.6%	16.1%	58.4%	6.5%	0.4%	564
	EB	3.2%	3.4%	4.6%	2.1%	0.6%	
1981-1990	%	1.8%	3.0%	56.4%	36.3%	2.5%	61
	EB	3.0%	3.3%	12.4%	12.2%	4.1%	
1991-2000	%	2.6%	0.2%	13.4%	83.2%	0.6%	88
	EB	4.2%	0.4%	6.2%	7.4%	1.0%	
Post 2000	%	0.1%	—	8.8%	86.9%	4.3%	78
	EB	0.1%	—	5.2%	6.2%	3.5%	
All Vintages	%	11.6%	9.7%	43.9%	33.6%	1.3%	791
	EB	2.0%	2.1%	4.0%	4.0%	0.8%	

Table 24 shows the distribution of insulation levels in masonry walls. This table combines masonry walls that occur both above and below grade, but shows a similar pattern in all the masonry walls, namely that even in vintages where codes were enforced, the amount of uninsulated wall surface in all masonry walls remains a majority of below-grade walls. In Washington and Oregon, these walls are regulated and insulated. However, in Montana and to some extent in Idaho, the majority of these masonry walls actually occur in basements. In these cases, the use of basement wall insulation is a more recent code development. Thus, even in relatively recent home construction, uninsulated masonry walls dominate the region's masonry wall landscape.

Table 24: Distribution of Masonry Wall Insulation Levels by Home Vintage

Vintage		Masonry Wall Insulation Levels					
		None	R1-R9	R10-R15	R15-R20	R21+	n
Pre 1981	%	74.1%	5.2%	14.6%	5.9%	0.3%	426
	EB	4.8%	2.0%	4.1%	2.5%	0.4%	
1981-1990	%	46.7%	5.4%	28.4%	19.5%	—	42
	EB	20.4%	5.4%	21.3%	12.8%	—	
1991-2000	%	41.0%	10.7%	23.7%	23.4%	1.3%	58
	EB	14.3%	10.8%	11.2%	14.3%	2.2%	
Post 2000	%	42.7%	—	19.7%	31.9%	5.7%	35
	EB	18.3%	—	13.4%	15.8%	6.9%	
All Frame Types	%	65.5%	5.7%	17.4%	10.8%	0.7%	561
	EB	4.8%	2.1%	4.1%	3.0%	0.6%	

Table 25 summarizes the observation of insulated sheathing. This table is actually dominated by Idaho vintages in the area from the 1990s, when the Idaho residential standards focused on 2x4 framing and one inch of insulation over some percentage of the wall was an acceptable standard for Idaho building. Thus, most of the sheathing observed was one-inch thick and in Idaho. Even though the insulated sheathing appears in only about 7% of the walls surveyed across the region, we believe this number is somewhat biased by the fact that this component is difficult to observe, and even harder to impute. Therefore, we expected surveyors to err on the side of not assuming insulated sheathing even when it might have been there.

Table 25: Distribution of Observed Wall Sheathing Insulation by Framing Type

Framing Type		Observed Wall Sheathing Insulation Levels				
		1 Inch	2 Inch	3 Inch	None	n
2x4	%	4.9%	0.6%	0.0%	94.5%	990
	EB	1.5%	0.4%	0.1%	1.5%	
2x6	%	5.8%	1.6%	—	92.7%	490
	EB	2.1%	1.6%	—	2.6%	
2x8	%	2.8%	15.2%	8.9%	73.0%	10
	EB	4.9%	23.3%	14.6%	27.0%	
Alternative	%	—	—	—	100.0%	1
	EB	—	—	—	0.0%	
All Framing Types	%	5.2%	1.0%	0.1%	93.7%	1,491
	EB	1.2%	0.6%	0.1%	1.4%	

4.1.2. Floors and Basements

4.1.2.1. Basements

The surveyors observed insulation levels in both the floors above basements and basement walls and slab floors, within the same process. In accordance with the RBSA protocol definition, the basement was considered conditioned space when heating, hot water heaters, and/or major appliances are located in the basement, regardless of the level of finish in the basement itself.

Table 26 and Table 27 show the percentage of homes with basements across the sample, and the percentage of those basements that are conditioned, by this definition. Table 27 shows the level of slab insulation that occurs in these homes, even though slab insulation is difficult for the surveyor to verify. For the most part, it is not a current practice to insulate slabs of basements at the perimeter except in more recently constructed homes in Washington and Oregon where it has become part of the code. Aside from this situation, virtually no other vintage or locality would require the insulation, and in most cases we suspect that it has not been included in those homes.

Table 26: Percentage of Homes with Basements by State

State	Homes with Basements		
	%	EB	n
ID	41.6%	6.4%	185
MT	58.0%	6.5%	169
OR	22.5%	5.0%	314
WA	35.4%	3.5%	736
Region	34.0%	2.5%	1,404

Table 27: Percentage of Basements that Are Conditioned by State

State	Conditioned Basements		
	%	EB	n
ID	96.1%	3.3%	87
MT	95.4%	3.5%	97
OR	94.4%	5.3%	60
WA	94.9%	2.1%	276
Region	95.0%	1.6%	520

Table 28 summarizes basement insulation levels. The basement slab is required to be insulated in modern codes. In general, this practice is infrequent even where required by code. The dominant insulation type is “None” and it represents in excess of 90% of the basement slabs observed. Only about 7% of the basement slab floors show any evidence of insulation at the slab perimeter.

Table 28: Distribution of Basement Slab Insulation by Insulation Level

Insulation Level	Basement Perimeter Slab Insulation		
	%	EB	n
1 Inch	2.0%	1.2%	9
2 Inches	5.4%	2.0%	27
None	92.6%	2.2%	485
Total	100.0%	—	521

4.1.2.2. Crawlspaces

Crawlspaces are the most common type of floor construction in the region, particularly in western Washington and western Oregon. The eastern climates use basements more frequently because they are often required to excavate the footings below the frost line. In many colder climates, this requires four feet of excavation, so the basement becomes a feasible option. Table 29 shows the percentage of homes with some amount of floor area over a crawlspace.

Table 29: Percentage of Homes with Floor Area over Crawlspace by State

State	Homes with Floor Area over Crawlspace		
	%	EB	n
ID	57.4%	6.5%	185
MT	49.2%	6.6%	169
OR	81.6%	4.7%	314
WA	66.6%	3.6%	736
Region	68.6%	2.5%	1,404

There are two strategies for insulating crawlspace areas. The first, which is practiced almost exclusively in Oregon and Washington, is to use fiberglass insulation to insulate the floor between the crawlspace and the home. This is relatively straightforward to observe, and Table 30 shows the distribution of floor insulation under this method. For inclusion in this table, the floor insulation has to be between the insulated conditioned floor of the home and an uninsulated or unconditioned area of the home. Generally, the uninsulated/unconditioned area involves crawlspaces, but in a few cases it involves garages or even unconditioned basements when that judgment was appropriate. The insulation levels of floors across the region begin with less than half of the floors insulated in 1950 vintage and gradually become more insulated. Generally speaking, floors are quite straightforward to retrofit insulation into, and so it is not surprising that even though these older floors undoubtedly were built originally without insulation, they have been retrofit over the decades.

Table 30: Distribution of Floor Insulation by Home Vintage

Vintage		Floor Insulation Levels								
		None	R1-R3	R4-R10	R11-R15	R16-R22	R23-R27	R28-R35	R38+	n
Pre 1981	%	38.9%	1.9%	3.4%	7.9%	32.3%	9.8%	5.6%	0.3%	590
	EB	4.7%	1.5%	1.6%	2.3%	4.6%	3.0%	2.0%	0.2%	
1981-1990	%	33.5%	2.3%	2.1%	10.1%	45.9%	5.4%	0.7%	0.1%	90
	EB	10.5%	3.7%	3.4%	6.1%	10.9%	3.8%	0.8%	0.1%	
1991-2000	%	15.7%	—	—	3.4%	35.4%	30.7%	14.3%	0.6%	134
	EB	5.9%	—	—	2.4%	9.8%	9.0%	5.4%	0.9%	
Post 2000	%	11.5%	—	—	—	33.7%	19.8%	33.9%	1.1%	129
	EB	4.6%	—	—	—	8.5%	7.3%	8.9%	1.1%	
All Vintages	%	30.0%	1.3%	2.1%	6.1%	34.6%	14.5%	11.0%	0.4%	943
	EB	3.2%	0.9%	1.0%	1.5%	3.5%	2.7%	2.2%	0.3%	

By the beginning of 2000, virtually no homes were built without substantial floor insulation. It does appear that minimum levels of approximately R19 were used, and in about one-third of the cases, insulation levels of R30 or higher were observed. Approximately 30% of homes with crawlspaces have no floor insulation, although in newer homes the heat loss is partially offset by the use of crawlspace wall insulation.

The second approach to floor insulation when a crawlspace is present is the insulation of the crawlspace wall. This has the effect of reducing the heat loss to the outside through that wall, but heat loss through the ground contact at the floor of the crawlspace is increased. Usually this strategy calls for an alternative venting strategy or for manual operation of crawlspace vents seasonally. In colder climates, this technique is thought to offer freeze protection for plumbing services in the crawlspace and to simplify the installation of ducts, plumbing, and wiring. Table 31 shows the percentage of homes with crawlspaces that use this insulation strategy. This insulation strategy is applied almost exclusively in the colder climates of Idaho and Montana.[10]

[10] The IECC code used in Idaho and Montana allows R10 wall crawlspace wall insulation as an alternative to R30 floor insulation. This trade-off is by far the dominant construction type in those states. Washington and Oregon have effectively outlawed this practice in energy codes enforced over the last 20 years.

Table 31: Percentage of Crawlspaces with Insulated Walls by State

State	Insulated Crawlspace Walls		
	%	EB	n
ID	31.8%	8.4%	100
MT	43.1%	9.3%	85
OR	9.6%	3.8%	262
WA	4.5%	2.3%	487
Region	11.2%	2.1%	934

4.1.3. Ceilings and Attics

The dominant ceiling and roof structure in the region is an attic/ceiling system. This trend has been true across virtually all construction and all vintages. Table 32 shows the percentage of homes with attics. Almost 94% of all homes observed had attic construction as their ceiling type. Attic insulation is relatively cost-effective and among the easier components to insulate as a retrofit. Table 33 shows the levels of insulation observed across the entire region. Because many of these homes have been retrofitted, about 85% of all homes have R16 insulation or above, no matter when the buildings were constructed originally. Table 33 shows that 6% of homes have little or no attic insulation.

Table 32: Percentage of Homes with Attics by State

State	Homes with Attics		
	%	EB	n
ID	92.6%	3.4%	185
MT	92.4%	3.4%	169
OR	92.4%	2.7%	314
WA	95.2%	1.7%	736
Region	93.8%	1.3%	1,404

Table 33: Distribution of Attic Insulation Levels

Insulation Level	Attic Insulation Level		
	%	EB	n
R0	1.1%	0.5%	35
R1-R10	4.9%	1.3%	79
R11-R15	8.2%	1.5%	138
R16-R20	11.4%	2.0%	162
R21-25	11.5%	2.0%	150
R26-R30	16.2%	2.3%	223
R31-R40	36.0%	3.0%	447
R41-R50	7.8%	1.6%	103
R50+	3.0%	1.0%	43
Total	100.0%	—	1,380

The surveyors assessed the amount of insulation that *could* be installed in these homes. Table 34 shows the insulation upgrade estimates by home vintage. Based on surveyor estimates, about 70% of the homes with attics could have additional insulation of between R11 and R30. This estimate was meant to reflect the overall size and clearance in the attic.

Table 34: Distribution of Insulation Upgrade Potential Estimates by Home Vintage

Vintage		Estimated Attic Insulation Upgrades					
		R1-R10	R11-R20	R21-R30	>R30	None	n
Pre 1981	%	8.7%	26.3%	8.4%	40.4%	16.2%	820
	EB	1.7%	3.2%	2.2%	3.6%	2.7%	
1981-1990	%	18.7%	44.4%	5.1%	18.4%	13.5%	105
	EB	7.2%	9.7%	4.0%	7.3%	5.6%	
1991-2000	%	14.1%	39.4%	3.1%	24.2%	19.3%	169
	EB	5.2%	8.0%	2.1%	7.1%	6.0%	
Post 2000	%	14.8%	30.8%	2.3%	23.3%	28.8%	164
	EB	5.0%	7.0%	2.1%	6.7%	7.0%	
All Vintages	%	11.3%	30.6%	6.5%	33.6%	18.0%	1,258
	EB	1.6%	2.7%	1.5%	2.7%	2.1%	

About 23% of all homes have vault ceilings or roof deck ceilings. This percentage does not mean that 23% of the roof area is vault ceiling, but some amount of vault ceiling is present in about 23% of all homes. These ceiling are characterized by a single layer of insulation either in a framing cavity above the ceiling or as rigid insulation adhered to the roof surface prior to roofing. Table 35 and Table 36 show the percentage of homes with these types of ceilings.

Table 35: Percentage of Homes with Vault Ceilings by State

State	Homes with Vault Ceilings		
	%	EB	n
ID	11.9%	4.2%	185
MT	26.9%	5.8%	169
OR	21.7%	4.5%	314
WA	22.0%	2.9%	736
Region	20.9%	2.1%	1,404

Table 36: Percentage of Homes with Roof Deck Ceilings by State

State	Homes with Roof Deck Ceilings		
	%	EB	n
ID	1.9%	1.8%	185
MT	0.0%	0.0%	169
OR	1.2%	1.1%	314
WA	2.1%	0.9%	736
Region	1.6%	0.6%	1,404

Table 37 and Table 38 show the ceiling insulation levels in these homes. Like other components, about 30% of these have insulation levels between R16 and R20, and about 20% have R15 or less insulation. These areas were typically quite difficult for the surveyor to assess, and some substantial amount of insulation data could not be collected, introducing the possibility of a bias in these estimates.

Table 37: Distribution of Vault Ceiling Insulation Level

Insulation Level	Vault Ceiling Insulation Level		
	%	EB	n
R0	2.9%	1.3%	32
R1-R15	18.3%	4.3%	103
R16-R20	28.3%	6.9%	79
R21-R25	15.8%	6.3%	35
R26-R30	16.3%	5.1%	56
R31-R40	13.8%	4.0%	48
R41-R50	4.6%	2.3%	14
Total	100.0%	—	367

Table 38: Distribution of Roof Deck Insulation Levels

Insulation Level	Roof Deck Insulation Levels		
	%	EB	n
2 Inch	38.8%	0.0%	7
3.5 Inch	21.4%	0.0%	8
6 Inch	11.5%	0.0%	4
8 Inch	28.2%	0.0%	4
Total	100.0%	—	23

4.1.4. Doors and Windows

Surveyors were asked to assess the exterior doors, based on their construction characteristics. Table 39 shows the distribution of doors per homes. Approximately 45% are solid wood doors; the remainder is divided almost equally between metal insulated doors and wood doors with substantial amounts of glazing (at least half and sometimes more).

Table 39: Distribution of Door Types

Door Type	Doors		
	%	EB	n
Metal Insulated	28.9%	2.2%	735
Wood	45.6%	2.3%	1,311
Wood with Glazing	25.5%	2.0%	741
Total	100.0%	—	2,787

For window surveys, the surveyors class the windows by:

- Frame type (metal, wood/vinyl/fiberglass)
- Number of glazings
- Presence of Low-E coatings
- Presence of storm windows
- Presence of indications of gas-fill plugs

Ecotope assigned U-values to the windows based on the combination of the observed characteristics.

Table 40 shows the distribution of the primary windows as observed across the region. Table 41 shows the distribution of storm windows.

Table 40: Distribution of Window Types by State

Window Type		Windows					
		ID	MT	OR	WA	Region	n
Single Glazed Metal Frame	%	2.0%	0.2%	4.0%	3.8%	3.4%	110
	EB	1.5%	0.2%	1.7%	1.2%	0.8%	
Double Glazed Metal Frame	%	10.9%	4.1%	9.7%	17.0%	13.2%	239
	EB	3.8%	3.2%	3.0%	3.0%	1.9%	
Triple Glazed Metal Frame	%	0.3%	—	—	0.1%	0.1%	2
	EB	0.4%	—	—	0.1%	0.1%	
Single Glazed Wood/Vinyl/Fiberglass Frame	%	9.2%	10.0%	10.8%	6.9%	8.6%	238
	EB	4.1%	3.5%	4.3%	1.5%	1.6%	
Double Glazed Wood/Vinyl/Fiberglass Frame	%	77.6%	82.9%	73.5%	71.7%	73.7%	1,197
	EB	5.5%	5.1%	5.2%	3.4%	2.5%	
Triple Glazed Wood/Vinyl/Fiberglass Frame	%	—	2.7%	2.0%	0.4%	1.0%	13
	EB	—	2.8%	2.0%	0.3%	0.6%	
All Window Types	%	12.1%	6.5%	30.1%	51.3%	100.0%	1,799
	EB	0.8%	0.5%	1.4%	1.4%		

Table 41: Percentage of Homes with Storm Windows by State

State	Homes with Storm Windows		
	%	EB	n
ID	9.3%	3.8%	24
MT	12.4%	4.4%	30
OR	10.2%	4.3%	38
WA	11.2%	2.2%	119
Region	10.8%	1.8%	211

Table 42 shows the window area as a percentage of conditioned floor area across the region. This table has been divided into homes with and without basements. Basements tend to have less glazing and therefore lower window area ratios. The mean window-to-floor area ratio for homes without basements is 13%.

Table 42: Window Area to Floor Area Ratio by Presence of Basement

Basements	Ratio of Window to Floor Area		
	Mean	EB	n
Homes with Basements	0.113	0.004	515
Homes without Basements	0.131	0.002	872
All Homes	0.125	0.002	1,387

4.1.5. Overall Heat Loss

After establishing the insulation levels and characteristics of the home, Ecotope compiled the overall heat loss rate.[11] U-values were assigned to each building envelope component where insulation levels were established. Even a simple home has at least five components that must have both insulation level and areas established before a conductive heat loss can be calculated. About 12% of the surveys did not have complete information to calculate the UA.[12]

Table 43 shows the distribution of heat loss rate by state and by vintage. The figures presented here are based on a normalized UA, which was calculated by dividing the total heat loss rate by the conditioned floor area. Ecotope applied this normalization procedure in order to provide an index value that can be compared independent of home size. The UA summarized in Table 43 is the "conductive heat loss." This summary does not include air infiltration; those components of the homes were tested separately and are reported in the next section (see Section 4.2).[13]

[11] Overall heat loss rate is typically defined as the rate at which a building loses heat relative to a change in outside temperature. This rate is typically expressed as British thermal units per hour per degree Fahrenheit (Btu/hr-°F) and is the product of the overall conductivity (U-value) of each building component (e.g., wall) and the area of that component. The insulation levels summarized in the previous section provide a review of these components. The heat loss rate is typically summarized as the conductivity (U) times the area (A) and abbreviated as UA. As the UA is reduced, the overall heating requirements of the home are reduced.

[12] The development of UA from component information requires that both the area and the insulation level be assessed. In the cases where a UA could not be developed, some individual component was missing and could not be verified either from field notes or from other information about the house.

[13] The convective heat loss is typically referred to as "infiltration." This component of overall heat loss is a function of the tightness of the building shell. Although we measured the building tightness in about 30% of the buildings surveyed, we have not included that component here because it would require a complex and error-prone transformation of the limited dataset collected to extend to all the homes in the RBSA.

Table 43: Average Normalized Heat-Loss Rate by Vintage and State

Vintage		Heat Loss Rate (UA/conditioned sq.ft.) per Home					
		ID	MT	OR	WA	Region	n
Pre 1981	**Mean**	0.375	0.298	0.394	0.386	0.381	816
	EB	0.036	0.019	0.026	0.018	0.013	
1981–1990	**Mean**	0.250	0.275	0.301	0.283	0.284	116
	EB	0.026	0.072	0.028	0.027	0.018	
1991–2000	**Mean**	0.239	0.221	0.217	0.229	0.226	184
	EB	0.020	0.023	0.013	0.016	0.009	
Post 2000	**Mean**	0.220	0.232	0.211	0.193	0.206	169
	EB	0.017	0.020	0.019	0.009	0.008	
All Vintages	**Mean**	0.306	0.273	0.339	0.329	0.325	1,285
	EB	0.021	0.015	0.020	0.013	0.009	

As Table 43 shows, when these data were analyzed across the entire range of vintages, the UA per square foot has been cut in half over the last 30 years. The percentage decreases are most striking in Oregon and Washington, but even in Idaho and Montana the current insulation standards have smoothed the gaps between the states. It should be pointed out, however, that typical climate variation in these eastern climates are more severe and the impact of higher heat loss rates are more important than in the milder western climates of Washington and Oregon. In the most recent vintages, the heat loss rates in these climates remain 10–15% higher than in the western states.

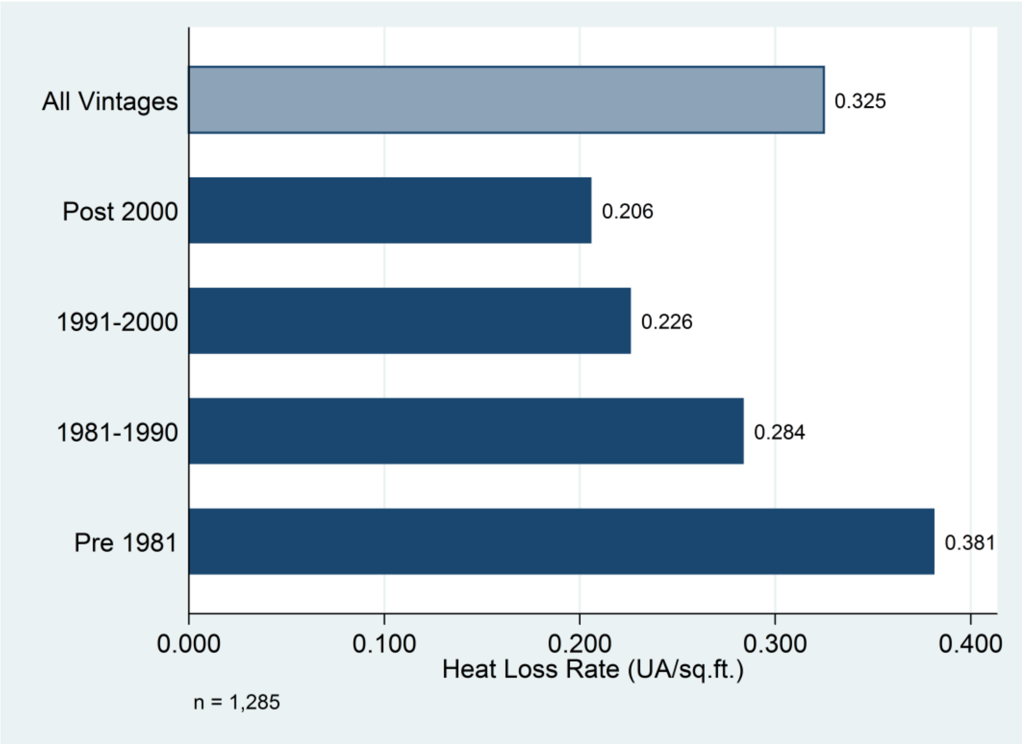
Table 44 shows the absolute heat loss rate (conductive only) distributed by vintage. The reduction in heat loss is about 50% from the earliest to the latest vintage bins. This compares with the reduction in normalized heat loss in Table 43 of almost twice that reduction. The difference between these two tables is essentially the increase in house size over the period from 1980 to 2010. It should be noted, however, that changes in energy codes and construction practices have more than compensated for the increase in house size in all of the states in the region as well as the region as a whole.

Table 44: Average Heat-Loss Rate by Vintage and State

Vintage		Heat Loss Rate (UA) per Home					
		ID	MT	OR	WA	Region	n
Pre 1981	Mean	686	583	693	696	686	817
	EB	64	48	63	30	27	
1981–1990	Mean	515	592	588	584	578	116
	EB	89	217	110	90	61	
1991–2000	Mean	481	556	478	485	488	184
	EB	70	83	60	51	33	
Post 2000	Mean	501	513	402	431	445	169
	EB	47	68	53	34	24	
All Vintages	Mean	589	568	617	620	611	1,285
	EB	39	41	46	24	19	

Figure 5 shows the declining heat loss rate over the 30 years in which codes were implemented in the region. This graph shows the regional average, but Washington and Oregon dominate this calculation because they are much more populous and thus have higher statistical weights in the regional summaries.

Figure 5: Average Heat Loss Rate by Vintage



4.2. Air Leakage

The final step in evaluating the heat-loss rate of the home envelope included the air tightness or air infiltration of the home. This component of the evaluation was implemented on a limited sample of homes (see Section 2.1.4), designed to be representative by state, across the region, but not large enough to allow characterization of other geographic or utility subgroups. Thus, inference of infiltration rates across the homes not in the air leakage sample is complex and was not attempted in this analysis. Reported here are the results of the tests on the sample where a blower door tightness test was done. Appendix C includes a description of the blower door testing procedure.

Table 45 summarizes the results of the blower door test using the standard measure of tightness—i.e., cubic feet per minute (CFM) of air flow through the home's enclosure to the outside when the differential pressure to the outside is raised to 50 Pascals (Pa). The summary provides the air flow in absolute terms.

Table 45: Average Blower Door Air Flow by State

State	Blower Door Air Flow (CFM @ 50 Pa)		
	Mean	EB	n
ID	1,902	209	64
MT	2,117	287	55
OR	2,829	212	120
WA	2,721	173	189
Region	2,605	112	428

These data were then converted to total air changes per hour at the 50 Pa reference pressure (ACH50) from CFM at 50 Pascals by taking into consideration the volume of air in the house. Table 46 and Figure 6 show the average blower door air tightness across the states and within the region, through all vintages of the sample. This value is close to 10 ACH50, but the homes in Idaho and Montana are noticeably tighter on average. This difference is partly because those homes tend to be newer, but also because with the addition of a basement as part of the conditioned area, the envelope associated with the basement itself is actually not very leaky. And as a result, the normalized leakage rates expressed as air changes per hour (ACH) go down because of the extra volume from the conditioned basement.

Table 46: Average Blower Door Air Tightness by State

State	Blower Door Air Tightness (ACH50)		
	Mean	EB	n
ID	7.37	0.94	64
MT	8.31	1.46	55
OR	11.65	0.80	120
WA	10.41	0.62	189
Region	10.25	0.42	428

Figure 6: Average Blower Door Air Tightness by State (ACH50)

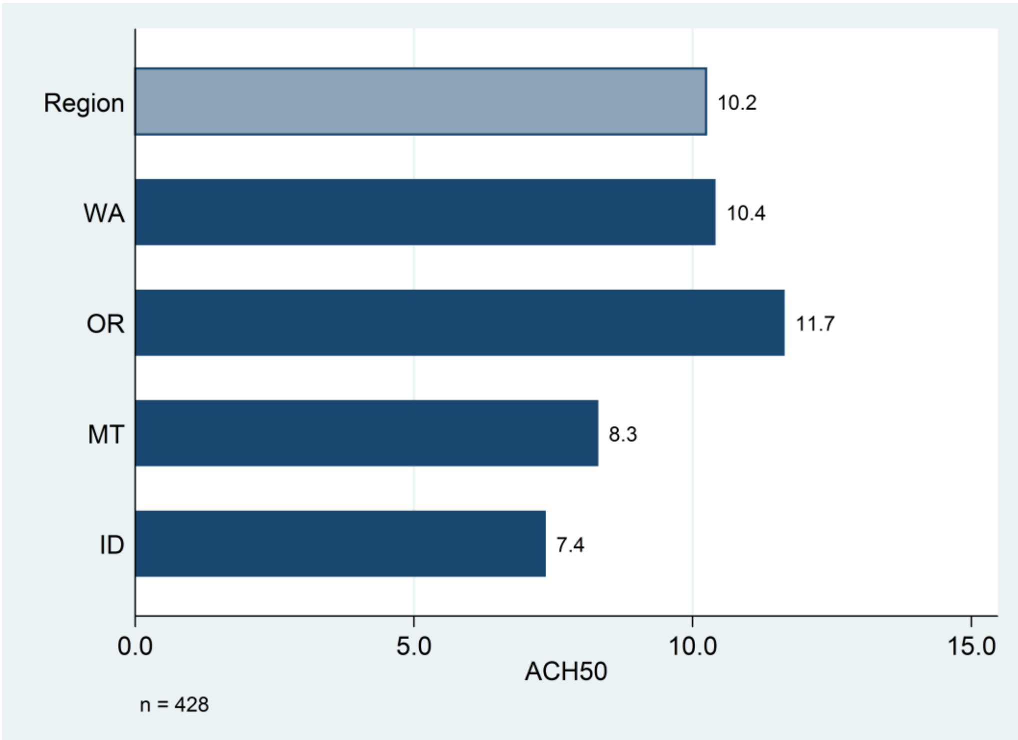


Table 47 shows the blower door results by vintage. This distribution illustrates how important home vintage is across all states and home types. The air infiltration rate (ACH50) goes down uniformly as we move from older homes to newer homes. Although the air infiltration rate also has some impact by state, for the most part this pattern is preserved in all four states, ending with an overall air tightness of approximately half the initial value seen in the pre-1951 homes.

Table 47: Average Blower Door Air Tightness by Home Vintage

Vintage	Blower Door Air Tightness (ACH50)		
	Mean	EB	n
Pre 1951	13.74	1.01	102
1951-1960	11.56	1.47	36
1961-1970	10.60	0.89	50
1971-1980	10.08	1.15	72
1981-1985	7.56	1.19	18
1986-1990	8.14	1.33	18
1991-1995	8.26	0.71	32
1996-2000	7.52	1.06	32
2001-2005	7.50	0.91	40
2006-2010	6.33	1.76	20
Post 2010	6.62	0.00	1
All Vintages	10.25	0.42	421

Table 48 and Table 49 show the effective natural infiltration rate inferred from this level of envelope tightness. Overall, this level of convective heat loss suggests that infiltration accounts for about 25% of the overall heat loss of the average home. To use the test data (CFM at 50 Pa) for assessing air infiltration rates in normal conditions (typically less than 4 Pa of differential pressure), two analytical approaches are presented (see Table 48 and Table 49). In effect, Table 46 and Table 48 show that the ACH at 50 Pa in Washington is 10.41, which converts for this sample into an ACH at normal conditions of 0.52. This rate means that every hour, approximately half of the conditioned air in the home is replaced by unconditioned air from outside:

- The ACH50 divided by 20 used to calculate the values in Table 48 is a standard short-hand estimating procedure to convert the air tightness measurement into an estimate of infiltration when the house is not pressurized as it is during the test. The technique was verified with tracer gas in early work sponsored by the BPA (Palmiter and Brown, 1989).
- Table 49 uses the current procedure developed for and published in 1993 (ASHRAE Standard 136-93). This procedure used weather conditions to customize the estimate. This standard was recently revised as part of the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Standard 62.2-2010 (Addendum N).[14] Table 49 shows the results of applying this calculation procedure to the air tightness test results.

[14] The ASHRAE Standard 62.2 is a consensus standard for evaluating and designing low-rise residential ventilation systems. The Addendum N calculation procedure was approved for publication in January 2012.

Table 48: Average Infiltration Rate by State, ACH50 Divided by 20

State	Infiltration Rate (ACH50/20)		
	Mean	EB	n
ID	0.368	0.047	64
MT	0.416	0.073	55
OR	0.583	0.040	120
WA	0.521	0.031	189
Region	0.512	0.021	428

Table 49: Average Infiltration Rate by State, ASHRAE 62.2

State	Infiltration Rate (ACH Natural, ASHRAE 62.2)		
	Mean	EB	n
ID	0.362	0.048	64
MT	0.489	0.106	55
OR	0.526	0.045	120
WA	0.466	0.033	189
Region	0.473	0.023	428

5. HVAC Systems

Surveyors reviewed HVAC systems during each home survey. This review was designed to assess all of the available heating and cooling equipment as well as ducting and other distribution systems in the home. The surveyors reviewed all HVAC equipment, regardless of which equipment was identified by the homeowner as primary heating equipment. To make this determination, the surveyors first interviewed the occupants and asked which heating system they use most. The surveyors then reviewed the systems and, in a few cases, modified that response to an alternative system. This adjustment was typically made when wood heat and electric heat were present in the same home. When the electric system was controlled by thermostat and in use, the primary system was defined as electric. The surveyor made this judgment onsite, and that judgment was used in the report summaries.

About one of the several days of training for surveyors on the overall RBSA survey protocol was dedicated to assessment of home HVAC systems. HVAC systems covered in the training included heating and cooling equipment (central and otherwise), water heating systems, ducts, and ventilation systems.

The surveyors were instructed to spend most time on the identification of primary central system data. Surveyors were asked to identify the type of system, system age, and system capacity (from nameplate data). They were also asked to identify the primary heating and cooling system in the home from a combination of homeowner interview and evidence of system usage. Central system air handler motor type was tallied because there are efficiency implications for the different types. The motor types include: permanent split capacitors (PSC), found on older systems; and electronically commutated motors (ECM), found on many newer systems.

For homes with multiple HVAC systems, the secondary system was also characterized. Examples of secondary systems include plug-in 120V heaters, woodstoves, and portable air conditioning units. In a small number of cases, what would normally be considered primary systems were not in frequent use (e.g., oil furnaces) and the secondary system was actually coded and summarized as “primary.”

Surveyors recorded the age and type of equipment. Ecotope categorized combustion appliances by type of venting system (as well as nameplate output and input) in order to estimate efficiency. Surveyors recorded condenser make, model, and size for heat pumps and central air conditioning (AC) equipment. Analysts used these data to estimate Seasonal Energy Efficiency Ratio (SEER) and heating seasonal performance factor (HSPF).

In most cases, surveyors collected more limited information on secondary systems. They collected make and model information on portable AC units. Zonal electric heat was characterized only by number of heaters.

Surveyors divided combustion stoves into rated and non-rated categories; rated stoves have tightly fitting doors and dampered combustion air. Generally, pellet stoves were considered rated, but open hearth or fireplaces with glass doors were considered non-rated equipment.

5.1. Heating Systems

Table 50 categorizes the primary heating equipment[15] including forced air furnaces, electric and other zonal heating systems (mostly gas wall heaters), and ducted air and ground-source heat pumps. Ductless heat pumps (DHPs) are summarized separately from central ducted heat pumps. The zonal systems are divided between electric baseboards/wall heaters and combustion stoves and heaters located in a single (usually central) zone. Table 51 shows the distribution of fuel choice in the primary systems in each state. The primary heating system was typically identified by the participant during the interview phase of the onsite survey. Figure 7 and Figure 8 show the distribution of fuel choice in primary systems for the region and by state, respectively.

Approximately 67.5% of the primary heating systems are ducted forced air systems, including forced air furnaces and conventional (air-source), ground source, and dual-fuel heat pumps. About 30% of these forced air systems are electrically heated, either with a heat pump or an electric furnace. The remaining 70% of the forced air systems are mostly gas fueled with a small percentage of propane and oil.

Most of the remaining third of primary systems are zonal systems about equally divided between electric zonal heating and combustion heating stoves. These stoves are typically located in the central part of the home with a supplemental system also installed. Wood is the fuel used in 60% of the combustion heating stoves. This group also includes fireplaces, fireplace inserts, and other zonal combustion devices that are typically located without distribution systems in the central zone of the home. Overall, 85% of primary heating systems are electric or natural gas (see Figure 7). About half of the remaining 17% is wood. The remainder is divided among oil, pellets, and propane.

Table 50: Distribution of Primary Heating Systems

Heating System Type	Primary Heating Systems		
	%	EB	n
Forced Air Furnace	54.1%	2.7%	702
Ductless Heat Pump	1.4%	0.6%	25
Baseboard Heater	12.3%	1.7%	209
Boiler	5.1%	1.0%	83
Fireplace	0.1%	0.1%	2
Ground Source Heat Pump	0.8%	0.4%	14
Air Source Heat Pump	11.4%	1.8%	166
Dual Fuel Heat Pump	1.2%	0.6%	17
Heating Stove	12.8%	1.8%	201
Plug-In Heater	1.0%	0.5%	14
Total	100.0%	—	1,433

[15] Of the 1,404 homes in the sample, 46 had two primary heating systems, usually heating separate living zones.

Table 51: Distribution of Fuel Choice for Primary Heating Systems by State

Fuel Type		Fuel Choice (Primary System)					
		ID	MT	OR	WA	Region	N
Electric	%	28.2%	13.6%	34.0%	38.8%	34.2%	540
	EB	5.9%	4.3%	5.2%	3.6%	2.5%	
Gas	%	58.4%	64.5%	47.4%	46.2%	49.4%	639
	EB	6.5%	5.8%	5.4%	3.8%	2.7%	
Oil	%	1.6%	0.8%	5.4%	3.9%	3.8%	59
	EB	1.4%	0.9%	2.5%	1.4%	1.0%	
Pellets	%	1.2%	0.4%	2.3%	1.5%	1.6%	23
	EB	1.3%	0.6%	1.6%	1.1%	0.8%	
Propane	%	5.4%	7.8%	1.3%	2.1%	2.7%	44
	EB	2.9%	3.5%	1.3%	1.0%	0.8%	
Wood	%	5.2%	12.9%	9.7%	7.6%	8.3%	128
	EB	2.8%	3.9%	3.2%	2.1%	1.5%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,433

Figure 7: Distribution of Fuel Choice for Primary Heating System

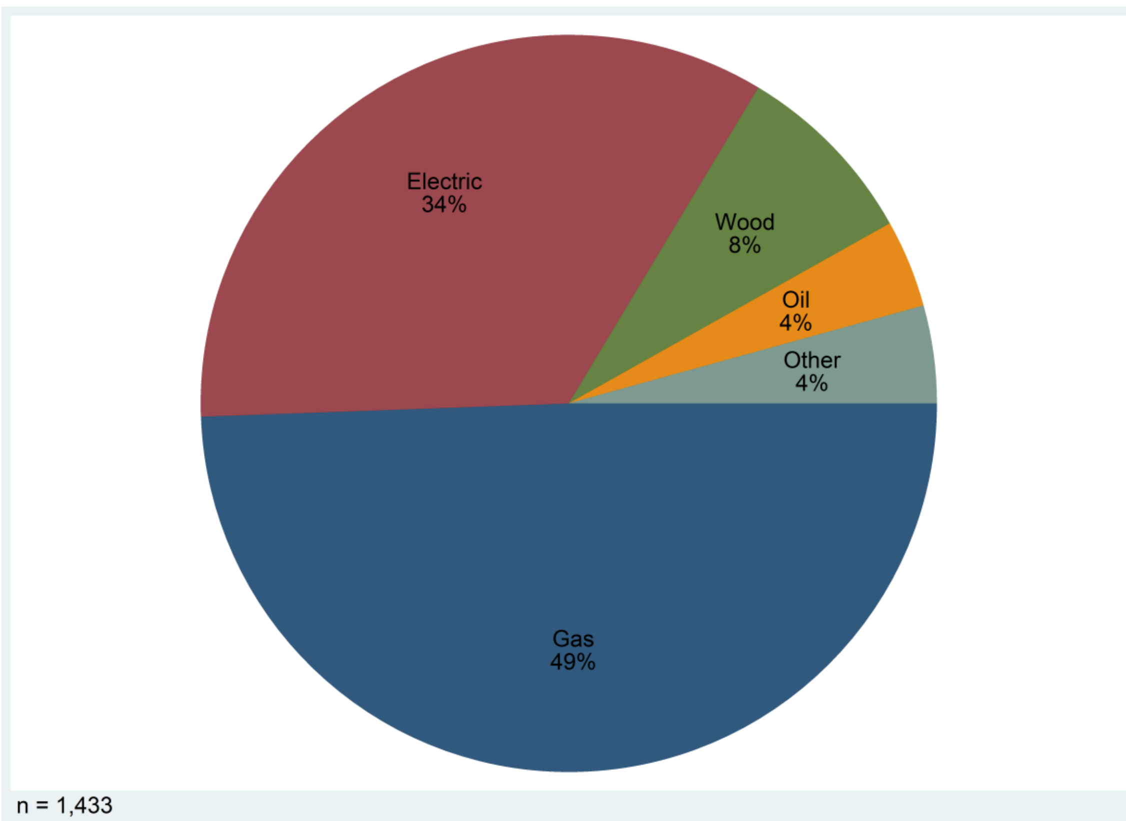


Figure 8: Distribution of Fuel Choice for Primary Heating Systems by State

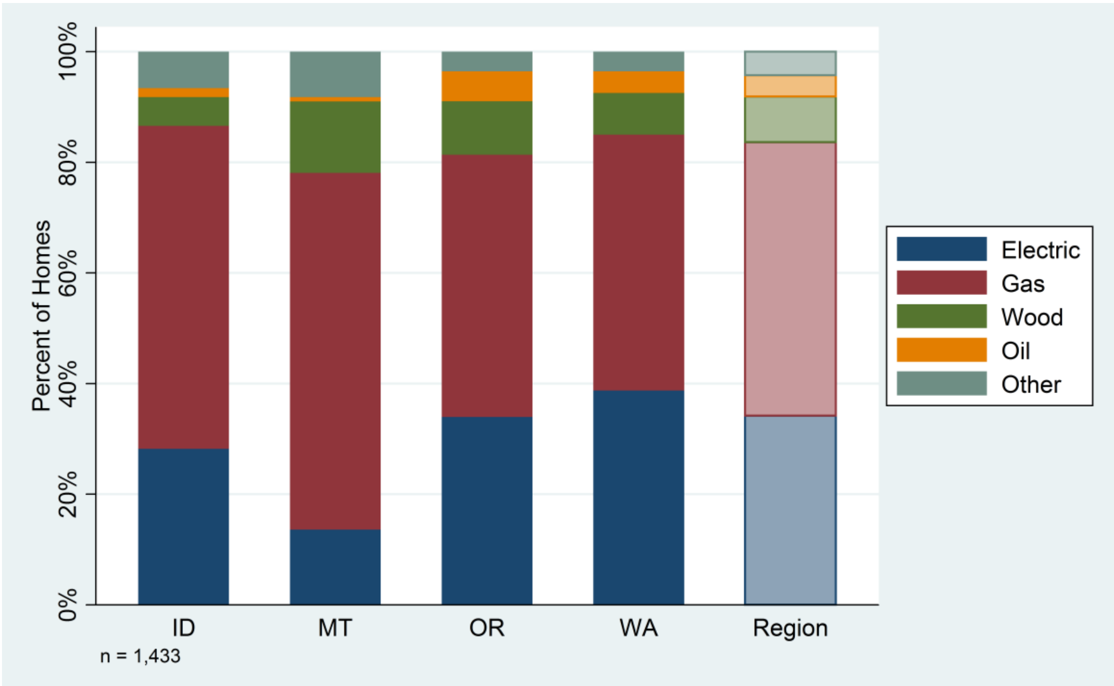


Table 52 shows the distribution of secondary heating systems by type. Secondary heating systems include all systems that were not designated as primary. Homes can have several secondary heating systems. The surveyors did not collect information on the relative importance of the secondary systems. Table 53 shows the distribution of fuel choice for the secondary systems. These summaries treat each system as a separate data point; in most cases, these systems represent a small contribution to the overall space heat needs of the home.

Table 52: Distribution of Secondary Heating Systems by System Type

Heating System Type	Secondary Heating Systems		
	%	EB	n
Forced Air Furnace	2.3%	0.9%	28
Baseboard Heater	21.8%	2.5%	275
Boiler	1.0%	0.8%	7
Fireplace	8.9%	2.1%	88
Heat Pump	1.2%	0.5%	22
Dual Fuel Heat Pump	0.1%	0.2%	1
Heating Stove	47.2%	3.2%	531
Plug-In Heater	17.5%	2.2%	195
Total	100.0%	—	1,147

Table 53: Distribution of Fuel Choice by Secondary Heating System and State

Fuel Type		Fuel Choice (Secondary Systems)					
		ID	MT	OR	WA	Region	n
Electric	%	42.1%	31.3%	46.8%	38.4%	41.3%	496
	EB	7.0%	8.8%	5.8%	3.9%	3.0%	
Gas	%	19.7%	23.4%	19.3%	15.3%	17.4%	174
	EB	7.1%	9.6%	5.7%	3.3%	2.7%	
Oil	%	—	—	0.1%	—	0.0%	1
	EB	—	—	0.2%	—	0.1%	
Pellets	%	2.8%	—	2.4%	2.3%	2.3%	27
	EB	2.5%	—	1.7%	1.6%	1.0%	
Propane	%	4.9%	16.5%	5.6%	7.5%	6.9%	77
	EB	3.2%	8.1%	3.1%	2.8%	1.9%	
Wood	%	29.5%	28.7%	25.8%	36.4%	31.9%	369
	EB	6.8%	9.7%	5.0%	4.4%	3.0%	
Other	%	1.1%	—	—	0.1%	0.2%	3
	EB	1.8%	—	—	0.2%	0.2%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,147

Electric systems are the most commonly used secondary system, accounting for more than 40% of all the secondary use. These systems are largely zonal systems such as permanently installed baseboards, wall heaters, or portable "plug-in" heaters. Wood is the other major fuel used by secondary systems, accounting for about 30% of the systems. These are largely wood stoves, although some fireplaces are also used.

In general, Table 52 and Table 53 show a distribution of secondary heat that is substantially focused on zonal heating as secondary fuel sources that supplement primary central air distribution systems.

Table 54, Table 55, and Table 56 break out the distribution of fuel choices for the three principal heating systems in this sample with the most diverse fuel selection: forced air furnaces, boilers, and combustion heating stoves. The three tables below include both the primary and secondary systems. The tables illustrate the dominance of particular fuel types in these separate systems. More than 80% of the forced air furnaces are gas fired, while more than 60% of the combustion stoves are wood or pellet fired.

Table 54: Distribution of Fuel Choice, Forced Air Furnaces

Fuel Type	Fuel Choice (Forced Air Furnaces)		
	%	EB	n
Electric	9.8%	2.1%	85
Gas	80.4%	2.8%	561
Oil	6.7%	1.9%	55
Propane	3.2%	1.2%	29
Total	100.0%	—	730

Table 55: Distribution of Fuel Choice, Boilers

Fuel Type	Fuel Choice (Boilers)		
	%	EB	n
Electric	18.5%	10.2%	13
Gas	77.1%	10.2%	71
Oil	2.1%	2.0%	3
Propane	2.2%	2.2%	3
Total	100.0%	—	90

Table 56: Distribution of Fuel Choice, Combustion Heating Stoves

Fuel Type	Fuel Choice (Combustion Stoves)		
	%	EB	n
Gas	28.4%	3.8%	181
Oil	0.1%	0.2%	2
Pellets	6.7%	2.3%	50
Propane	11.7%	2.9%	82
Wood	52.8%	4.0%	415
Other	0.3%	0.3%	3
Total	100.0%	—	733

5.2. Heating System Efficiencies

Surveyors were asked to record make, model, and nameplate information for all major heating and cooling equipment. The systems where nameplate information was reliably gathered were limited to central systems such as gas furnaces and heat pumps. The nameplate information was not always available or was improperly transcribed, and about 25% of the heat pumps and furnaces could not be assigned an efficiency rating. Efficiency information was collected from standard reference sources provided by the manufacturer or rating agencies such as Air-Conditioning, Heating, and Refrigeration Institute (AHRI) or Gas Appliance Manufacturers Association (GAMA).

Table 57 shows the distribution of gas furnace efficiency by vintage and state. Overall changes in the combustion efficiency of basic furnace models has driven significant increases in average efficiencies as newer equipment has been introduced into the market.

Federal standards for gas furnaces have not changed in the period between 1990 and 2011. What has changed, however, is the presence of increasing market share of high efficiency (90% plus) condensing gas furnaces and, to some extent, increasing efficiencies in those condensing furnaces. These trends have increased the average efficiency of gas furnaces by almost 10% between 1990 and 2011.

Table 57 also shows that in recent years, the Oregon and Montana markets are choosing higher-efficiency models beyond the regional norm. This variance may be the result of the utility efforts in those states. The average Annual Fuel Utilization Efficiency (AFUE) in the post 2006 vintages in Oregon indicate that newer furnaces in Oregon are almost exclusively condensing type, which is not the case in Washington as can be seen by the average efficiency of .84.

Table 57: Average Gas Furnace Efficiency (AFUE) by Equipment Vintage and State

Vintage		Efficiency (AFUE)					
		ID	MT	OR	WA	Region	n
Pre 1990	**%**	77.2%	82.9%	79.2%	80.8%	80.2%	58
	EB	5.2%	2.8%	0.7%	1.5%	1.2%	
1990-1999	**%**	84.0%	86.7%	81.3%	84.8%	83.5%	154
	EB	2.7%	2.4%	1.5%	1.5%	1.0%	
2000-2005	**%**	82.2%	83.0%	84.7%	82.5%	83.1%	109
	EB	2.4%	3.2%	2.3%	1.1%	1.0%	
Post 2006	**%**	87.0%	88.9%	92.7%	86.1%	88.0%	129
	EB	2.3%	3.5%	2.2%	1.7%	1.2%	
All Vintages	**%**	83.8%	85.1%	84.4%	84.1%	84.2%	450
	EB	1.5%	1.5%	1.4%	0.9%	0.6%	

Table 58 shows the distribution of gas furnaces by efficiency vintage. The efficiency bins correspond to federal efficiency standards maintained over the last 30 years. The furnaces with AFUE below 80% are generally older technology largely abandoned with the development of modern efficiency standards. The 2013 federal standards will be increased to an AFUE of 90% or better. As shown in the table about a third of the region's furnace stock already meets or exceeds this standard.

Table 58: Distribution of Gas Furnace Efficiency (AFUE) by State

Furnace Efficiency		Percentage of Homes					
		ID	MT	OR	WA	Region	n
<80%	**%**	11.3%	9.8%	9.2%	9.3%	9.6%	51
	EB	6.4%	6.1%	5.8%	3.8%	2.7%	
80–89%	**%**	56.5%	45.6%	53.8%	58.3%	55.7%	267
	EB	9.9%	10.5%	10.1%	6.6%	4.6%	
90–94%	**%**	22.5%	34.9%	26.8%	24.9%	25.8%	114
	EB	8.1%	10.1%	9.2%	6.3%	4.3%	
>94%	**%**	9.8%	9.8%	10.2%	7.5%	8.8%	44
	EB	6.0%	6.1%	6.0%	3.1%	2.5%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	476

Table 59 shows the average efficiency for air source heat pumps. Central, ducted air-source heat pumps are rated by HSPF, which includes the underlying efficiency of the compressor and coils and includes allowances for defrost penalty and cycling losses. Heat pumps show the same trend as gas furnaces, with an increasing average HSPF over the period from 1990 to 2006. In 2006, the federal minimum HSPF increased from 6.8 to 7.7. However, the average HSPF observed in the field after 2006 (8.6), is greater than 7.7, indicating some consumers are buying heat pumps that have considerably better ratings than the federal minimum.

Table 59 includes about 68% of all heat pumps observed in the survey. Of the remaining 32%, about 4% were manufactured before 1990 and an additional 8% were ground source heat pumps. The remaining 20% of the heat pumps observed did not have useable nameplate information, and so no efficiency rating could be generated.

Table 59: Average Air Source Heat Pump Efficiency (HSPF) by Equipment Vintage

Vintage*	Efficiency (HSPF)		
	Mean	EB	n
1990–1999	7.19	0.083	38
2000–2005	7.54	0.148	44
Post 2006	8.56	0.129	72
All Vintages	8.00	0.135	154

*Heat Pump HSPF was not included if units predated 1990.

Table 60 shows the distribution of heat pumps by heating efficiency bin. Federal standards mandated that heat pumps manufactured after 2005 deliver a minimum of 7.7 HSPF. Prior to that, HSPF was mandated at 6.8 beginning in the late 1980s. Beginning in 2015 the federal standard will be increased to HSPF 8.2. Table 60 illustrates a striking distribution in that the 44% of the heat pumps in this survey already meet the federal standards for 2015.

Table 60: Distribution of Air Source Heat Pump Efficiency (HSPF) by State

HSPF		Percentage of Homes					
		ID	MT	OR	WA	Region	n
6.8–7.6	**%**	20.5%	—	34.2%	35.1%	34.0%	60
	EB	29.2%	—	13.6%	9.2%	7.5%	
7.7–8.2	**%**	19.3%	100.0%	31.0%	15.4%	21.9%	36
	EB	22.4%	0.0%	14.0%	6.4%	6.9%	
8.3–8.9	**%**	12.9%	—	17.6%	17.6%	17.3%	36
	EB	15.4%	—	9.7%	6.8%	5.4%	
9.0+	**%**	47.3%	—	17.2%	31.9%	26.8%	32
	EB	33.0%	—	10.9%	11.2%	8.1%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	164

5.3. Cooling Systems and Efficiencies

The surveyors were instructed to gather all available information on cooling equipment while onsite. In some cases, they asked for information about systems that had been stored for the winter, as would be expected for window air conditioners (for example). The surveyors could not confirm this self-reported data, especially during the surveys done after October 1, 2011 (about half the sample). Table 61 shows the percentage of cooling equipment by cooling zone and state across the region. The table references cooling zones as defined by the Council, which describe increasing cooling loads in various micro climates throughout the region. The data in Table 61 are based on the presence of any cooling equipment; in general, this represents about 40% of all the homes. In cooling zone 3, the saturation of cooling equipment is more than twice that amount, reflecting the higher cooling loads in those locations.

Table 61: Percentage of Homes with Cooling Equipment by Cooling Zone and State

Cooling Zone		Cooling Equipment per Home (All Systems)					
		ID	MT	OR	WA	Region	n
Cooling Zone 1	%	29.7%	18.6%	53.1%	24.2%	31.6%	1,025
	EB	14.3%	5.7%	7.2%	3.3%	2.9%	
Cooling Zone 2	%	47.5%	31.6%	41.9%	72.0%	51.6%	261
	EB	10.3%	13.7%	10.2%	12.9%	6.4%	
Cooling Zone 3	%	87.5%	—	97.3%	74.2%	85.4%	118
	EB	6.6%	—	4.6%	21.0%	7.2%	
All Cooling Zones	%	64.1%	21.5%	51.2%	34.4%	42.3%	1,404
	EB	6.2%	5.4%	5.9%	3.4%	2.6%	

Table 62 shows the distribution of cooling equipment types across all primary cooling systems observed. In this table, homes with only one cooling system are included even if the system is a window AC unit or another single-zone system. Packaged Terminal Air Conditioner (PTAC) units are single-zone, wall-mounted AC units.[16]

[16] In some homes, portable cooling equipment is used. This equipment is usually a small AC or evaporative cooler mounted on wheels and designed to be moved from room to room. The systems included in Table 62 are designed to be mounted in one place. Window AC units are typically installed in a single location and removed after the cooling season.

Table 62: Distribution of Primary Cooling Systems in Cooling Zones by Type

Cooling System Type		Percentage of Primary Cooling Systems				
		Cooling Zone 1	Cooling Zone 2	Cooling Zone 3	All Cooling Zones	n
PTAC	%	4.1%	9.9%	3.5%	5.7%	31
	EB	2.5%	4.7%	2.9%	2.0%	
Central AC	%	30.4%	48.9%	48.1%	39.9%	184
	EB	5.6%	8.7%	8.1%	4.1%	
Evaporative Cooler	%	1.0%	0.2%	5.5%	1.7%	11
	EB	0.9%	0.4%	3.6%	0.9%	
Ground Source Heat Pump	%	1.4%	2.4%	1.5%	1.7%	14
	EB	0.8%	2.7%	1.8%	1.0%	
Air Source Heat Pump	%	40.0%	18.4%	31.5%	31.6%	206
	EB	5.5%	6.9%	8.2%	3.8%	
Ductless Heat Pump	%	6.9%	1.1%	—	3.6%	26
	EB	2.7%	1.0%	—	1.3%	
Window AC	%	16.2%	19.0%	10.0%	15.7%	93
	EB	4.2%	6.8%	5.4%	3.1%	
Total		100.0%	100.0%	100.0%	100.0%	565

Table 63 and Table 64 summarize the observed equipment efficiency for both central AC and heat pump cooling equipment. The SEER efficiencies are shown by vintage. Unlike the heating trends shown in Table 57, the distribution of SEER does not change dramatically by vintage until the increase in federal efficiency standards in the post-2006 period.

The 2006 federal standard set a minimum SEER of 13.0, and it appears from Table 63 that most central AC equipment was very close to the minimum standard. In contrast, Table 64 shows the SEER efficiencies of the split system heat pumps. In this technology, the SEER ratings show a clear trend over the last 20 years with a considerably larger jump in the post-2006 vintage. This increase in efficiency could be explained partly by the advent of the stricter federal standard. In the case of air source heat pumps, the extra efficiency observed in HSPF (Table 59) resulted in an increased cooling efficiency (Table 63). Note that Table 63 does not include SEER ratings for pre-1990 AC systems. Lookup model numbers for the few cases in this vintage range were not available.

Table 63: Average Cooling Efficiency (SEER) for Central AC Systems by Vintage

Vintage*	Efficiency (SEER)		
	Mean	EB	n
1990-1999	10.3	0.169	39
2000-2005	10.9	0.330	58
Post 2006	13.4	0.324	32
All Vintages	11.1	0.241	129

*Central AC SEER was not determined if units predated 1990.

Table 64: Average Cooling Efficiency (SEER) for Central Air Source Heat Pump Systems by Vintage

Vintage*	Efficiency (SEER)		
	Mean	EB	n
1990-1999	10.7	0.177	38
2000-2005	11.6	0.435	46
Post 2006	14.6	0.361	81
All Vintages	13.0	0.373	165

*Heat Pump SEER was not determined if units predated 1990.

5.4. Portable Cooling Devices

The surveyors conducted a census of portable cooling devices. The survey protocol defined this appliance as cooling equipment that is on wheels and can be moved around from place to place in the home. Table 65 shows that the regional saturation of this equipment is about 12%.

Table 65: Average Number of Portable Cooling Devices per Home by State

State	Number of Portable Cooling Devices per Home		
	Mean	EB	n
ID	0.086	0.037	179
MT	0.096	0.042	125
OR	0.149	0.045	274
WA	0.119	0.033	522
Region	0.122	0.022	1,100

6. Duct Systems

Surveyors reviewed all duct systems and collected minimal information about duct types and location. Surveyors used a detailed protocol to perform duct leakage tests on a percentage of the duct distribution systems. This section summarizes findings from the basic duct system surveys as well as the detailed duct leakage tests.

In the basic survey, ducts were characterized in terms of the percentage of supply or return ducts located in unconditioned space. This characterization permits a rough evaluation of the potential for energy savings through duct retrofits.

More detailed duct information was collected for sites that received a duct leakage and system airflow tests. Surveyors were given a one-day classroom training followed by a one-day field training on use of industry standard leakage and airflow measurement techniques. Surveyors were also asked to report the R-value and surface area of ducts located in unheated buffer spaces such as attics, garages, and crawlspaces as part of the field survey.

Surveyors measured duct leakage to outside, when possible, at standard test pressures of 25 and 50 Pa. A two-point (i.e., testing at two pressures) test allows for onsite error checking and also allows a duct leakage flow equation to be calculated so that leakage can be estimated at other leak pressures, if desired, such as furnace operating conditions. Supply and return static pressures at normal operating conditions were also measured to allow for normalization of leakage to what is called the half-plenum pressure (an approach most notably used in ASHRAE Standard 152). The highest static pressure in a duct system is at the plenums, and lowest static pressure is found where the conditioned air enters a room. The half-plenum pressure is a mathematical construct that purports to represent the average static pressure in the duct system. Because duct leakage is the result of this static pressure, this procedure evaluates the effective leakage rate relative to the actual furnace system.

Approximately 258 surveys included a duct leakage test. In general, this is a complex test that can be easily compromised by high leakage rates or difficulty in measuring furnace fan flows or outdoor wind speeds. Summaries were developed for partial tests, but only about 63% of the duct leakage tests and furnace fan flow tests could be used in combination.

6.1. Duct Characteristics

Table 66 shows the percentage of homes with ducts across each state. Ducts are present in nearly 75% of the surveyed homes.

Table 66: Percentage of Homes with Duct Systems by State

State	Homes with Ducts		
	%	EB	n
ID	75.6%	5.5%	185
MT	57.1%	6.6%	169
OR	77.4%	4.5%	309
WA	72.5%	3.5%	737
Region	73.2%	2.3%	1,400

Table 67 shows the percentage of ducts per home in unconditioned space. Unconditioned spaces are zones such as crawlspaces, attics, and garages. If ducts leak to or from these zones, energy waste occurs. This percentage was estimated by the surveyor and divided into three bins. Nearly 40% of all the ducts are completely in conditioned space, and an almost equal percentage are completely in unconditioned space, with the balance of the systems being somewhere in between. Table 68 shows the insulation levels on these ducts, divided into major insulation bins. Table 68 does not include ducts that are located completely in heated space. Duct insulation appears to be dominated by insulation levels less than R5. This finding indicates that there is some potential for duct insulation retrofits.

Table 67: Distribution of Ducts per Home in Unconditioned Space by State

Percentage of Ducts in Unconditioned Space		Homes with Ducts					
		ID	MT	OR	WA	Region	n
1-50%	**%**	8.2%	7.3%	13.7%	17.7%	14.6%	147
	EB	4.2%	4.5%	4.5%	3.4%	2.3%	
51-99%	**%**	4.1%	1.3%	11.4%	11.7%	10.0%	75
	EB	3.1%	2.1%	4.4%	3.3%	2.2%	
100%	**%**	35.0%	8.2%	56.9%	29.7%	37.6%	341
	EB	7.4%	4.2%	6.8%	4.0%	3.1%	
None	**%**	52.7%	83.3%	18.0%	40.9%	37.8%	420
	EB	7.7%	6.3%	5.4%	4.4%	3.0%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	983

Table 68: Distribution of Duct Insulation Levels

Duct Insulation Level	Homes with Ducts		
	%	EB	n
None	37.7%	3.1%	395
R1-R4	20.1%	2.4%	203
R5-R7	10.6%	2.0%	100
R8-R10	14.8%	2.4%	134
R10+	16.8%	2.6%	142
Total	100.0%	—	974

6.2. Duct Leakage Tests

A duct tightness test was completed in approximately 20% of ducted homes in the single-family sample. This subset of homes included all ducted sites that are now being submetered for various end-uses. The duct leakage tests reflect duct leakage to outside (as opposed to total duct leakage). Appendix C includes a description of the air leakage testing procedure.

Table 69Table 69 and Table 70 show the results of the duct leakage tests. Table 69 presents average total flow results reported in CFM, and Table 70 presents average normalized flow based on total square footage of the home. These tests were checked for accuracy based on the total set of data available so the numbers of tests in each summary can vary slightly.

For all homes that received a duct tightness test, a furnace air handler flow was also measured. Surveyors used Energy Conservatory TrueFlow® Air Handler flow meters to measure system airflow so that the duct leakage figures could be normalized by system flow.

Table 70 shows the values measured in the field. These values suggest that total duct leakage rates in this sample average about twice the maximum leakage allowed by the Performance Tested Comfort Systems (PTCS) duct sealing program.[17]

Table 69: Average Duct Leakage Total Flow by State

State	Duct Leakage Total Flow (CFM @ 50 Pa)		
	Mean	EB	n
ID	273	50	29
MT	382	158	14
OR	377	56	62
WA	402	79	90
Region	377	45	195

Table 70: Average Duct Leakage Total Flow (Normalized by House Area) by State

State	Duct Leakage Total Flow (CFM/sq.ft. @ 50 Pa)		
	Mean	EB	n
ID	0.152	0.034	29
MT	0.175	0.066	14
OR	0.228	0.036	62
WA	0.210	0.050	90
Region	0.207	0.028	195

[17] http://www.bpa.gov/reshvac/DuctSealing_Specifications_2009.pdf

Table 71 and Table 72 show the average leakage fraction of the ducts as a function of the furnace fan's total flow. This calculation is based on the duct leakage measurement in combination with a measurement of the actual furnace fan flow under operating conditions. The leakage fraction is the percentage of conditioned air that is either not making it into the home directly (supply leakage fraction) or that is coming from outside of the home (return leakage fraction) during the central heating/cooling system's operation.

This particular summary uses the plenum pressure to provide the basis for assessing the potential leakage of the system. Supply leakage averages about 14%, while return leakage average is about 19% across the homes in the region. Supply leakage is a much more important measurement in terms of energy waste, but return leakage fraction is also reported for completeness. Return leakage indicates leaks from outside the house into the return ducts as the air is returning to the furnace. The target for Energy Star Northwest Homes is 6% for supply and 3% for return leakage. As Table 71 and Table 72 illustrate, the duct leakage across all states is much higher than the Energy Star targets and indicates the potential for duct sealing across the region.

Table 71: Supply Duct Leakage Fraction by State

State	Supply Duct Leakage Fraction (Half Plenum Pressure)		
	%	EB	n
ID	9.7%	3.0%	24
MT	12.5%	7.7%	9
OR	12.7%	2.7%	55
WA	15.0%	2.9%	78
Region	13.5%	1.8%	166

Table 72: Return Duct Leakage Fraction by State

State	Return Duct Leakage Percentage (Half Plenum Pressure)		
	%	EB	n
ID	17.5%	4.6%	24
MT	11.4%	5.6%	9
OR	18.4%	4.2%	56
WA	20.4%	3.4%	75
Region	19.1%	2.3%	164

7. Lighting

A detailed lighting audit was specified as part of the single-family residential survey. This audit established the characteristics of lighting systems, the type of lighting technologies used, the number of lamps, and total lighting power in each home surveyed. Surveyors were instructed to move from room to room throughout the home. In each room, surveyors completed a lamp count, lamp assessment (including connected watts), lamp, fixture types, and fixture count. All types of lights (hard-wired, table top and floor lamps) were included. In addition, an associated room area was measured, computed, and included with the lighting characteristics. This dataset was then compiled to develop both the lighting power density (LPD) for each room and an overall LPD for the home, with LPD expressed as Watts per square foot (W/sq.ft.).

The lighting audit was designed to identify lamp types and allow an after-the-fact judgment on the status of the lamp types relative to the federal regulation of lamp efficacies. Analysts reviewed the audits.

With the implementation of the federal lighting standards mandated by the Energy Independence and Security Act of 2007 (EISA 2007), many lamps that would have been targets of the utilities' efficient lighting programs would now be mandated to be adapted to high efficacy lamps such as compact fluorescent lamps (CFLs). The lighting audit recorded the characteristics of the lamps in each home. Based on the actual detailed lamp descriptions, the lamps identified in the audit were divided into three categories:

- **EISA compliant**: Lamps that already meet the EISA standards.
- **EISA non-compliant**: Lamps that would eventually have to be replaced with high efficacy lamps under the EISA standards.
- **EISA exempt**: Lamps that would not be required to meet EISA standards regardless of their efficiency.

These standards will be phased in from 2012 through 2014. For this analysis, we used the lighting standards at full implementation as the basis for categorizing the lamps in the lighting audits in the three categories above in order to assess the potential for the amount of lighting wattage that may be eligible for utility programs because they are exempt from EISA standards.

7.1. Lamp Quantity and Description

Table 73 shows the average number of individual lamp sockets observed in each home. This summary includes all the lamps observed in the individual rooms and exterior lamps. The total lamp count, across the region, is approximately 63 lamps per home. This finding compares with the lamp count in the previous 2007 RLW study (RLW 2007a) of 61.5 lamps per home and with the new construction survey results of 77 lamps per home (RLW 2007b).

Table 73: Average Number of Lamps per Home by State

State	Lamps per Home		
	Mean	EB	n
ID	63.6	4.89	168
MT	56.7	4.08	165
OR	63.2	3.91	304
WA	64.1	3.50	675
Region	63.2	2.21	1,312

Table 74 shows the average total number of fixtures per home. Although this average is relatively consistent from one state to the next, the Montana results continue to be somewhat lower than the other states. Based on these lighting audit data, a total of 40 fixtures could be expected in each home with a total of about 63 lamps in those fixtures.

Table 74: Average Number of Fixtures per Home

State	Fixtures per Home		
	Mean	EB	n
ID	40.3	4.20	180
MT	36.0	2.78	167
OR	40.4	2.39	314
WA	40.1	1.68	715
Region	39.9	1.25	1,376

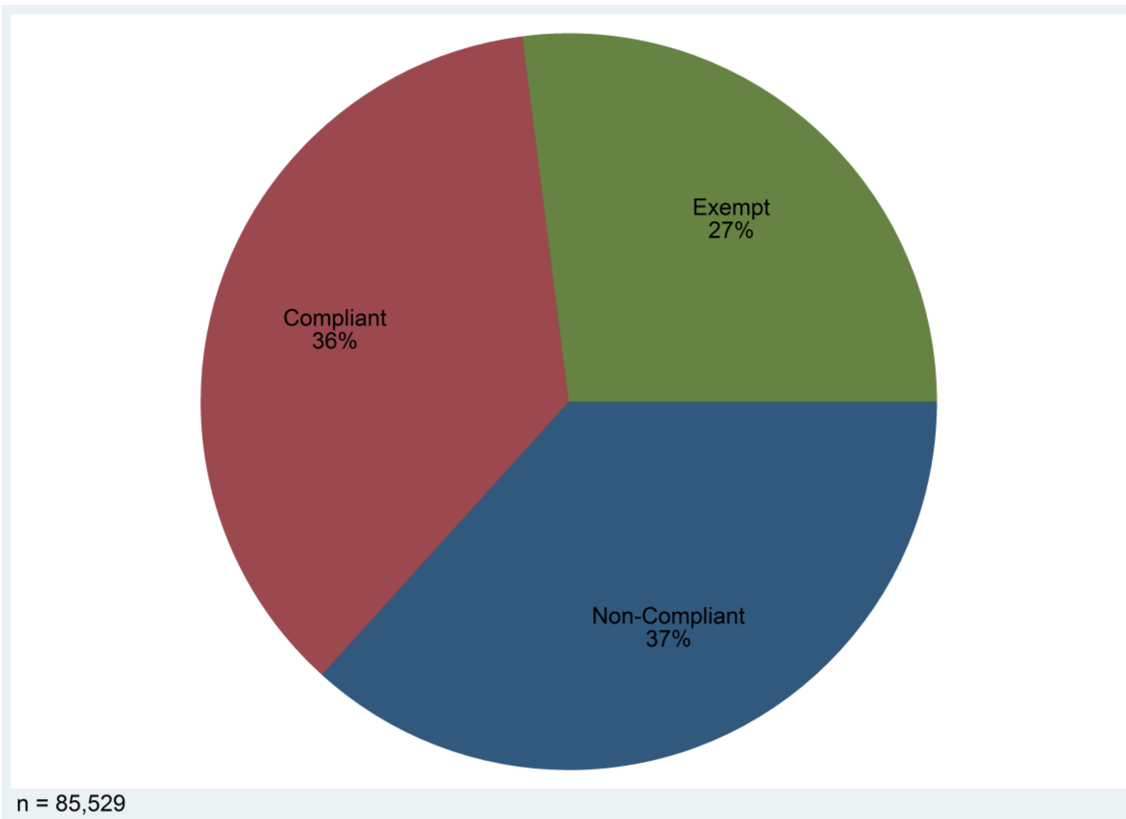
Table 75 and Figure 9 show the distribution of EISA exempt, non-compliant, and compliant lamps. The EISA compliant lamps currently meet or exceed the EISA standards for lighting efficacy (lumens per watt). About 36% of all the lamps observed are currently in compliance with the EISA standards. Most of these lamps are CFLs, although linear fluorescent lamps were also included in this category.

EISA exempt lamps are typically categories that include specialty lamps, especially integral reflectors, colored lamps, and other special use lamps of various sorts. These are fairly broad categories. Approximately 27% of all lamps will be exempt from the fully implemented EISA standard, which will be in full effect by 2015. Slightly more than 37% of the lamps that are regulated by EISA do not currently meet the lumens per wattage standards of the full EISA implementation. These are mostly incandescent lamps, although some other lamp types are included.

Table 75: Distribution of Lamps by EISA Category and State

EISA Category		Percentage of Lamps					
		ID	MT	OR	WA	Region	n
Exempt	%	22.9%	21.2%	27.4%	28.6%	27.0%	22,572
	EB	3.6%	2.8%	2.5%	1.6%	1.2%	
Non-Compliant	%	40.9%	46.6%	39.9%	32.4%	36.7%	31,594
	EB	3.6%	2.8%	2.5%	1.4%	1.2%	
Compliant	%	36.3%	32.2%	32.7%	39.0%	36.3%	31,363
	EB	3.3%	3.2%	2.5%	1.8%	1.3%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	85,529

Figure 9: Distribution of Lamps by EISA Category



7.2. Lamp Type

Lamp types were described beyond their EISA category characterization into five general categories: CFL, halogen (including MR16 types), incandescent, linear fluorescent, and other. Most of the instances in the “Other” category are light-emitting diode (LED) lamps, although other types of specialty display lamps occur in this category. As shown in Table 76, the mean saturation of CFLs throughout the region is about 25% of all lamps. This summary is based not on the number of lamps in any particular home, but the total population of CFLs throughout the region as a percentage of the total number of lamps in the individual sampling regions. The error bound on this estimate is about 1%. The distribution of CFLs in the states remains reasonably comparable with a higher saturation in Washington than in the other states.

Table 76: Distribution of Lamps by Type and State

Lamp Type		Percentage of Lamps					
		ID	MT	OR	WA	Region	n
Compact Fluorescent	%	24.9%	21.4%	21.3%	27.7%	25.0%	21,852
	EB	3.1%	2.8%	2.3%	1.9%	1.2%	
Halogen	%	2.7%	2.8%	6.7%	8.0%	6.5%	5,076
	EB	0.7%	1.1%	1.4%	1.2%	0.7%	
Incandescent	%	61.0%	65.0%	60.5%	52.8%	57.0%	48,885
	EB	3.3%	3.1%	2.6%	1.9%	1.3%	
Linear Fluorescent	%	11.1%	10.7%	11.1%	10.5%	10.8%	9,117
	EB	1.6%	1.7%	1.2%	0.9%	0.6%	
Other	%	0.3%	0.1%	0.5%	1.0%	0.7%	599
	EB	0.3%	0.1%	0.2%	0.5%	0.2%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	85,529

Linear fluorescent lamps were observed throughout the sample, consistently representing about 11% of the lamps throughout the region that are typically located in shops, basements, and kitchens.

The largest lamp type category is incandescent, representing 57% of the lamps observed. Only in Washington is there an appreciably lower saturation of incandescent lamps, presumably because of the greater emphasis on CFL lighting among the state’s utilities. Montana, on the other hand, has an 8% higher percentage of incandescent lamps, also a statistically significant difference from the region as a whole.

Table 77 shows the distribution of lamp types by room. All the lighting data collected during the survey included the room type in which the fixtures and lamps were observed. The use of CFLs seems reasonably similar across most room types. Of interior rooms, only dining rooms have an appreciably lower incidence of CFLs. This room type is the most likely to have dimming controls on the fixtures. In this sample, more than 20% of all lamps in dining rooms are controlled by dimmers. Across the entire sample, only about 5% of lamps are controlled with dimmers. CFL technology is not typically used in such fixtures because the continuous dimming effects are difficult to achieve with fluorescent lighting technologies.

Table 77: Distribution of Lamps by Type and Room

Lamp Type	Percent of Lamps					
	Compact Fluorescent	Halogen	Incandescent	Linear Fluorescent	Other	n
Bathroom	22.0%	4.1%	71.5%	2.1%	0.3%	12,977
Bedroom	29.4%	3.8%	63.6%	2.9%	0.2%	9,847
Closet	24.6%	2.6%	58.2%	14.3%	0.3%	1,747
Dining Room	18.0%	5.2%	74.6%	1.9%	0.3%	4,314
Exterior	24.3%	14.3%	55.2%	4.6%	1.6%	8,174
Family Room	28.4%	7.7%	56.0%	7.0%	0.8%	4,724
Garage	13.3%	0.7%	33.4%	52.2%	0.3%	5,474
Hall	28.6%	4.7%	64.0%	1.9%	0.7%	6,270
Kitchen	26.9%	12.0%	41.4%	18.4%	1.2%	9,665
Laundry Room	27.9%	5.3%	40.2%	26.2%	0.5%	2,284
Living Room	31.0%	7.5%	59.2%	1.5%	0.8%	7,662
Master Bedroom	28.8%	5.1%	63.9%	1.4%	0.8%	4,015
Office	28.1%	8.0%	49.0%	13.6%	1.3%	2,879
Other	18.5%	3.9%	44.2%	32.9%	0.4%	5,477
All Room Types	25.0%	6.5%	57.0%	10.8%	0.7%	85,509

The lighting audit identified lamps divided into the five categories shown in Table 76:

- Compact Fluorescent
- Halogen
- Incandescent
- Linear Fluorescent
- Other (including various specialty lamps and LED lamps)

Table 78 through Table 82 show the average number of lamps in each category in each home. A total of 1,312 homes had sufficient data to summarize all the lamps by type. As these tables show, incandescent lamps far outnumber any other type, but the more efficient fluorescent and halogen lamps make up more than 40% of all lamps in homes in the region.

Table 78: Average Number of CFLs Installed per Home by State

State	Number of Lamps		
	Mean	EB	n
ID	15.1	1.96	168
MT	12.0	1.51	165
OR	13.6	1.43	304
WA	17.3	1.21	675
Region	15.5	0.79	1,312

Table 79: Average Number of Halogen Lamps Installed per Home by State

State	Number of Lamps		
	Mean	EB	n
ID	1.76	0.48	168
MT	1.63	0.69	165
OR	4.34	0.97	304
WA	4.79	0.78	675
Region	4.03	0.49	1,312

Table 80: Average Number of Incandescent Lamps Installed per Home by State

State	Number of Lamps		
	Mean	EB	n
ID	38.8	4.26	168
MT	37.2	3.42	165
OR	38.0	3.11	304
WA	34.7	2.62	675
Region	36.4	1.71	1,312

Table 81: Average Number of Linear Fluorescent Lamps Installed per Home by State

State	Number of Lamps		
	Mean	EB	n
ID	7.62	1.20	168
MT	5.86	1.11	165
OR	6.96	0.91	304
WA	6.56	0.70	675
Region	6.76	0.48	1,312

Table 82: Average Number of Other Lamps Installed per Home by State

State	Number of Lamps		
	Mean	EB	n
ID	0.28	0.19	168
MT	0.07	0.06	165
OR	0.31	0.14	304
WA	0.69	0.35	675
Region	0.48	0.18	1,312

During the homeowner interview, the surveyor asked to see the CFL lamps stored in closets or cabinets and counted the number of lamps stored. Table 83 summarizes the average number of CFLs stored at these sites. Consistent with the installed lamps, the Washington homes had somewhat larger numbers of CFLs in storage.

Table 83: Average Number of Stored Compact Fluorescent Lamps by State

State	Stored Compact Fluorescent Lamps		
	Mean	EB	n
ID	3.77	0.773	184
MT	4.21	0.773	169
OR	4.69	0.644	313
WA	5.06	0.462	723
Region	4.72	0.321	1,389

The results of the lighting audit and the count of stored CFL lamps were combined to estimate the fraction of all CFLs that are currently stored. This calculation was made for each house and is summarized in Table 84. In this calculation, Idaho shows a lower storage rate than the other states, although this result is not statistically significant.

Table 84: Percentage of All CFLs that Are Stored

State	CFLs		
	%	EB	n
ID	19.4%	3.7%	158
MT	25.7%	3.5%	150
OR	25.9%	3.1%	284
WA	23.1%	1.8%	639
Region	23.7%	1.4%	1,231

7.3. Lighting Power Density (LPD)

The surveyors were instructed to assess the wattage of each lamp. The surveyors used direct observation or, in some cases, a schedule of typical wattages based on lighting type. The surveyors were encouraged to find the exact wattage, although an approximation was allowed where this determination was not possible. Thus, all of the lamps observed were assigned a wattage designation, and that wattage was, at a minimum, in a class consistent with the type of lamps observed.

Analysts then combined these wattages to develop lighting power for the building as a whole, and in each individual room. The lighting power was the basis for assessing LPD throughout the home. Each room had an estimated or measured floor area in addition to the lighting audit. The actual overall square footage of the home was also calculated during the survey. This area was calculated from the exterior dimensions of home. This area differs from the sum of room areas by the thickness of the walls, both interior and exterior. The difference between these two measures is about a 10% difference in floor area. The overall lighting power density was calculated from the overall conditioned home area measured by the surveyor (see Section 3.4 for a discussion of area calculations). The LPD for each room was based on the rooms' interior area and calculated separately.

Table 85 and Figure 10 show the average LPD by state across all the single-family surveys. Approximately 3.5% of the surveys were not included here because of combinations of data collection errors. Most of these issues were the results of ambiguous or missing lamp assignments that could not be resolved in the analysis. Nevertheless, the overall LPD of all existing homes in the single-family residential sector across the region is shown to be about 1.4 W/sq.ft.

Table 85: Average Lighting Power Density (LPD) by State

State	Home LPD (W/sq.ft.)		
	Mean	EB	n
ID	1.44	0.076	181
MT	1.30	0.075	163
OR	1.55	0.072	297
WA	1.35	0.042	714
Region	1.42	0.032	1,355

Figure 10: Average Lighting Power Density (LPD) by State

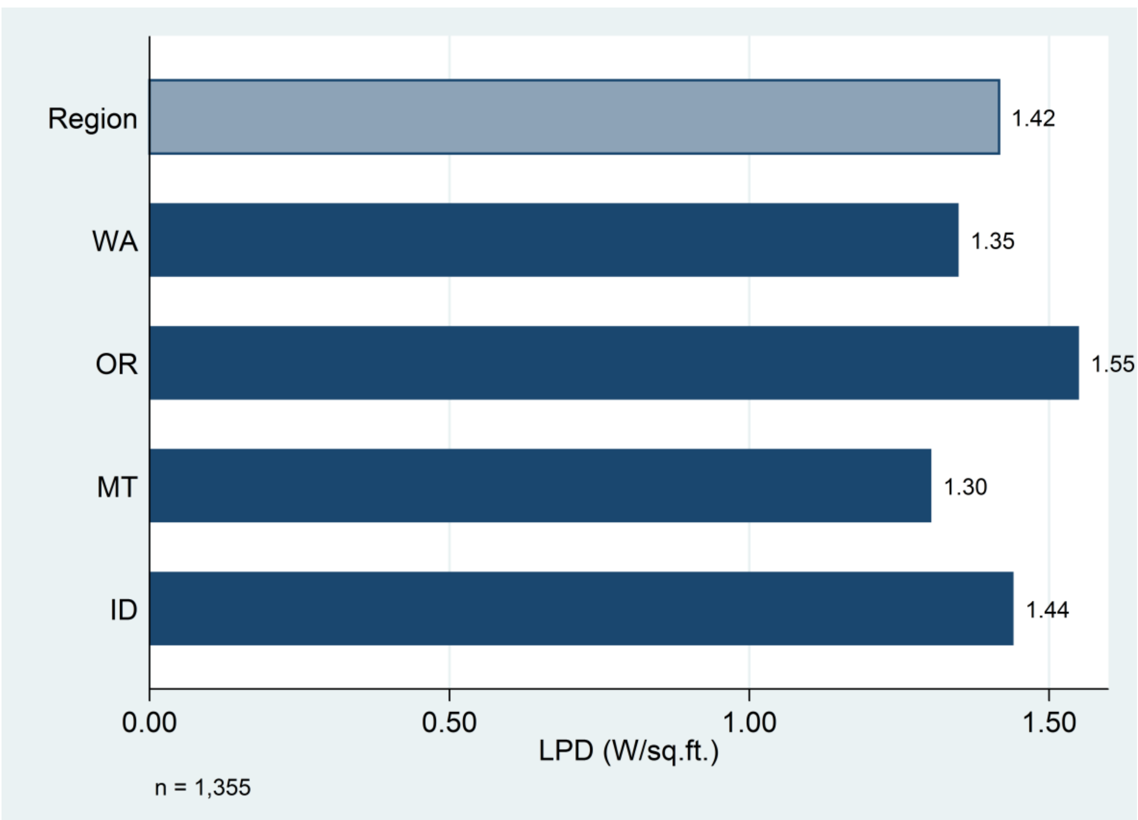


Table 85 shows a regional LPD of 1.42, which is somewhat lower than the 1.75 W/sq.ft. LPD that was assumed in the Council's Sixth Power Plan (Council 2010). This calculation assumes no high-efficacy lamps in the lighting system. The observed LPD in this study is consistent with the Council's assumption given the presence of 25% high-efficacy CFLs in our sample.

Montana and Washington are significantly lower than the regional average. Washington's lower LPD of 1.35 may be the result of the increased incidence of CFLs. Montana's LPD of 1.3 is likely the result of reduced numbers of fixtures and lamps that are present over the characteristics in the other three states.

Table 86 shows the distribution of average LPD across various room types. The list of rooms is from a "pick list" that the surveyors used to assign rooms during the survey. Table 86 shows about a 13% difference between the LPD estimated by room from interior dimensions and LPD estimated by total conditioned floor area. Most of this difference springs from the fact that the sum of interior room areas is typically about 10% lower than the area calculated from the home's exterior dimensions, as described above.

Table 86: Average Lighting Power Density (LPD) by Room Type

Room Type	Room LPD (W/sq.ft.)		
	Mean	EB	n
Bathroom	3.52	0.127	2,942
Bedroom	0.93	0.031	3,123
Closet	2.05	0.162	1,067
Dining Room	1.55	0.083	894
Family Room	1.03	0.075	738
Garage	0.58	0.029	849
Hall	1.51	0.064	2,315
Kitchen	1.69	0.081	1,404
Laundry Room	1.26	0.065	982
Living Room	0.94	0.043	1,325
Master Bedroom	0.99	0.046	877
Office	1.22	0.090	736
Other	1.04	0.072	1,270
All Room Types	1.60	0.039	18,522

The LPDs in Table 86 are summarized based on the area of the individual rooms. The total room audits conducted in this sample was about 18,500, or slightly more than 13 rooms per home. This lighting summary does not include exterior lamps, only lamps observed in individual rooms. The patterns shown here are fairly unsurprising, with the highest LPD observed in the bathrooms, with at least two sets of lamps for vanity mirrors, etc. The lowest LPDs occur in the garage, living room, and bedroom. The living rooms and bedrooms have relatively lower LPD in part due to the use of stand lights which usually do not light the room as completely as a central lighting system.

8. Appliances

The appliance audit focused on a detailed accounting and characterization of the appliances in each home. The audit was designed to provide a picture of the region's home appliance stock. This effort focused on characterizing the appliance types and characteristics. Actual efficiency of the individual appliances was of secondary interest and is not summarized here.

The surveyors developed a detailed census of appliances throughout the homes. For this purpose, appliances are defined as large "white goods" as well as water heaters and any other equipment that result in large and/or unusual energy loads. This process documented the presence of the appliance, and any key factors that were thought to have an impact on energy use and/or potential market impacts of utility programs.

The large appliance audit characterized the major energy using components of these appliances as well as their age. Table 87 shows the average number of the household appliances per home for the total region. With the exception of freezers, virtually every home in the region has a full complement of appliances.

Table 87: Average Number of Appliances per Home by Type

Appliance	Number of Appliances per Home n=1,404	
	Mean	EB
Clothes Washer	0.99	0.01
Dryer	0.98	0.01
Dishwasher	0.89	0.02
Freezer	0.53	0.03
Refrigerator	1.29	0.03
Water Heater	1.05	0.01

8.1. Refrigerator/Freezers

The survey of refrigerators focused on vintage and style. About 73% of all homes have only one refrigerator; 25% of those homes have a standalone freezer.

Table 88 shows the distribution of refrigerator/freezer vintages. This table includes both refrigerators and standalone freezers observed in the survey. The age distribution of standalone freezers and refrigerators is essentially identical. With slightly more than half the refrigerators manufactured since 2000, the table is consistent with a refrigerator life expectancy of about 10 years with more than half the refrigerator stock purchased since 2000. Federal appliance standards for refrigerator/freezers began in 1990, but in 1994 the efficiency standard was improved to a modern standard.

Table 88: Distribution of Refrigerator/Freezers by Vintage

Vintage	Refrigerators		
	%	EB	n
Pre 1980	4.2%	0.9%	95
1980-1989	9.0%	1.3%	220
1990-1994	11.7%	1.4%	273
1995-1999	17.5%	1.6%	398
2000-2004	22.2%	1.7%	513
2005-2009	27.3%	1.9%	618
Post 2009	8.1%	1.3%	167
Total	100.0%	—	2,284

Table 89 shows the distribution of refrigerator types by position of the refrigerator doors and freezers. This table does not include standalone freezers.

Table 89: Distribution of Refrigerators by Type

Refrigerator Type	Refrigerators		
	%	EB	n
Full Size Refrigerator Only	4.1%	1.1%	71
Mini Refrigerator	0.9%	0.4%	20
Refrigerator with Bottom Freezer	15.8%	1.9%	279
Refrigerator with Side-by-Side Freezer	30.7%	2.2%	545
Refrigerator with Top Freezer	45.1%	2.4%	832
Side-by-Side Refrigerator with Bottom Freezer	3.1%	0.8%	66
Refrigerated Wine Cooler	0.3%	0.3%	5
Total	100.0%	—	1,818

Surveyors generally recorded the volumes for refrigerators and freezers from the information provided in the model number and manufacturer's literature. Table 90 shows the average refrigerator volume by type of refrigerator across the region. The average refrigerator size is approximately 21 cubic feet (cu.ft.).

Table 90: Average Refrigerator Volume by Type

Refrigerator Type	Volume (cu.ft.)		
	Mean	EB	n
Full Size Refrigerator Only	11.5	1.89	71
Mini Refrigerator	5.7	1.00	20
Refrigerator with Bottom Freezer	22.6	0.37	279
Refrigerator with Side-by-Side Freezer	23.5	0.28	545
Refrigerator with Top Freezer	19.6	0.23	832
Side-by-Side Refrigerator with Bottom Freezer	24.3	0.61	66
Refrigerated Wine Cooler	5.3	3.74	5
All Refrigerator Types	20.8	0.24	1,818

Table 91 shows the distribution of standalone freezer type divided between upright and chest freezers. Table 92 shows the distribution of freezer volumes by type of freezer observed. The average freezer volume is 17 cu.ft.

Table 91: Distribution of Freezers by Type in Homes with Freezers

Freezer Type	Freezers		
	%	EB	n
Chest Freezer	40.5%	3.8%	296
Upright Freezer	59.5%	3.8%	430
Total	100.0%	—	726

Table 92: Average Freezer Volume by Type

Freezer Type	Freezer Volume (cu.ft.)		
	Mean	EB	n
Chest Freezer	15.5	0.705	296
Upright Freezer	18.0	0.412	429
All Freezers Types	17.0	0.395	725

8.2. Clothes Washers

Surveyors determined the age and type of clothes washers. This effort was either based on model numbers that were observed onsite and referenced later from literature available for those models, or based on the participant interview and/or documentation provided by the participant.

Table 93 shows the distribution of clothes washer vintages observed in this sample. The bulk of these washers were manufactured since 2000. This amounts to about 70% of the washers observed. The average age of the washers in this sample is less than 10 years.

Table 93: Distribution of Clothes Washers by Vintage

Vintage	Clothes Washers		
	%	EB	n
Pre 1980	1.6%	0.6%	26
1980-1989	5.3%	1.2%	78
1990-1994	8.0%	1.4%	123
1995-1999	15.7%	2.1%	205
2000-2004	27.3%	2.5%	376
2005-2009	33.7%	2.7%	434
Post 2009	8.4%	1.6%	111
Total	100.0%	—	1,353

Table 94 shows the distribution of clothes washer types across the region. For the most part, there is no difference between the state populations in the selection of clothes washer types. These types are characterized as horizontal or vertical axis washing machines as well as stacked and combination washer/dryers. As shown, the majority of washing machines are vertical axis washing machines, with approximately one-third of the washing machines observed being high-efficiency horizontal axis machines. A variation on this horizontal axis technology is the vertical axis without agitator. Combined, these two washer types account for almost 40% of the current stock.

Table 95 shows the distribution of clothes washer types by vintage. It is apparent from these two tables that the horizontal axis technology began to make inroads in the clothes washer market in the mid 1990s and is now a significant part of the new clothes washer market. In the 15 years since this technology became available, the horizontal axis washers exceed 40% of the clothes washers in service.

Table 94: Distribution of Clothes Washers by Type and State

Clothes Washer Type		Clothes Washers					
		ID	MT	OR	WA	Region	n
Combined Washer/Dryer, One Drum	%	—	0.42%	0.37%	0.25%	0.26%	7
	EB	—	0.68%	0.36%	0.24%	0.17%	
Horizontal Axis	%	28.16%	31.38%	38.15%	33.61%	34.07%	480
	EB	5.89%	6.20%	5.79%	3.47%	2.60%	
Stacked Washer/Dryer	%	3.58%	2.38%	1.69%	2.86%	2.58%	38
	EB	2.44%	2.03%	1.71%	1.33%	0.91%	
Vertical Axis (with Agitator)	%	62.73%	57.96%	55.03%	59.56%	58.54%	788
	EB	6.39%	6.65%	5.92%	3.69%	2.72%	
Vertical Axis (without Agitator)	%	5.53%	7.86%	4.75%	3.73%	4.55%	66
	EB	3.11%	3.71%	2.40%	1.48%	1.14%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,379

Table 95: Distribution of Clothes Washers by Type and Vintage

Clothes Washer Type		Vintage						
		Pre 1990	1990-1994	1995-1999	2000-2004	2005-2009	Post 2009	n
Combined Washer/Dryer, One Drum	%	—	—	27.53%	14.02%	58.46%	—	6
	EB	—	—	28.61%	21.84%	32.53%	—	
Horizontal Axis	%	—	1.45%	4.15%	25.65%	54.56%	14.18%	477
	EB	—	0.99%	1.46%	4.01%	4.63%	3.16%	
Stacked Washer/Dryer	%	8.58%	4.63%	4.97%	22.11%	53.20%	6.52%	37
	EB	13.21%	4.61%	7.96%	11.52%	17.71%	6.96%	
Vertical Axis (with Agitator)	%	10.49%	12.32%	23.91%	29.29%	20.16%	3.83%	765
	EB	2.05%	2.22%	3.37%	3.42%	3.08%	1.65%	
Vertical Axis (without Agitator)	%	5.73%	6.36%	4.34%	19.19%	38.30%	26.07%	60
	EB	4.96%	8.31%	3.64%	9.82%	12.67%	13.09%	
All Clothes Washer Types	%	6.89%	8.05%	15.69%	27.29%	33.68%	8.41%	1,345
	EB	1.29%	1.40%	2.14%	2.49%	2.71%	1.61%	

Surveyors asked participants about the number of washer loads performed each week in the home. Table 96 summarizes these results and shows an average of about five loads of washing per week.

Table 96: Average Number of Clothes Washer Loads per Week by State

State	Clothes Washer Loads per Week		
	Mean	EB	n
ID	5.71	0.581	185
MT	4.38	0.329	168
OR	4.84	0.389	312
WA	4.84	0.240	733
Region	4.92	0.184	1,398

8.3. Clothes Dryers

Surveyors recorded only the vintage and usage for clothes dryers. Table 97 shows the distribution of clothes dryer vintages. In general, the vintage distribution is similar to clothes washer vintages, suggesting that these were matched and purchased by the participants at the same time. In all states, the use of gas fueled dryers is rare. About 5% of all dryers are fueled with natural gas or propane.

Table 97: Distribution of Clothes Dryers by Vintage

Vintage	Clothes Dryers		
	%	EB	n
Pre 1980	2.3%	1.0%	28
1980-1989	7.0%	1.3%	106
1990-1994	9.2%	1.6%	132
1995-1999	17.6%	2.2%	236
2000-2004	27.1%	2.5%	372
2005-2009	29.8%	2.6%	405
Post 2009	7.0%	1.5%	88
Total	100.0%	—	1,367

When surveyors interviewed participants about their clothes washer use, they also asked participants to estimate the percentage of the washer loads that actually became dryer loads. Table 98 shows the responses to this question. Approximately 90% of all washer loads become dryer loads across the region.

Table 98: Percentage of Dryer Loads per Washer Load by State

State	Dryer Loads per Washer Load		
	%	EB	n
ID	87.4%	2.7%	180
MT	86.6%	3.2%	162
OR	88.8%	2.4%	299
WA	90.2%	1.5%	719
Region	89.2%	1.1%	1,360

8.4. Dishwashers

As with clothes dryers, surveyors recorded only the vintage and usage for dishwashers. They determined vintages onsite using model numbers or by information and/or documentation provided by the participant. Table 99 shows that about two-thirds of the dishwashers were purchased since the year 2000.

Table 99: Distribution of Dishwashers by Vintage

Vintage	Dishwashers		
	%	EB	n
Pre 1980	1.1%	0.4%	21
1980-1989	5.3%	1.3%	63
1990-1994	7.6%	1.7%	80
1995-1999	18.2%	2.3%	222
2000-2004	26.4%	2.7%	312
2005-2009	34.0%	2.8%	402
Post 2009	7.5%	1.7%	80
Total	100.0%	—	1,180

Surveyors asked participants how many loads per week they ran through the dishwasher. Table 100 summarizes the average number of dishwasher loads per week by state.

Table 100: Average Number of Dishwasher Loads per Week

State	Dishwasher Loads per Week		
	Mean	EB	n
ID	3.62	0.433	178
MT	2.86	0.347	162
OR	3.17	0.344	303
WA	3.27	0.226	712
Region	3.26	0.165	1,355

8.5. Cooking Appliances

Table 101 shows the distribution of cook top fuel for the entire region, and Table 102 shows the distribution of oven fuel.

Table 101: Distribution of Cook Top Fuel by Type

Fuel Type	Cook Top Fuel		
	%	EB	n
Electric	75.1%	2.3%	1,085
Gas	20.8%	2.2%	285
Propane	4.0%	1.0%	62
Other	0.0%	0.1%	1
Total	100.0%	—	1,433

Table 102: Distribution of Oven Fuel by Type

Fuel Type	Oven Fuel		
	%	EB	n
Electric	85.3%	1.9%	1,216
Gas	12.2%	1.8%	178
Other	0.0%	0.1%	1
Propane	2.3%	0.8%	37
No Oven	0.2%	0.2%	3
Total	100.0%	—	1,435

8.6. Water Heaters

Surveyors included water heaters with the audit of large appliances. Water heater efficiency was not targeted because the variation in potential efficiency is narrowed by federal standards, obviating the need for a program baseline.

Table 103 shows the distribution of water heater fuel across the states. In general, this distribution reflects a somewhat higher saturation of electric energy for the domestic hot water (DHW) system than for gas fuel. However, there is a clear preference for gas water heating in Montana as differentiated from the more populous western states. When natural gas is combined with propane, more than 60% of the households in the Montana sample choose gas fuel for water heating. In the region as a whole, less than 45% of the households choose gas or propane.

Table 103: Distribution of Water Heater Fuel by State

Water Heater Fuel Type		Water Heaters					
		ID	MT	OR	WA	Region	n
Electricity	**%**	52.0%	38.1%	54.6%	58.8%	55.2%	864
	EB	6.7%	6.3%	5.6%	3.8%	2.7%	
Gas	**%**	45.3%	59.1%	42.8%	40.0%	42.8%	557
	EB	6.6%	6.4%	5.5%	3.8%	2.7%	
Oil/Kerosene	**%**	—	0.8%	0.9%	0.1%	0.4%	5
	EB	—	1.3%	1.2%	0.2%	0.4%	
Propane	**%**	2.7%	2.0%	1.5%	1.2%	1.5%	26
	EB	2.5%	1.7%	1.2%	0.7%	0.6%	
Wood	**%**	—	—	0.2%	—	0.0%	1
	EB	—	—	0.3%	—	0.1%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,453

Table 104 shows the regional water heater distribution by type. About 97% of all water heaters in the sample are storage tank type water heaters and only approximately 3% are instantaneous water heaters. The instantaneous water heaters are typically gas fired when they are designed to meet the needs of the entire home, but are often electric fired when they are supplemental to storage tank type systems at particular hot water loads within the home.

Table 104: Distribution of Water Heaters by Type

Heater Type	Water Heaters		
	%	EB	n
Instantaneous	3.2%	0.9%	45
Storage	96.8%	0.9%	1,407
Total	100.0%	—	1,452

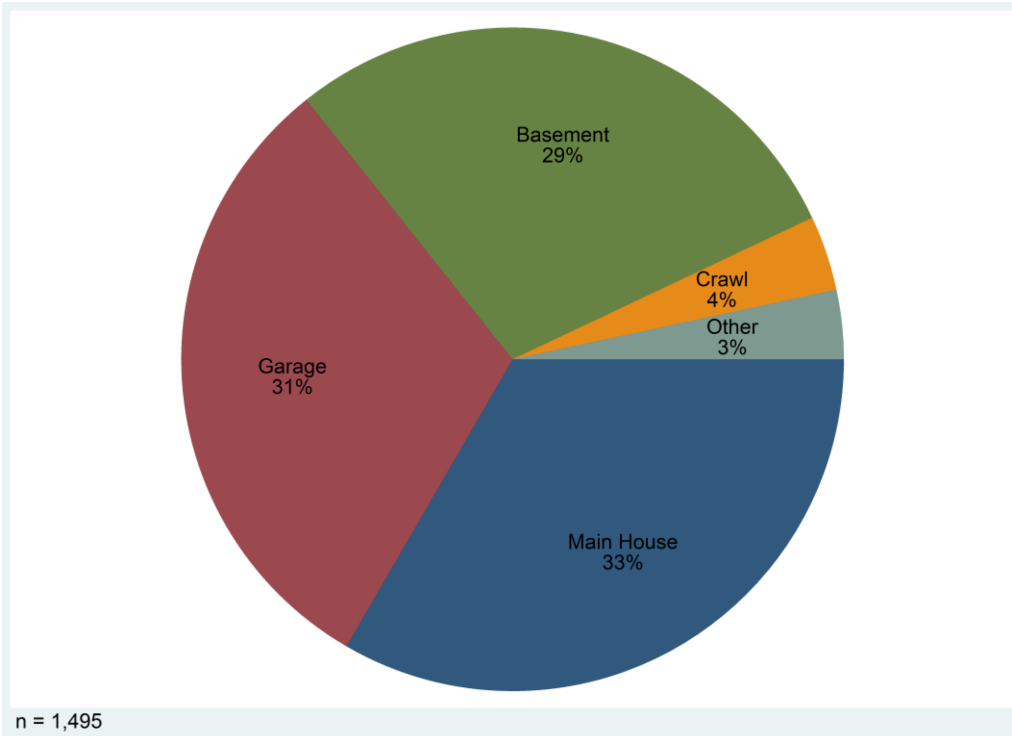
Table 105 and Figure 11 show the distribution of water heater location by state. Overall, the water heaters located in the main living area of the home represent about one-third of the Washington and Oregon cases and about one-third of the region overall, but only about one-quarter of the water heaters in Idaho and Montana.

These differences in water heater locations reflect differences in these four states, especially with respect to the use of basements as a part of common construction. Idaho and Montana have more basements available than Washington and Oregon as a percentage of total homes, and thus the location of the water heater in the basement is far more likely in those states. A similar situation exists in eastern Washington and eastern Oregon, although these represent a relatively small fraction of the total state populations in those states. Only about 4% of the basements are actually unconditioned by the definition used in these surveys (see Section 4.1.2).

Table 105: Distribution of Water Heater Location by State

Water Heater Location		Water Heaters					
		ID	MT	OR	WA	Region	n
Basement	**%**	39.4%	55.7%	18.4%	28.6%	28.8%	475
	EB	6.3%	6.7%	5.0%	3.3%	2.4%	
Crawlspace	**%**	5.7%	11.2%	1.1%	3.6%	3.6%	57
	EB	3.1%	4.2%	0.6%	1.7%	1.0%	
Garage	**%**	25.1%	2.4%	38.6%	32.4%	31.3%	395
	EB	5.8%	2.0%	5.5%	3.3%	2.5%	
Main House	**%**	26.9%	26.8%	38.6%	31.8%	32.8%	467
	EB	5.8%	5.9%	5.5%	3.7%	2.6%	
Other	**%**	2.9%	3.9%	3.4%	3.5%	3.4%	56
	EB	2.7%	2.8%	1.7%	1.2%	0.9%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,450

Figure 11: Distribution of Water Heater Location



For assessing the feasibility of a heat pump water heater (HPWH), the heating fuel must be considered as well as the water heater fuel and location. Table 106, Table 107, and Table 108 show the distributions of water heater tank location and primary heating fuel type. Table 106 shows all storage tank locations as they distribute across all primary space fuels. Table 107 shows the same distribution for electric hot water tanks only and Table 108 this distribution for gas heated hot water tanks only.

Table 106: Distribution of All Water Heater Locations by Space Heating Fuel Type

Water Heater Location		All Water Heaters by Space Heating Fuel							
		Electric	Gas	Oil	Pellets	Propane	Wood	All Fuels	n
Basement	**%**	23.7%	32.0%	38.5%	22.2%	46.1%	20.2%	28.7%	484
	EB	3.8%	3.6%	12.6%	15.9%	14.9%	6.7%	2.4%	
Crawlspace	**%**	3.3%	3.8%	5.5%	2.5%	6.0%	2.6%	3.7%	59
	EB	1.8%	1.4%	5.4%	4.1%	6.9%	1.8%	1.0%	
Garage	**%**	27.3%	40.1%	4.8%	17.2%	15.3%	11.3%	30.9%	397
	EB	3.9%	3.9%	3.6%	17.1%	10.2%	6.0%	2.5%	
Main House	**%**	42.0%	21.1%	50.2%	58.1%	26.3%	60.8%	33.4%	475
	EB	4.3%	3.4%	13.5%	22.4%	13.0%	9.1%	2.7%	
Other	**%**	3.7%	3.0%	1.0%	—	6.3%	5.0%	3.4%	57
	EB	1.5%	1.2%	1.6%	—	5.1%	4.4%	0.9%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	1,472

Table 107: Distribution of Electric Water Heater Location by Primary Space Heating Fuel Type

Water Heater Location		Electric Water Heaters by Space Heating Fuel							
		Electric	Gas	Oil	Pellets	Propane	Wood	All Fuels	n
Basement	%	24.2%	40.1%	42.2%	26.3%	52.8%	20.4%	29.0%	274
	EB	4.0%	8.9%	13.5%	18.9%	18.1%	7.4%	3.3%	
Crawlspace	%	3.0%	5.9%	6.2%	2.9%	6.1%	2.8%	3.8%	34
	EB	1.9%	3.2%	6.1%	4.9%	9.6%	2.0%	1.3%	
Garage	%	24.7%	14.9%	5.5%	7.9%	4.9%	12.1%	19.0%	167
	EB	3.9%	6.1%	4.1%	8.1%	5.7%	6.8%	2.7%	
Main House	%	44.2%	35.5%	45.0%	62.9%	31.1%	62.0%	44.8%	354
	EB	4.6%	9.2%	14.4%	22.1%	17.5%	9.6%	3.7%	
Other	%	3.9%	3.6%	1.1%	—	5.1%	2.7%	3.4%	34
	EB	1.7%	2.4%	1.8%	—	5.9%	2.8%	1.1%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	863

Table 108: Distribution of Gas Water Heater Location by Space Heating Fuel Type

Water Heater Location		Gas Water Heaters by Space Heating Fuel					
		Electric	Gas	Propane	Wood	All Fuels	n
Basement	%	17.9%	29.6%	15.7%	16.9%	28.2%	197
	EB	10.2%	3.9%	25.0%	15.4%	3.6%	
Crawlspace	%	7.8%	3.3%	23.5%	2.5%	3.6%	25
	EB	8.7%	1.6%	27.7%	4.4%	1.6%	
Garage	%	53.8%	47.2%	38.9%	11.0%	46.6%	221
	EB	15.8%	4.4%	44.0%	17.4%	4.3%	
Main House	%	18.1%	17.1%	21.9%	69.6%	18.9%	109
	EB	11.1%	3.3%	32.5%	23.7%	3.5%	
Other	%	2.4%	2.8%	—	—	2.7%	19
	EB	2.8%	1.4%	—	—	1.2%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	571

In addition to water heater fuel type and location, the size of the water tank constrains the potential market for high efficiency HPWHs. Table 109 shows the distribution of tank size by water heater fuel. The tank size is divided into two categories. The larger size is thought to be more challenging for HPWH technology given the recovery speed and size of the larger units. As can be seen in Table 109, however, only about 9% of all water tanks are in the larger size category.

Table 109: Distribution of Tank Size by Fuel Type

Fuel Type		Tank Size		
		0-55 gallons	>55 gallons	n
Electricity	%	88.3%	11.7%	849
	EB	2.2%	2.2%	
Gas	%	94.5%	5.5%	518
	EB	1.9%	1.9%	
Oil/Kerosene	%	91.4%	8.6%	4
	EB	15.9%	15.9%	
Propane	%	95.9%	4.1%	20
	EB	6.7%	6.7%	
Unknown	%	100.0%	—	1
	EB	0.0%	—	
All Fuel Types	%	91.0%	9.0%	1,392
	EB	1.5%	1.5%	

Table 110 and Table 111 divide the data in Table 109 by the two major fuel types, electric and gas. These tables show the distribution of tank size by location. Table 110 shows a slight increase in preference for larger tanks in homes with electric DHW systems.

Table 110: Distribution of Electric Water Heater Tank Size by Location

Location		Electric Water Heater Tank Size		
		0-55 gallons	>55 gallons	n
Basement	%	83.3%	16.7%	273
	EB	5.1%	5.1%	
Crawl Space	%	89.2%	10.8%	33
	EB	10.2%	10.2%	
Garage	%	88.0%	12.0%	162
	EB	4.5%	4.5%	
Main House	%	91.2%	8.8%	349
	EB	2.9%	2.9%	
Other	%	94.3%	5.7%	32
	EB	5.7%	5.7%	
All Locations	%	88.3%	11.7%	849
	EB	2.2%	2.2%	

Table 111: Distribution of Gas Water Heater Tank Size by Location

Location		Gas Water Heater Tank Size		
		0-55 gallons	>55 gallons	n
Basement	**%**	94.9%	5.1%	168
	EB	3.3%	3.3%	
Crawl Space	**%**	87.9%	12.1%	20
	EB	15.7%	15.7%	
Garage	**%**	95.2%	4.8%	205
	EB	2.7%	2.7%	
Main House	**%**	93.3%	6.7%	100
	EB	5.2%	5.2%	
Other Location	**%**	94.8%	5.2%	14
	EB	8.7%	8.7%	
Unknown	**%**	100.0%	—	2
	EB	0.0%	—	
All Locations	**%**	94.5%	5.5%	509
	EB	1.9%	1.9%	

Table 112 shows the regional distribution of water heater vintage. As Table 112 shows, the water heaters generally are distributed uniformly between 1990 and 2010 with only a few water heaters being more than 20 years old. This distribution is consistent with a water heater life of about 10 years on average, given that about 60% of the water heaters were installed prior to 2004.

Table 112: Distribution of Water Heaters by Vintage

Vintage	Water Heaters		
	%	EB	n
Pre 1990	6.3%	1.4%	79
1990-1999	28.4%	2.6%	380
2000-2004	24.0%	2.3%	342
2005-2009	33.5%	2.6%	448
Post 2009	7.8%	1.5%	102
Total	100.0%	—	1,351

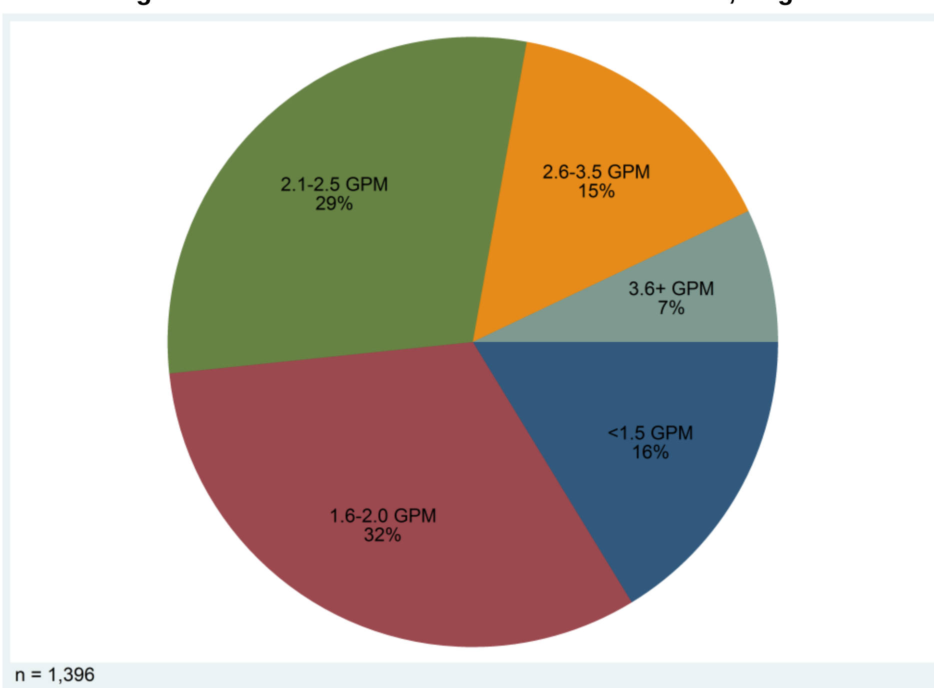
8.7. Showerheads

The surveyors took a census of showerheads in each home and used a Micro-Wier™ to measure the flow rate of the main showerhead when the faucets were turned on full. Table 113 and Figure 12 show the distribution of flow rates in these showerheads across the states. It should be noted that a relatively high percentage of these showerheads are low-flow, which is 2 gallons per minute (GPM) or less. The distribution of these low-flow showerheads is relatively similar across all states.

Table 113: Distribution of Showerhead Flow Rate by State

Flow Rate (GPM)		Showerheads					
		ID	MT	OR	WA	Region	n
<1.5	%	6.5%	21.7%	18.2%	16.8%	16.3%	239
	EB	3.4%	5.3%	4.6%	2.7%	2.0%	
1.6-2.0	%	38.0%	28.0%	29.7%	32.5%	32.1%	445
	EB	6.5%	5.9%	5.3%	3.6%	2.6%	
2.1-2.5	%	40.6%	22.5%	20.0%	33.2%	29.5%	411
	EB	6.5%	5.6%	4.7%	3.7%	2.5%	
2.6-3.5	%	11.1%	22.5%	19.8%	12.3%	15.1%	209
	EB	4.2%	5.6%	4.6%	2.6%	2.0%	
3.6+	%	3.7%	5.3%	12.3%	5.1%	7.1%	92
	EB	2.6%	3.0%	4.0%	1.3%	1.4%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,396

Figure 12: Distribution of Showerhead Flow Rate, Region



9. Consumer Electronics

Surveyors conducted the electronics audit on a room-by-room basis. This approach resulted in a census of electronic equipment by room. The following summary tables include the results for major electronic equipment types.

9.1. Televisions

Ecotope developed the saturation of televisions per home by compiling all the TVs observed in the individual rooms. Table 114 shows that the overall number of TVs across the region is slightly more than two TVs per home.

Table 114: Average Number of Televisions per Home by State

State	Televisions per Home		
	Mean	EB	n
ID	2.31	0.173	185
MT	1.93	0.142	169
OR	2.28	0.147	314
WA	2.34	0.107	736
Region	2.29	0.074	1,404

When the information was accessible, the surveyors also recorded television power in Watts for primary televisions. Table 115 shows the television power for the measured TVs by TV vintage. The surveyors measured TV power on approximately 60% of the TVs observed in the sample.

Table 115: Average Television Power by Vintage

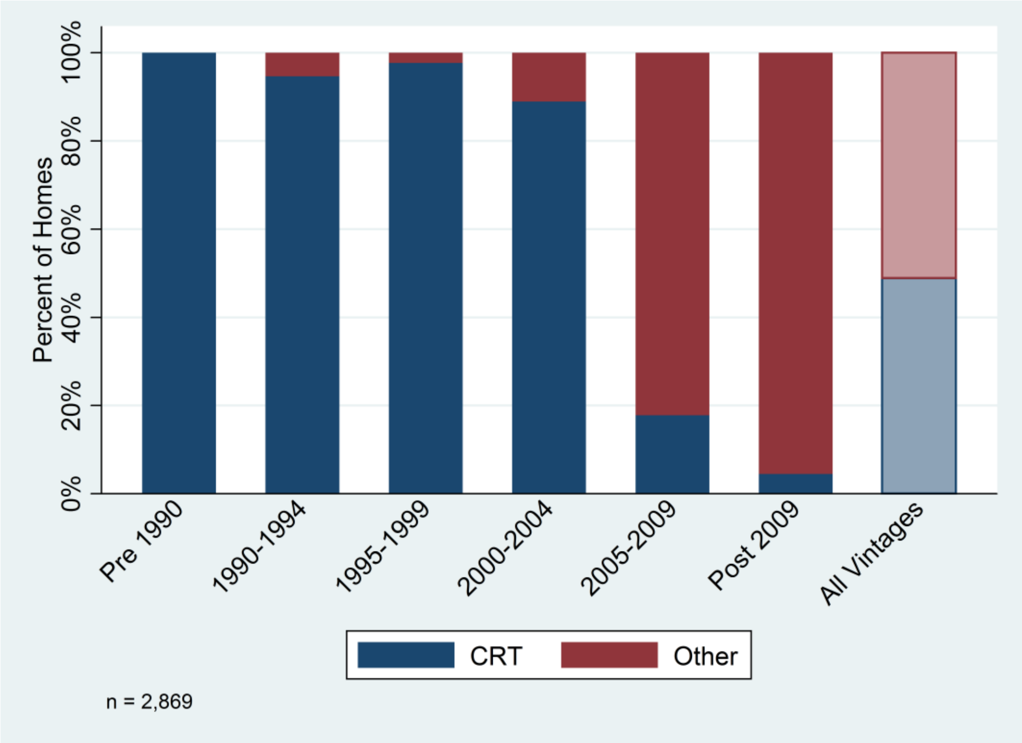
Vintage	Television Power (W)		
	Mean	EB	n
Pre 1990	77.5	9.56	24
1990-1994	80.9	5.53	129
1995-1999	84.4	4.79	211
2000-2004	90.2	5.84	270
2005-2009	136.9	6.65	762
Post 2010	99.1	8.76	292
All Vintages	111.6	3.70	1,688

Table 116 and Figure 13 show the percentage of TVs in each vintage bin. As Table 116 shows, TVs were categorized into two types. CRT denotes conventional tube type TVs that for the most part were made obsolete in the last eight years. Nevertheless, this type of TV was dominant in the earlier time periods. The “Other Type” is meant to be flat screen TVs, although the surveyor was not asked to try to determine the differences among Plasma, LED, and liquid crystal display (LCD) because those were thought to be inscrutable relative to the available documentation. Thus, the “Other Type” category has an increasing number of LED and LCD TVs as we move from older styles to the newer styles.

Table 116: Distribution of Television Screens by Type and Vintage

Vintage		Television Screens		
		CRT	Other Type	n
Pre 1990	%	100.0%	—	52
	EB	0.0%	—	
1990-1994	%	94.7%	5.3%	259
	EB	2.4%	2.4%	
1995-1999	%	97.7%	2.3%	476
	EB	1.0%	1.0%	
2000-2004	%	88.9%	11.1%	506
	EB	2.8%	2.8%	
2005-2009	%	17.8%	82.2%	1,166
	EB	2.4%	2.4%	
Post 2009	%	4.5%	95.5%	410
	EB	1.6%	1.6%	
All Vintages	%	48.9%	51.1%	2,869
	EB	1.6%	1.6%	

Figure 13: Distribution of Television Screens by Type and Vintage



The flat screen TVs have achieved penetration of about 96% of the market in the most recent cohort observed, compared to about 5% in the early 1990s.

Table 117 shows the location of TVs throughout the home. Across the region, family rooms, living rooms, and bedrooms are the locations with the largest numbers, although many other locations were also mentioned.

Table 117: Distribution of Televisions by Room Type

Room	Televisions		
	%	EB	n
Bathroom	0.9%	0.4%	22
Bedroom	24.5%	1.6%	765
Closet	0.0%	0.0%	2
Dining Room	1.6%	0.5%	46
Exterior	0.0%	0.1%	2
Family Room	16.8%	1.3%	541
Garage	1.2%	0.4%	34
Hall	0.0%	0.0%	1
Kitchen	3.7%	0.6%	120
Laundry Room	0.6%	0.3%	16
Living Room	29.1%	1.4%	924
Master Bedroom	13.3%	1.0%	399
Office	4.3%	0.8%	131
Other	3.8%	0.7%	125
Total	100.0%	—	3,128

Surveyors also asked participants to report the number of hours the primary TV was turned on per day. Table 118 shows that there seems to be relatively little difference between states on this dimension.

Table 118: Average Primary Television On-Time Hours per Day per Home by State

State	Television Use per Home (hours/day)		
	Mean	EB	n
ID	5.61	0.562	182
MT	5.04	0.465	164
OR	5.37	0.470	283
WA	5.40	0.372	714
Region	5.39	0.246	1,343

9.2. Set-Top Boxes

In the process of evaluating the TVs, the surveyors documented the number of set-top boxes per home. Surveyors were asked to categorize set-top boxes as the devices that received the cable or satellite feed for the television. Other devices such as gaming systems or internet connections were not included in this category. The surveyors also noted the type of set-top box and digital video recorder (DVR) capability.

Table 119 summarizes the average number of set-top boxes per home. Table 120 shows the saturation of set-top boxes in homes across the region. Table 121 shows the percentage of set-top boxes with DVR capability such as a TiVo. As with most of the TVs and accessories, there is very little difference between states on these characteristics.

Table 119: Average Number of Set-Top Boxes per Home by State

State	Set-Top Boxes per Home		
	Mean	EB	n
ID	1.32	0.166	185
MT	1.34	0.154	169
OR	1.63	0.158	314
WA	1.60	0.096	736
Region	1.55	0.071	1,404

Table 120: Percentage of Homes with Set-Top Boxes

State	Homes with Set-Top Boxes		
	%	EB	n
ID	75.6%	5.7%	185
MT	76.5%	5.6%	169
OR	80.2%	4.5%	314
WA	82.8%	3.0%	736
Region	80.6%	2.2%	1,404

Table 121: Percentage of Set-Top Boxes with DVR Capability by State

State	Set-Top Boxes with DVR		
	%	EB	n
ID	34.4%	6.4%	299
MT	23.1%	6.4%	243
OR	32.4%	4.8%	525
WA	25.8%	3.2%	1,330
Region	28.6%	2.3%	2,397

9.3. Gaming Systems

Table 122 and Table 123 summarize gaming system in the region. Table 122 shows the percentage of homes with gaming systems by state. Across most states, 30–35% of homes have gaming systems. Montana is the exception where nearly 25% of homes have gaming systems. Table 123 shows the average number of gaming systems that are present in homes that have gaming systems. There is little variation across states for this characteristic, and the regional average is about 1.5 gaming systems in homes that have gaming systems.

Table 122: Percentage of Homes with Gaming Systems

State	Homes With Gaming Systems		
	%	EB	n
ID	33.5%	6.3%	185
MT	23.4%	5.6%	169
OR	30.8%	5.3%	314
WA	36.0%	3.7%	736
Region	33.2%	2.6%	1,404

Table 123: Average Number of Gaming Systems per Home with Gaming Systems

State	Gaming Systems per Home		
	Mean	EB	n
ID	1.53	0.113	185
MT	1.30	0.085	169
OR	1.44	0.088	314
WA	1.51	0.064	736
Region	1.48	0.044	1,404

9.4. Computers and Accessories

The surveyors conducted a census of computers by room. They counted only computers that were plugged in or in some way directly in use. Thus, laptops that were not immediately obvious were not included. Table 124 presents the saturation of computers per home across the four states. Table 125 shows the percentage of homes with computers by state. The percentage of homes with computers does not vary greatly across the region; however, more than 90% of homes in Oregon and Washington have computers and 80–87% of homes in Idaho and Montana have computers.

Table 124: Average Number of Computers per Home by State

State	Computers per Home		
	Mean	EB	n
ID	1.58	0.160	185
MT	1.26	0.126	169
OR	1.58	0.128	314
WA	1.79	0.102	736
Region	1.67	0.067	1,404

Table 125: Percentage of Homes with Computers by State

State	Homes with Computers		
	%	EB	n
ID	87.6%	4.2%	185
MT	80.9%	5.3%	169
OR	91.0%	3.4%	314
WA	92.3%	1.9%	736
Region	90.5%	1.5%	1,404

9.5. Audio Systems

Surveyors observed the number of audio systems and certain aspects of these audio systems, especially the presence of passive subwoofers and powered subwoofers. Table 126 and Table 127 describe the average number of audio systems and subwoofers in the sample.

Table 126: Average Number of Audio Systems per Home by State

State	Audio Systems per Home		
	Mean	EB	n
ID	1.57	0.197	185
MT	1.47	0.203	169
OR	2.10	0.266	314
WA	2.10	0.151	736
Region	1.99	0.113	1,404

On average, each home in the region has about two audio systems; Oregon and Washington have about 34% more audio systems per home than Idaho and Montana. The subwoofers were classified as "passive," which run off amplifier power, and "powered," where the device requires its own power source to boost the performance and has an ongoing standby load. Table 127 shows the saturation of subwoofers per home by type. The saturation is slightly less than 50% for all subwoofers, and less than half of these are powered subwoofers.

Table 127: Average Number of Subwoofers per Home by Type

Subwoofer Type	Subwoofers per Home n=1,404	
	Mean	EB
Passive	0.263	0.029
Powered	0.206	0.025
All Subwoofers	0.468	0.039

10. Occupant Demographics and Behavior

At the beginning of the onsite visits, the surveyors conducted a 10- to 15-minute interview with the participant to collect information about the home and how it was used, to establish a rapport with the participant, and to secure signed releases for obtaining utility billing data. For purposes of continuity, this report summarizes a number of participant responses relating to specific appliances in the sections describing those appliances. This section focuses on demographic and behavior responses such as occupancy and energy use.

10.1. Occupancy

The participants provided information on the number and age of occupants in the home. Table 128 shows the average occupant age per home. Both Montana and Oregon have an average occupant age per home of about 51 years old, whereas the average age per home in Idaho and Washington are slightly lower, 47 years old and about 45 years old, respectively. Table 129 summarizes the average number of occupants per home. The average number of occupants per home for the region is about 2.7.

Table 128: Average Occupant Age per Home by State

State	Occupant Age		
	Mean	EB	n
ID	47.0	2.8	180
MT	50.6	2.5	169
OR	50.8	2.2	311
WA	45.2	1.5	720
Region	47.5	1.1	1,380

Table 129: Average Number of Occupants per Home by State

State	Occupants per Home		
	Mean	EB	n
ID	2.95	0.22	183
MT	2.43	0.18	169
OR	2.53	0.15	311
WA	2.81	0.16	723
Region	2.72	0.10	1,386

The ACS data suggests 2.48 occupants per home, which is outside the error bounds of this survey. The ACS survey includes all building types. The addition of multifamily households would tend to result in a smaller average number of occupants. This would explain most of this variation and the apparent significance of the difference.

Table 130 breaks out the average number of occupants by age category. Across the region, each home has about 1.5 adults (18–64 years), about .5 seniors (65 and older), and about .75 children (0–17 years).

Table 130: Average Number of Occupants by Age Category by State

Age Category		Number of Occupants (n = 1,386)				
		ID	MT	OR	WA	Region
Adults (18 to 64)	%	1.41	1.33	1.39	1.54	1.46
	EB	0.15	0.14	0.11	0.08	0.06
Children (0 to 17)	%	0.92	0.54	0.54	0.81	0.73
	EB	0.18	0.14	0.13	0.13	0.08
Seniors (65 and over)	%	0.63	0.56	0.60	0.46	0.53
	EB	0.11	0.10	0.09	0.06	0.04

Table 131 summarizes home ownership status, including renting, own or buying, or cases where the occupant does not own the home but does not pay rent to live in the home. Occupancy without either ownership or paying rent is rare; there are seven homes in this category.

Table 131: Distribution of Homes by Ownership Type and State

Ownership Type		Percentage of Homes					
		ID	MT	OR	WA	Region	n
Occupied Without Rent	%	0.7%	0.4%	0.1%	1.2%	0.8%	7
	EB	0.6%	0.7%	0.2%	1.4%	0.7%	
Own/Buying	%	88.0%	86.8%	86.8%	85.3%	86.2%	1,215
	EB	4.3%	4.5%	4.0%	2.8%	2.0%	
Renting	%	11.3%	12.8%	13.0%	13.5%	13.0%	181
	EB	4.3%	4.5%	4.0%	2.5%	1.9%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,403

Surveyors asked participants whether the surveyed home was the participant's primary residence. The question was intended to determine whether the home was a secondary home and thus intermittently occupied. Table 132 presents the percentage of homes identified as the primary residence. Throughout the region, the percentage of primary residences in the sample is nearly 100%.

Table 132: Percentage of Homes as Primary Residence by State

State	Homes as Primary Residence		
	%	EB	n
ID	96.4%	2.4%	184
MT	97.8%	2.1%	169
OR	99.6%	0.4%	314
WA	98.4%	0.8%	736
Region	98.5%	0.5%	1,403

The surveyors asked participants if they maintained a home office as part of their employment, including working at home or having a business in their home. Table 133 summarizes the percentage of these types of home offices. Oregon and Idaho homes have the highest percentage of homes with home offices at about 25% each. Montana and Washington both have less than 20%.

Table 133: Percentage of Homes with Home Offices by State

State	Homes with a Home Office/Business		
	%	EB	n
ID	24.3%	5.7%	184
MT	18.6%	5.0%	169
OR	25.1%	5.2%	314
WA	16.5%	2.8%	736
Region	20.2%	2.3%	1,403

10.2. Fuel Assistance

Surveyors asked participants whether they receive fuel financial assistance from either the utility or a federal subsidy. Although fuel assistance was rarely reported, about 2.5% of the homes reported some form of electric bill paying assistance. About 1% of gas heated homes reported such assistance. Table 134 and Table 135 summarize the distribution of fuel assistance by type of fuel. The tables categorize the amount of fuel assistance as “No Utility Bill Assistance” through “100% Utility Bill Assistance.” The respondents indicated which of these categories characterized their fuel assistance grants.

Table 134: Distribution of Homes with Electric Fuel Assistance by Percentage of Assistance and State

Percentage of Assistance		Homes with Electric Fuel Assistance					
		ID	MT	OR	WA	Region	n
25% Utility Bill Assistance	%	1.5%	3.0%	1.7%	0.4%	1.1%	20
	EB	1.7%	2.4%	1.3%	0.3%	0.5%	
50% Utility Bill Assistance	%	0.7%	0.4%	0.2%	0.9%	0.6%	10
	EB	1.2%	0.7%	0.3%	0.6%	0.4%	
75% Utility Bill Assistance	%	—	—	—	0.2%	0.1%	1
	EB	—	—	—	0.4%	0.2%	
100% Utility Bill Assistance	%	0.2%	0.8%	—	0.9%	0.5%	8
	EB	0.4%	0.9%	—	0.7%	0.4%	
No Utility Bill Assistance	%	97.6%	95.8%	98.1%	97.5%	97.6%	1,361
	EB	2.1%	2.6%	1.3%	1.1%	0.7%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,400

Table 135: Distribution of Homes with Gas Fuel Assistance by Percentage of Assistance and State

Percentage of Assistance		Homes with Gas Fuel Assistance					
		ID	MT	OR	WA	Region	n
25% Utility Bill Assistance	%	1.2%	2.2%	0.3%	0.1%	0.4%	9
	EB	1.3%	2.1%	0.3%	0.1%	0.3%	
50% Utility Bill Assistance	%	0.7%	—	0.2%	0.1%	0.2%	3
	EB	1.2%	—	0.3%	0.1%	0.2%	
75% Utility Bill Assistance	%	—	—	—	—	—	0
	EB	—	—	—	—	—	
100% Utility Bill Assistance	%	—	1.6%	—	0.1%	0.2%	5
	EB	—	1.3%	—	0.1%	0.1%	
No Utility Bill Assistance	%	98.1%	96.2%	99.5%	99.8%	99.2%	1,378
	EB	1.8%	2.4%	0.4%	0.2%	0.3%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,395

10.3. Thermostat Settings

The surveyors asked participants about their heating and cooling thermostat behavior. Table 136 summarizes the self-reported thermostat heating setpoint by state. Table 137 provides the percentage of homes that use night heating setback on a regular basis.[18] Table 138 shows the amount of thermostat setback that occupants said they used.

Table 136: Average Heating Thermostat Setpoint by State

State	Heating Thermostat Setpoint (°F)		
	Mean	EB	n
ID	69.7	0.454	179
MT	68.4	0.501	168
OR	68.7	0.330	313
WA	68.4	0.221	724
Region	68.7	0.163	1,384

Table 137: Percentage of Homes Reporting a Heating Setback by State

State	Homes Reporting Heating Setback		
	%	EB	n
ID	62.3%	6.4%	185
MT	63.4%	6.4%	169
OR	69.0%	5.3%	314
WA	71.8%	3.5%	736
Region	69.1%	2.5%	1,404

Table 138: Average Size of Heating Setback by State

State	Heating Setback (°F)		
	Mean	EB	n
ID	6.08	0.648	115
MT	6.22	0.561	108
OR	6.86	0.517	215
WA	6.50	0.331	529
Region	6.54	0.245	967

[18] Night setback is the process of adjusting the heating thermostat setting down during sleeping hours. The duration of this setback determines the amount of energy savings that might result. Typically, the home thermostat provides this capability and the setback is programmed into the thermostat. In those cases, the setback is automatic. In other cases, the occupant manually adjusts the thermostat on a nightly basis.

Table 139 presents the average setpoints for cooling in homes that have cooling.[19] Table 140 shows instances when occupants used a cooling setup that increased the cooling setpoint when the home was not occupied in the daytime.

Table 139: Average Cooling Thermostat Setpoint by State

State	Cooling Setpoint (°F)		
	Mean	EB	n
ID	73.9	0.750	111
MT	73.2	0.964	45
OR	74.2	0.713	154
WA	72.8	0.505	232
Region	73.5	0.357	542

Table 140: Percentage of Homes Reporting a Cooling Thermostat Setup by State

State	Homes Reporting Thermostat Setup		
	%	EB	n
ID	14.6%	4.7%	27
MT	6.7%	3.4%	10
OR	8.3%	2.8%	38
WA	9.5%	2.6%	53
Region	9.6%	1.7%	128

Although heating thermostat setbacks were quite common (with almost 70% of all households saying that this was a regular part of their use pattern during the heating season), cooling setup and adjustments were quite uncommon, with only about 10% of the households saying that such adjustments were part of their cooling use patterns.

10.4. Fuel Use

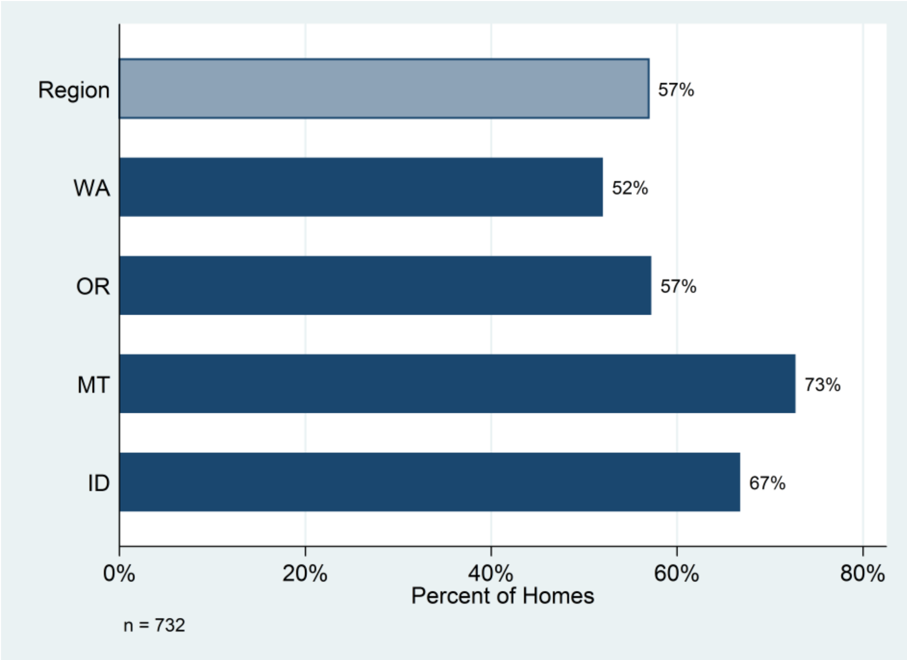
While they were onsite, the surveyors obtained billing releases for both electric and gas utility billing records. Table 141 and Figure 14 summarize the percentage of gas customers by state. The regional average is 57%. Oregon and Washington have a relatively similar percentage of gas customers and do not diverge too significantly from the regional average. Idaho has about 17% more gas customers than the region as a whole and Montana has about 28% more.

[19] For cooling, the setting adjustment occurs during the day when the home is unoccupied. This adjustment often takes the form of turning off the air conditioning equipment during the day and using it only in the hours after work. In that case, the interview question may not have captured that behavior.

Table 141: Percentage of Households Reporting Gas Service by State[20]

State	Households Reporting Gas Service		
	%	EB	n
ID	66.8%	6.1%	113
MT	72.7%	5.4%	115
OR	57.2%	5.2%	140
WA	52.0%	3.8%	364
Region	57.0%	2.6%	732

Figure 14: Percentage of Households Reporting Gas Service by State



In addition to the utility fuel questions, surveyors asked participants about non-utility fuel use such as wood, oil, and propane.

Table 142 and Figure 15 summarize the use of wood fuel for home heating. As Table 142 shows, about 20% of the sample reported wood use across the entire region. In Montana and Oregon, about 25% of the sample said they used some wood. In the Montana sample, half of this group used more than three cords a year, while in Oregon, 75% of the wood users used less than three cords per year.

[20] In a few cases, the gas service reported by the homeowner was in fact a propane service rather than natural gas. This discrepancy was resolved either by the surveyor or later during the collection of utility bills.

Figure 15 shows the distribution of reported wood fuel use graphically for those homes that reported wood use.

Table 142: Distribution of Wood Use as Heating Fuel by State

Annual Wood Use		Homes Using Wood Fuel					
		ID	MT	OR	WA	Region	n
<1 Cord	%	—	—	0.8%	0.2%	0.4%	3
	EB	—	—	1.2%	0.4%	0.4%	
1-3 Cords	%	13.4%	14.0%	19.1%	12.9%	14.9%	206
	EB	4.5%	4.5%	4.5%	2.6%	2.0%	
4-6 Cords	%	4.6%	9.3%	4.6%	3.4%	4.3%	71
	EB	2.6%	3.5%	2.3%	1.4%	1.1%	
>6 Cords	%	2.2%	3.1%	0.7%	0.7%	1.1%	22
	EB	1.8%	2.1%	0.5%	0.5%	0.4%	
None	%	79.8%	73.6%	74.8%	82.6%	79.3%	1,097
	EB	5.3%	5.5%	4.9%	3.0%	2.2%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,399

Figure 15: Distribution of Wood Use as Heating Fuel by State

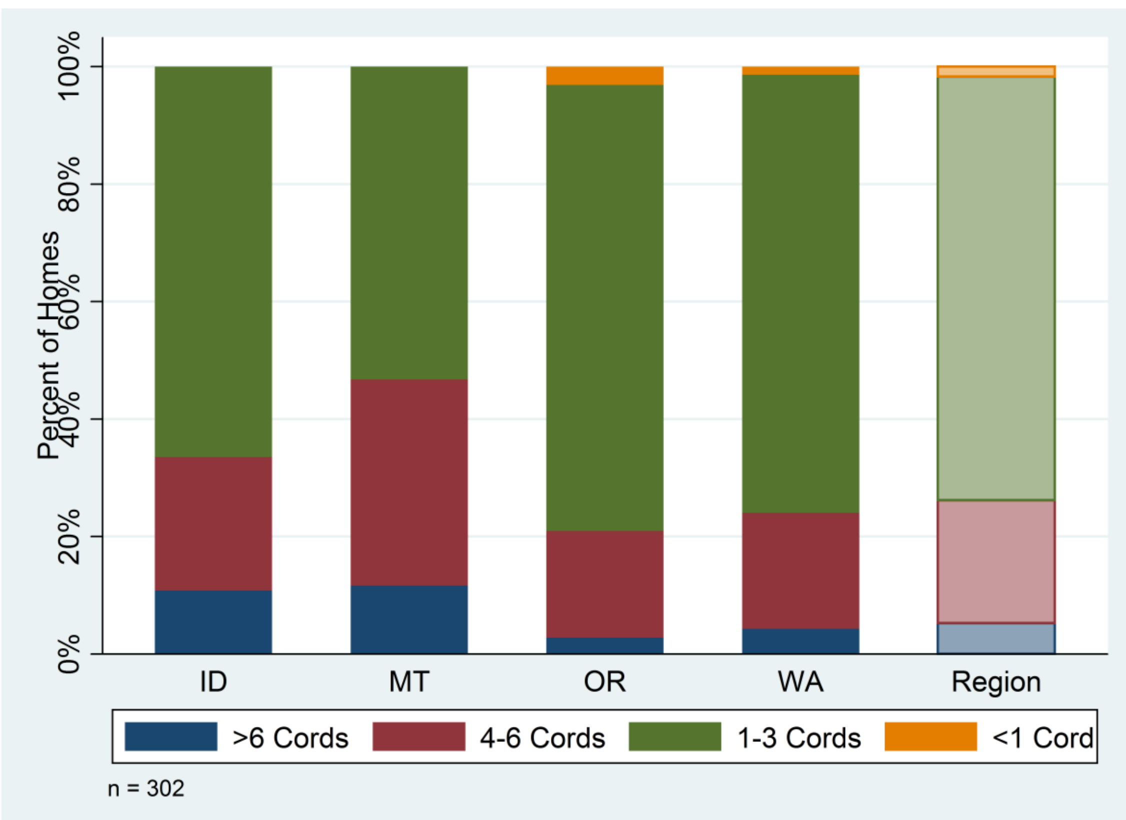


Table 143 shows the distribution of pellet fuel use by state. The data indicate that the use of pellet fuel for home heating is not significant.

Table 143: Distribution of Pellet Fuel Use by State

Annual Pellet Fuel Use		Homes Using Pellet Fuel					
		ID	MT	OR	WA	Region	n
<1 Ton	%	—	—	—	0.2%	0.1%	1
	EB	—	—	—	0.4%	0.2%	
1-2 Tons	%	2.2%	0.8%	3.8%	1.9%	2.4%	40
	EB	1.8%	0.9%	2.0%	0.9%	0.8%	
2-4 Tons	%	0.2%	—	1.5%	0.4%	0.7%	8
	EB	0.4%	—	1.6%	0.3%	0.5%	
>4 Tons	%	0.7%	—	0.1%	1.0%	0.6%	5
	EB	1.2%	—	0.2%	1.1%	0.6%	
None	%	96.9%	99.2%	94.6%	96.5%	96.2%	1,337
	EB	2.2%	0.9%	2.5%	1.5%	1.1%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,391

Table 144 and Table 145 summarize the use of oil and propane in the sample. About 4% of the population uses oil. About 10% of the survey population use propane fuel, and more than half of that used it in quantities that were sufficient to provide primary heating.

Table 144: Distribution of Oil Fuel Use by State

Annual Oil Fuel Use		Homes Using Oil Fuel					
		ID	MT	OR	WA	Region	n
<100 gallons	%	1.0%	0.8%	0.1%	0.4%	0.4%	8
	EB	1.3%	0.9%	0.2%	0.5%	0.3%	
100-250 gallons	%	1.0%	0.4%	0.6%	0.4%	0.5%	12
	EB	1.3%	0.7%	0.5%	0.3%	0.3%	
250-500 gallons	%	1.9%	0.7%	1.9%	1.1%	1.4%	21
	EB	1.8%	1.2%	1.7%	0.6%	0.6%	
500-1000 gallons	%	—	—	2.5%	0.7%	1.1%	7
	EB	—	—	1.9%	1.0%	0.8%	
>1000 gallons	%	—	—	—	0.1%	0.1%	1
	EB	—	—	—	0.2%	0.1%	
None	%	96.1%	98.1%	94.8%	97.3%	96.4%	1,343
	EB	2.5%	1.7%	2.6%	1.3%	1.1%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,391

Table 145: Distribution of Propane Fuel Use by State

Annual Propane Fuel Use		Homes Using Propane Fuel					
		ID	MT	OR	WA	Region	n
<50 gallons	%	3.8%	0.8%	0.9%	1.2%	1.4%	23
	EB	2.6%	0.9%	0.6%	0.7%	0.5%	
50-250 gallons	%	2.4%	4.3%	3.5%	5.7%	4.5%	57
	EB	2.1%	2.4%	2.0%	2.0%	1.2%	
250-500 gallons	%	3.8%	2.0%	1.8%	1.1%	1.7%	28
	EB	2.2%	1.4%	1.6%	0.7%	0.7%	
500-1000 gallons	%	3.8%	4.2%	1.4%	0.9%	1.7%	27
	EB	2.5%	2.5%	1.3%	0.7%	0.6%	
>1000 gallons	%	0.2%	4.9%	—	0.1%	0.4%	11
	EB	0.4%	2.8%	—	0.2%	0.2%	
None	%	86.0%	83.8%	92.5%	91.0%	90.3%	1,250
	EB	4.5%	4.4%	2.9%	2.3%	1.6%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	1,396

10.5. Conservation Expenditures

The participants also responded to questions about recent investments or actions taken to improve the energy efficiency of their home. Table 146 summarizes the percentage of households that implemented self-funded efficiency improvements without utility incentives. Nearly 50% of the sample responded positively to this question. Table 147Table 147 summarizes the percentage of households that used utility program incentives to fund efficiency measures. About 16% of the overall population, more or less uniformly distributed across the states, said that they had used utility incentives. Table 148 summarizes the percentage of households reporting the use of conservation tax credits, either for self-funded or utility program measures. About 16% of the overall population claimed a state or federal tax credit for their conservation improvements.

Table 146: Percentage of Households Reporting Recent Self-Funded Conservation by State

State	Households Reporting Recent Self Funded Conservation Improvements		
	%	EB	n
ID	37.3%	6.5%	185
MT	60.3%	6.5%	169
OR	41.6%	5.8%	314
WA	51.7%	3.9%	735
Region	47.5%	2.8%	1,403

Table 147: Percentage of Households Reporting Recent Use of Utility Conservation Programs by State

State	Households Reporting Use of Utility Incentives		
	%	EB	n
ID	15.8%	4.9%	185
MT	13.2%	4.4%	169
OR	15.4%	4.1%	314
WA	17.0%	2.7%	735
Region	16.1%	2.0%	1,403

Table 148: Percentage of Households Reporting Use of Conservation Tax Credit

State	Households Reporting Recent Conservation Tax Credits		
	%	EB	n
ID	12.0%	4.4%	185
MT	18.2%	5.0%	169
OR	19.3%	4.5%	314
WA	15.1%	2.5%	735
Region	16.2%	2.0%	1,403

Table 149 shows the percentage of participants that used both tax credits and utility incentives to help fund their conservation investments. Overall, only 6.5% of the households took advantage of both of these funding options. In Oregon, where state-level tax credits are available, a higher percentage of people used the tax credits. In Montana, the combination of tax credits and utility incentives is significantly rare.

Table 149: Percentage of Households Reporting Use of Both Utility and Tax Credit Conservation Programs

State	Households Reporting Use of Utility and Tax Credit Conservation Programs		
	%	EB	n
ID	5.5%	3.1%	185
MT	1.2%	1.1%	169
OR	8.9%	3.3%	314
WA	6.1%	1.5%	735
Region	6.5%	1.3%	1,403

11. Energy Benchmarking

This section presents the results of the billing analysis and energy benchmarking for the single-family residential sector. The RBSA sample presents a unique opportunity to develop energy-use profiles to assess the region's energy efficiency progress in this sector. The design and size of this study allows these benchmarks to extend to subregions and larger utility territories while maintaining the statistical integrity of the energy use estimates. Ecotope requested electric and gas bills for all participants in the single-family RBSA. Because of anomalous bill readings and unexplained consumption variations, some of the bills collected could not be used and were removed from the analysis. Overall, bills for 1,337 electric customers and 666 gas customers were summarized, and used for the energy-use analysis.

The RBSA energy benchmark can be compared to benchmarks implemented 20 years ago as well as to future residential sector baseline assessments to chart the progress of residential efficiency across the region. This energy benchmark also provides planners the opportunity to calibrate residential programs and residential program evaluations.

11.1. Billing Analysis Procedure

Ecotope used a standard VBDD approach to analyze utility bills. This procedure results in an estimate of the portion of any bill that is temperature-dependent. The estimate of the temperature dependence determines the space heat estimate for each home. The procedure for deriving and correcting these estimates was developed in Fels (1986) and expanded more recently in Geraghty & Baylon (2009).

In addition to developing a space heating estimate, the results of the VBDD analysis allow the bills to be adjusted to account for changes in weather and to be "normalized" to long-term weather data. The normalization process ensures that sites can be compared to one another and to future energy use without biasing the comparison as a result of short-term transients in the weather.

Ecotope applied the VBDD procedure to the both the electric and gas bills associated with each home. In the case of the electric bills, many homes do not use electricity for space heating (apart from very minimal portable units), so the use of VBDD largely fails to produce statistically acceptable estimates of electric space heat. To account for this, Ecotope screened results based on the "fit" and size of the heating signature. Bills that failed this screen were totaled and annualized, but a heating signature was not developed. To annualize these cases, Ecotope averaged the monthly consumption over the number of years available.

Gas bills were more likely to include space heating. As with the electric bills, Ecotope normalized the gas bills using the same VBDD procedure. A few cases had no evidence of space heating in the gas bills, and in those cases the same annualizing procedure used for electric bills was employed.

The wealth of characteristics data as well as the geographically representative sample design provides a significant opportunity to analyze energy use by geographic and building characteristics. The summaries presented here illustrate the breadth and quality of this energy use dataset and the potential for useful summaries by analysts in the region.

11.2. Electric Energy Use Indices

The electric loads summarized here include all the homes in the survey for which electric bills were available. In cases where the homes were primarily heated with electric (as determined in the onsite survey) summaries were separated for most homes characteristics and included in Appendix B. This appendix also includes average electric values for this subset of the population.

Table 150 shows the average per home total electricity use by state. This summary is based on annualized and normalized bills for 2011. The states all have similar overall electricity use on average (in spite of potential climate differences); only Montana shows a significantly different consumption. We suspect that this difference is the result of the prevalence of smaller homes with supplemental (non-electric) space heat from other fuels such as wood, propane, and oil.

Table 150: Average Annual kWh per Home by State

State	kWh per Home		
	Mean	EB	n
ID	14,039	1,070	177
MT	10,132	651	167
OR	11,917	612	282
WA	14,034	576	699
Region	13,124	371	1,325

The distribution of electric energy use by state is shown in Figure 16. The center of the box represents the median value and differs slightly from the tables. The tails show the distribution of use patterns across the sample. The tails do not include extreme outliers as this would expand the scale unnecessarily. The data presented in this graph represents more than 99% of all the cases in each state.

Figure 16: Average Annual kWh per Home by State

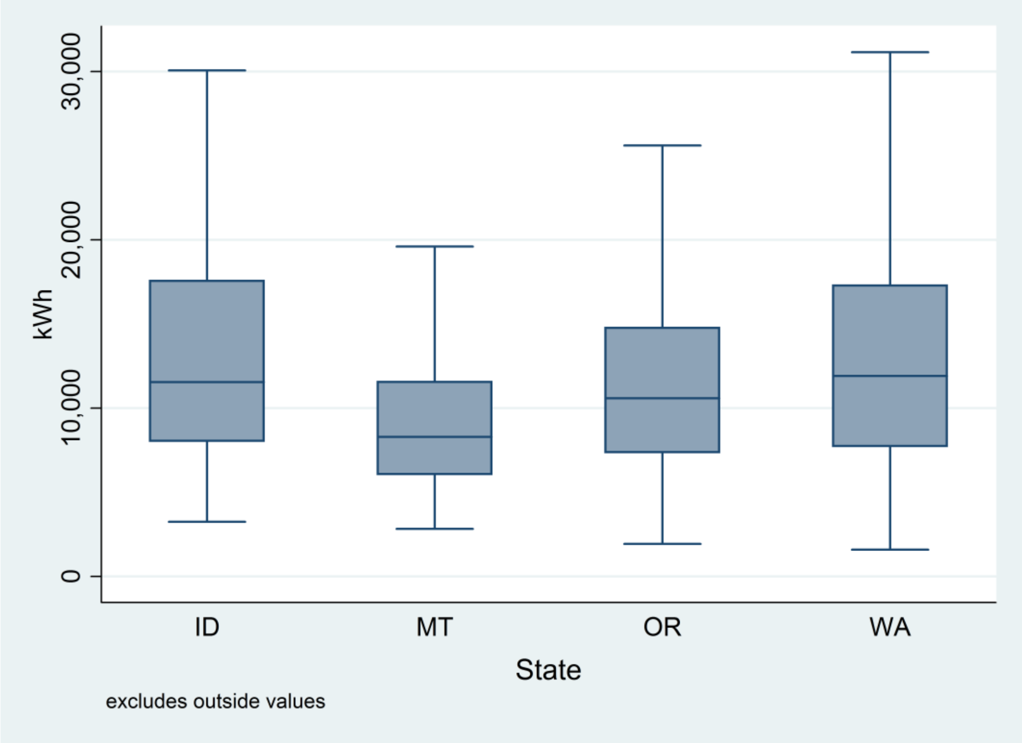


Table 151 and Figure 17 summarize the average per home total electricity use by state, but in this case the heating estimates for each site have weather-normalized to the long-term weather for the weather station assigned. In aggregate, the impact of weather normalization across these larger geographic areas is minimal relative to the size of the absolute usage. For individual homes, however, much larger adjustments might be expected depending on the prevailing weather conditions at the site.

Table 151: Average Weather Normalized kWh per Home by State

State	kWh per Home		
	Mean	EB	n
ID	13,747	1,028	178
MT	10,011	641	167
OR	11,620	587	286
WA	13,631	576	706
Region	12,787	365	1,337

Figure 17: Average Weather Normalized kWh per Home by State

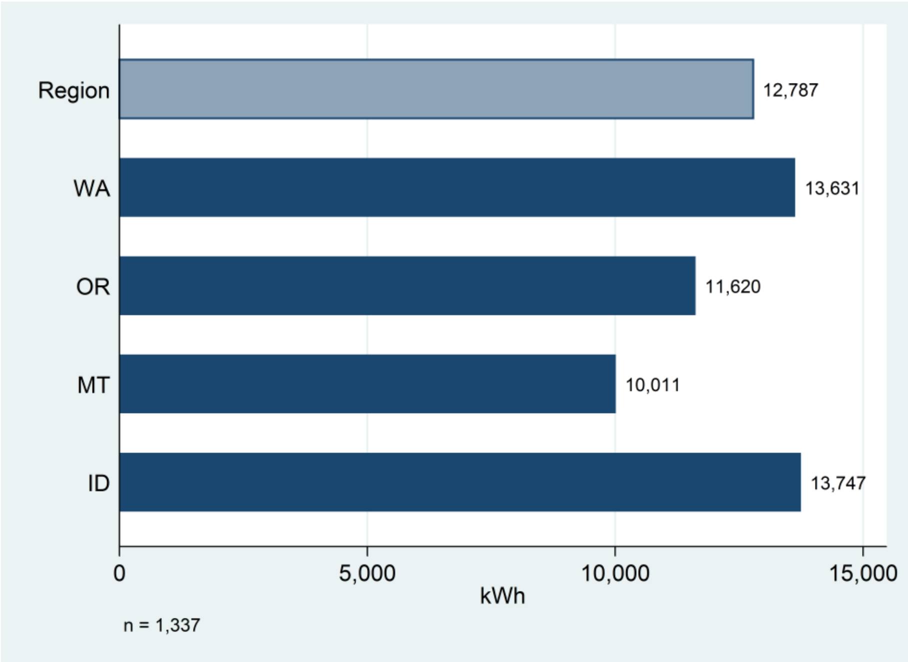


Table 152 summarizes the electricity use normalized by home size. This calculation uses the same conditioned floor area used to calculate LPD and normalize heat loss rates. In Table 152, the results are separated into two categories. If the survey identified a home with primary electric heat, the total kWh consumption is in the "Homes with Electric Heat" column; if not, then the consumption is summarized in the "Homes with Other Heat" column. This separation is based on the onsite survey results, not the VBDD regression fits. "All Homes" combines the two groups to provide an EUI for each state and the region.

Table 152: Average Electric EUI per Home by Heating Fuel Type and State

State		Electric EUI per Home (kWh/sq.ft.)			
		Homes w/ Electric Heat	Homes w/ Other Heat	All Homes	n
ID	Mean	10.96	6.32	7.61	177
	EB	1.19	0.57	0.60	
MT	Mean	9.94	4.67	5.38	167
	EB	1.73	0.35	0.43	
OR	Mean	10.31	5.83	7.35	280
	EB	1.01	0.43	0.50	
WA	Mean	11.18	5.50	7.72	694
	EB	0.55	0.31	0.35	
Region	Mean	10.87	5.64	7.42	1,318
	EB	0.45	0.21	0.24	

Table 153 shows the results of the heating estimates developed with the VBDD analysis. These estimates have been confined to homes reporting electricity as their primary heat source. In many cases, other fuel sources such as wood offset this heating load. Homes with electric heating systems that reported that their primary heating system was non-electric were not included in this summary.

Table 153: Average Estimated Annual Electric Space Heat per Home by State

State	Space Heat per Home (kWh)		
	Mean	EB	n
ID	8,629	1,473	51
MT	8,437	2,148	26
OR	5,992	626	124
WA	9,074	673	292
Region	8,116	478	493

11.3. Gas Energy Use Indices

Table 154 shows the average total gas use at homes with metered gas service. In this summary the gas use has been annualized only. As Table 154 shows, the Montana homes use significantly more gas than the other states. This result could be easily explained by the colder climates. On the other hand, the homes in Washington use significantly more gas than Oregon or Idaho. This difference may be due to the greater availability of gas in Washington or, potentially, the greater use of supplemental fuels in the other states

Table 154: Average Annual Gas Use per Home by State

State	Therms per Home		
	Mean	EB	n
ID	707	49	104
MT	914	86	83
OR	665	46	137
WA	767	37	342
Region	736	24	666

Table 155 shows the results of weather normalizing the gas consumption. The overall impact of weather normalization was less than 4%.

Table 155: Average Weather Normalized Gas Use per Home by State

State	Therms per Home		
	Mean	EB	n
ID	701	46	104
MT	897	86	83
OR	635	44	137
WA	732	37	342
Region	708	24	666

Table 156 summarizes the gas usage normalized by home size, with the results separated into two categories. If the survey identified a home with primary gas heat, the total therm consumption is in the "Homes with Gas Heat" column; if not, then the consumption is summarized in the "Homes with Other Heat" column. "All Homes" combines the two groups to provide a gas EUI for each state and the region. Table 157 shows the heating estimate for gas consumption.

Table 156: Average Gas EUI per Home by Heating Fuel and State

State		Gas EUI per Home (therms/sq.ft.)			
		Homes w/ Gas Heat	Homes w/ Other Heat	All Heat w/ Gas Meters	n
ID	Mean	0.362	0.283	0.357	104
	EB	0.024	0.131	0.024	
MT	Mean	0.452	0.198	0.445	83
	EB	0.033	0.155	0.033	
OR	Mean	0.372	0.206	0.348	137
	EB	0.024	0.048	0.025	
WA	Mean	0.388	0.260	0.377	342
	EB	0.017	0.067	0.017	
Region	Mean	0.384	0.235	0.370	666
	EB	0.012	0.039	0.012	

Table 157: Average Estimated Gas Space Heat by State

State	Space Heat per Home (therms)		
	Mean	EB	n
ID	597	40	97
MT	757	81	81
OR	583	39	114
WA	639	29	309
Region	625	20	601

11.4. Total Energy Use Indices

The combination of the electric and gas bills provides a picture of the total energy use of each home. Table 158 shows the total metered energy use. This total is expressed in kilo British thermal units (kBtu). In most cases, the occupants gave the surveyor an estimate of other fuels, but these estimates are not reliable and are not included in the summary of the total billed energy use.

Table 158: Average Annual Electricity and Gas Use per Home by State

State	kBtu per Home		
	Mean	EB	n
ID	92,012	5,400	177
MT	83,468	7,483	167
OR	77,974	4,495	282
WA	84,810	3,276	699
Region	83,678	2,288	1,325

Ecotope calculated EUIs from the total annual energy per home. The EUI is expressed as kBtu per square foot of conditioned floor area. Table 159, Table 160, and Figure 18 show the EUI results by state. Table 159 uses annualized values only, and Table 160 uses weather-normalized results divided by conditioned floor area.

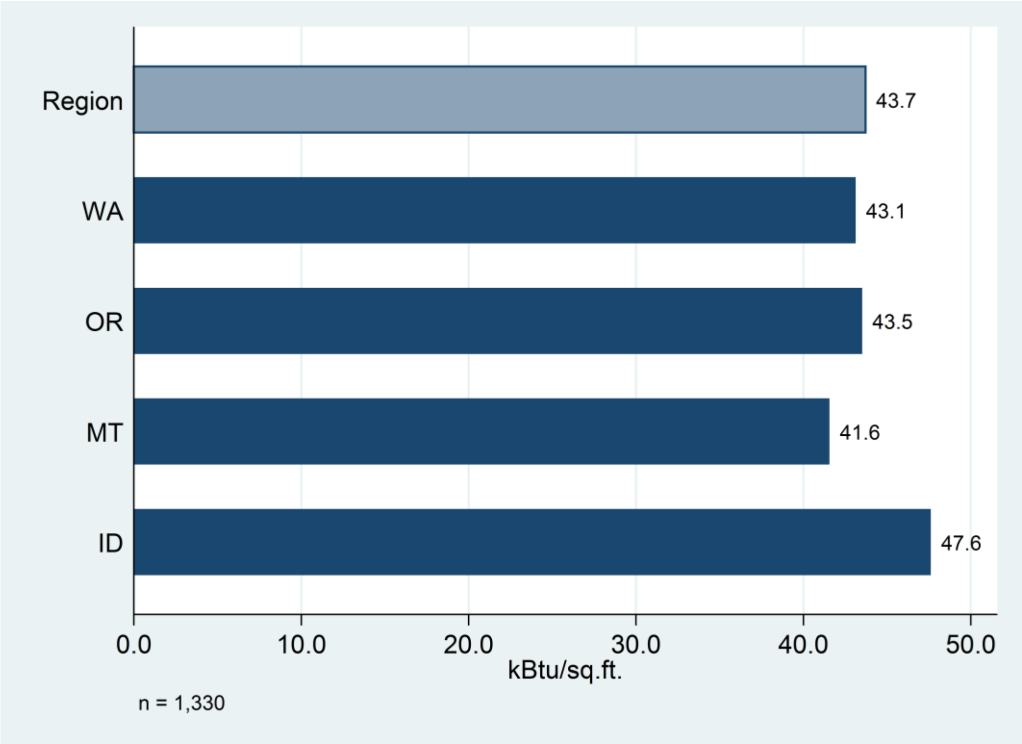
Table 159: Average Electricity and Gas EUI by State

State	EUI per Home (kBtu/sq.ft.)		
	Mean	EB	n
ID	48.3	2.70	177
MT	42.1	3.29	167
OR	45.0	2.48	280
WA	44.6	1.51	694
Region	45.0	1.13	1,318

Table 160: Average Weather-Normalized Electricity and Gas EUI by State

State	EUI per Home (kBtu/sq.ft.)		
	Mean	EB	n
ID	47.6	2.65	178
MT	41.6	3.30	167
OR	43.5	2.30	284
WA	43.1	1.47	701
Region	43.7	1.09	1,330

Figure 18: Average Home Energy Use (kBtu/sq.ft.) Weather Normalized



11.5. Other Fuel Use

Although the evaluation of other non-metered fuels is much less accurate and complete than the metered results, we have assembled the results to give some scale to the impact of these fuels. The heat value of propane and oil is well established. The value of wood is less well established. We have used 18,000 kBtu per cord and 16,000 kBtu per ton of pellet fuel. The heat value of oil was taken at 140 kBtu per gallon, and the heat value of propane was taken at 92 kBtu per gallon. Table 161 summarizes these values based on the approximations made by the occupant. Table 162 summarizes the EUI for the non-metered fuels. These values were averaged over all the sites in each state and the region. The values can be compared in aggregate to the values in Table 158 and Table 159, the annualized metered energy use.

The analysis of these non-metered fuels is compromised by the quality of self-reported data and the approximation required to develop summaries for self-reported energy use. As a result, Ecotope did not develop these numbers further, but it should be noted that if the fuel use estimates are actually unbiased (which is not guaranteed), the aggregate of these fuels would increase the home energy used by all single-family homes by about 18%.

Table 162 expresses the supplemental fuel use as an EUI. This index was calculated as the average for the entire sample. The high level of fuel use presented in Table 162 is a further implication of the importance of supplemental fuels across the region.

Table 161: Average Annual Other Fuel Use per Home by State

State	kBtu per Home		
	Mean	EB	n
ID	16,148	3,478	185
MT	23,064	4,628	169
OR	18,026	3,392	314
WA	12,251	2,225	736
Region	15,243	1,604	1,404

Table 162: Average EUI, Other Fuel Use

State	EUI per Home (kBtu/sq.ft.)		
	Mean	EB	n
ID	8.1	1.9	185
MT	10.5	2.1	169
OR	10.1	1.9	312
WA	6.7	1.3	731
Region	8.2	0.9	1,397

12. Conclusions and Comparisons

The nature of the RBSA was to collect as many characteristics of the single-family residential sector as possible in the context of an energy survey. In this sense, the primary finding of this study is that this goal is realistic if somewhat ambitious. The size of the sample was designed around a level of variance that would subsume many of the characteristics surveyed and provide a high degree of confidence in characteristics that, for many residential sector conservation initiatives, would provide the base for program design and program evaluation.

For most of the summaries shown in this report, the confidence interval meets the 90/10 criteria set as a goal for this sample. Furthermore, for the important variables used to target programs (building shell, lighting, and HVAC), the confidence intervals allow considerable flexibility in using these data and subdividing the data into finer geographic areas.

12.1. Findings and Comparisons to Previous Studies

The most comparable survey conducted in the region is the Single-Family Residential Existing Construction Stock Assessment (RLW 2007a). This study was smaller (429 residential surveys) than the current RBSA and had less geographic representation. However, the scope of the onsite surveys and the goals of the characterization were comparable to the current study. This section is organized around the major sections of the RBSA report and the comparison to 2007 study.

12.1.1. Building Size and Age

One goal of the RBSA was to remove the urban bias that was present in the 2007 study as a result of the clustered sample design. In the RBSA, about 63% of the homes surveyed were built before 1981, whereas in the 2007 study only 44% of the homes were built prior to 1980. The census values for this split indicate that about 62% of all residences were built before 1981. The census values are based on the 2000 census and on all housing types, not just single-family homes. This factor suggests that the sample used by 2007 study was biased toward newer buildings.

An approximate home size comparison can be made between the 2007 study and RBSA. The 2007 study area categories suggest an average home size of about 1,960 sq.ft. In the RBSA, the average home size is 2,006 sq.ft., plus or minus 47 sq.ft. In this case, there is good agreement between the two studies.

The 2007 study reported an average number of people in each home as 2.8. This average compares with the 2.72 number of people reported in the RBSA homes. These two values are well within the margin of error for this variable.

12.1.2. Building Envelope

Building insulation levels observed in the RBSA surveys are dominated by R11–R16 wall insulation. About 45% of the homes have this level of insulation, and about 13% of the sample has no wall insulation. Given the age of the housing stock, this finding suggests that a substantial percentage of the homes have been retrofit. The results are similar for ceiling (attic) insulation.

About 75% of all homes have greater than R20 ceiling insulation. In the 2007 study, about 84% of the homes had greater than R20 insulation in the ceiling and only about 5% of the homes had no insulation in the walls. These discrepancies may be explained by the home vintage differences in the 2007 sample.

Window specification across the RBSA surveys focused on the window frame material and glass types. The window types observed in the RBSA include more than 80% non-metal frames and about 87% double glaze glass or better. The 2007 study found 70% non-metal frames but 80% double glaze or better. The overall window area for the RBSA was 12.5% of conditioned floor area. This ratio was not reported in the 2007 study.

In the RBSA, the heat loss rate of the homes was developed without including convective air flow. The heat loss (normalized to floor area) in this sample showed a reduction of 50% between homes built before 1981 and after 2000. This pattern was pronounced in Washington and Oregon and less apparent in Idaho and Montana.

12.1.3. Lighting

The number of lamps per home in the RBSA sample is 63.2, which is similar to the 62.8 lamps per home reported in the 2007 study. The percentage of CFLs differs between the two studies. The 2007 study observed 9.4% CFL lamps per home, and a total of 11% of all lamps were fluorescent types. In the RBSA, 25% of all lamps are CFLs and a total of 35% of all lamps are some type of fluorescent lamp. This change may reflect the accelerating saturation of these lamp types since the 2007 study was conducted.

The overall LPD in the RBSA is 1.41 W/sq.ft. This calculation was not reported in the 2007 study, but the average total wattage per home was reported as 3,175 Watts. This finding compares with the RBSA average wattage of about 2,800 Watts. Presumably, the increase in fluorescent lamps would explain this difference.

12.1.4. HVAC

The distribution of fuel choices in primary heating systems is similar between the two surveys. The 2007 study noted that 50% of homes reported natural gas as their primary heating fuel compared to about 49% in the RBSA survey. Electric heat was reported as the primary fuel in 41% of the cases in the 2007 study and in 34% of the cases in the RBSA. About 39% of homes reported wood heat use in the 2007 study (about 15% of those cases used wood as their primary source). In contrast, in the RBSA about 20% of the households reported wood heating and about 8% reported wood as their primary heating source. The difference between the two samples relates to the response to the secondary heating fuel questions. About one-third of the 2007 participants said that wood was their secondary fuel, which is comparable to the RBSA finding of about 32%. About 63% of all primary heating systems were forced air furnaces in the 2007 study; about 54% of the primary heating systems in the RBSA consist of forced air furnaces. In addition, about 14% of the systems were ducted heat pumps in the 2007 study; ducted and ductless heat pumps were reported in about 15% of the RBSA homes. Electric zonal heat accounted for about 14% of the primary heating systems in the 2007 study and about 12% in the RBSA survey.

Gas furnace efficiency was compiled by both studies. In the 2007 study, it was reported as about 82%; in the RBSA, it was reported as 84%.

About 42% of the RBSA surveys reported cooling equipment, and the 2007 study reported cooling in about 62% of their sample. Observed SEER ratings for cooling equipment reported in the 2007 study was 10.7 and 10.5 for central AC and heat pumps, respectively. In the RBSA, the SEER ratings are 11.1 for central AC and 13.0 for heat pumps.

12.1.5. Domestic Hot Water

The fuel selected for water heat in the 2007 study was 54% electric and 45% gas, with the rest propane. In the RBSA, the fuel type for water heat is 55% electric and 43% gas, with the balance as propane or other fuel.

12.1.6. Appliances

About 58% of the refrigerators in the RBSA were purchased in 2000 or later. In the 2007 study, this ratio was 51%. Given the five-year gap between the two studies, this is good agreement. The RBSA reported an average refrigerator volume of 24.3 cu.ft.; the 2007 study reported an average refrigerator size of about 21 cu.ft.

About 34% of the clothes washers surveyed in the RBSA were reported as horizontal axis washers. The 2007 study reported about 19% horizontal axis washers. The 2007 study observed that 56% of all clothes washers surveyed were manufactured in 2000 or later. In the RBSA, 69% of all washers were in this vintage range.

The RBSA survey recorded the saturation of appliances. The 2007 study did not collect this information directly; however refrigerator and dishwasher saturations can be compared. The average number of refrigerators per home was about 1.33 in the 2007 study and 1.29 in the RBSA. In addition, the RBSA observed that about 53% of all homes have a standalone freezer. The saturation of dishwashers was about 92% in the 2007 study and about 89% in the RBSA.

12.1.7. Plug Loads

The 2007 study included a brief census of plug loads. This plug-load survey was similar to, but less comprehensive than, the RBSA survey. Televisions and computers can be compared between the two studies.

The average number of televisions per home was 2.6 in the 2007 study and 2.3 in the RBSA survey. In addition, the RBSA reports 1.5 set-top boxes per home and about 33% of homes with one or more gaming systems. In the 2007 study, 90% of homes had at least one computer and the average number of computers across the sample was 1.4 computers per home. In the RBSA survey, more than 90% of homes have a computer and the average number of computers is 1.67 per home (this only included computers that were plugged in, not portable laptops that might have been on the premises).

12.1.8. Energy Use

In the RBSA, electricity and gas bills were collected for about 99% of the sample. Although the 2007 study included electric consumption, the survey did not compile the overall average for the surveyed sample. In the RBSA, the average home across the region uses about 44 kBtu/sq.ft., including 10.8 kWh/sq.ft. of electric load, which represents 58% of all metered energy used per home. In addition, participants reported fuel use from non-metered sources. Although most of these reports could not be directly verified, the compilation of all sites suggests about 15 kBtu per home of non-metered fuel (mostly wood) on average throughout the region. This finding represents about a 15% increase in energy use per home above and beyond the metered energy use.

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September 18, 2012

RESIDENTIAL BUILDING STOCK ASSESSMENT: SINGLE-FAMILY CHARACTERISTICS AND ENERGY USE

Appendix A: Single-Family Onsite Data Collection Protocol

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Appendix A: Single-Family Onsite Data Collection Protocol

This protocol was designed to facilitate the development of the tablet PC data collection software. The following legend and example explain how the protocol is organized. The protocol includes questions surveyors used to survey each single-family home included in this study.

Legend

1. The grey header row represents the branching that occurs when a question is dependent on the response to a previous question.
2. A blue highlight represents a question as shown in the sample below.
3. The white pick list under a question represents potential responses for that question.
4. If one of the items in the pick list prompts additional unique questions, they are noted in a new blue question in a lower row and column (subsequent tier) to the right of the preceding question.

Example

- Question 1: what is the floor type?
  - Choices: slab, crawl, basement, Floor Over Other Area
- Question 2 (if you selected slab): is the slab heated?
  - Choices: yes, no
- Question 3 (if you selected Slab): Is slab insulated?
- Question 4 (if you selected "Yes" that the slab was insulated): Insulation level?
  - Pick list options are always listed below the question

Sample

Tier 1	Tier 2	Tier 3
Floor Type (enter multiple types if necessary)		
Slab		
	Is slab heated?	
	Yes	
	No	
	Is slab insulated?	
	Yes	
	No	
	na	
	unk	
		Insulation level?
		1"
		2"
		3"
		na
		unk

1. General Information

Tier 1	Tier 2	Tier 3
Metering equipment installed as part of RBSA		
Yes		
No		
Type of building		
Single Family, Detached		
Townhouse or Rowhouse		
Duplex, Triplex or Fourplex		
na		
unk		
Floors above ground		
1		
1.5		
2		
2.5		
3+		
na		
unk		
Foundation Type		
> 90% Crawl		
> 90% Slab		
Mixed crawl and slab		
Mixed crawl and room over garage		
> 90 unconditioned basement		
> 90% conditioned basement		
Mixed crawl and unconditioned basement		
Mixed crawl and conditioned basement		
Adiabatic Space Below		
unk		
na		
Are there any outbuildings >100 sq.ft. that are conditioned?		
Yes		
No		

Tier 1	Tier 2	Tier 3
	Fuel type of outbuilding	
	Electricity	
	Gas	
	LPG	
	Oil	
	Other	
	na	
	unk	
Is there a solar PV system present?		
Yes		
No		
Conditioned area of home (from sketch)		
Utility Gas meter number		
Utility Electric meter number		
Meter notes (other number, what they cover, etc)		
Number of incandescent stored (standard A lamp)		
Number of CFLs stored		
Number of other types of light bulbs stored		
Notes - Walk around		
Survey Start Time		
Survey Complete Time		

2. Floors

Tier 1	Tier 2	Tier 3
Floor Type (enter multiple types if necessary)		
Slab		
	Is slab heated?	
	No	
	Yes	
	Is slab insulated?	
	No	
	Yes	
	unk	
	na	
		Insulation level - Slab
		1"
		2"
		3"
		na
		unk
		Insulation position - Slab
		Perimeter
		Complete
		na
		unk
	Floor area - Slab (sq.ft.)	
	Slab Perimeter (LF)	
	Notes	
Crawl		
	Area	
	Floor Insulation Level	
	None	
	R1-R3	
	R4 - R10	
	R11- 15	
	R16-22	
	R23-27	
	R28-35	
	R38+	
	unk	
	na	
	Vents present	
	Yes	
	No	

Tier 1	Tier 2	Tier 3
		Vents blocked
		Yes
		No
	Floor Insulation Condition	
	100%	
	90%	
	75%	
	50%	
	25%	
	na	
	unk	
	Floor Framing	
	Post and Beam	
	Joist	
	na	
	unk	
		Joist Size
		2x6
		2x8
		2x10
		2x12
		na
		unk
	Is there enough room to bring the floor up to R30 without adding additional depth to the floor joists	
	No	
	Yes	
	Crawlspace wall insulated	
	Yes	
	No	
		Crawlspace wall insulation level
		R3-R11
		R12-R20
		R21-R30
		R31+
		na
		unk
	Notes	
Basement		
	Basement Conditioned	
	Yes	
	No	
	Floor above insulated	
	Yes	
	No	

Tier 1	Tier 2	Tier 3
		Floor Above Insulation Type
		Fiberglass-stapled
		Fiberglass-stapled
		Fiberglass-tied/stays
		Rigid
		Blow-in Batt
		Spray Foam
		unk
		na
		Floor Above Insulation Level
		None
		R1-R3
		R4 - R10
		R11- R15
		R16-R22
		R23-R27
		R28-R35
		R38+
		unk
		na
		Floor Above Insulation Condition
		0%
		25%
		50%
		75%
		100%
		unk
		na
		Floor Above Area
	Slab Heated	
	Yes	
	No	
	Slab Insulation	
	1"	
	2"	
	None	
	unk	
	na	

Tier 1	Tier 2	Tier 3
		Slab insulation position
		Complete
		Perimeter
		None
		unk
		na
	Slab area (Sq Ft)	
	Slab perimeter (Lineal Ft)	
	Notes	
Cantilever		
	Floor Insulation Level	
	None	
	R1-R3	
	R4 - R10	
	R11- R15	
	R16-R22	
	R23-R27	
	R28-R35	
	R38+	
	unk	
	na	
	Area	
Floor Over Other Area		
	Area below heated	
	Yes	
	No	
	Type of area below	
	Non Res Occupancy	
	Residential Occupancy	
	Garage	
	Parking	
	Storage	
	Other	
	na	
	unk	
	Floor Type	
	Frame	
	Slab (PT)	
	Other	
	na	
	unk	

Tier 1	Tier 2	Tier 3
	Floor Insulation Level	
	None	
	R1-R3	
	R4-R10	
	R11-R15	
	R16-R22	
	R23-R27	
	R28-R35	
	R38+	
	na	
	unk	
	Floor Insulation Condition	
	100%	
	90%	
	75%	
	50%	
	25%	
	na	
	unk	
	Area	

3. Ducts

Tier 1	Tier 3	Tier 3
Ducts Present?		
Yes		
No		
Type of Duct		
All Metal		
	Insulation type for all metal ducts	
	R0	
	R2 - R4	
	R7- R11	
	na	
	unk	
	Insulation Condition	
	100%	
	90%	
	75%	
	50%	
	25%	
	< 25%	
	na	
	unk	
Metal Plenum, Flex Runs		
	Insulation Type	
	R0 Metal; R4 Flex	
	R0 Metal; R6 Flex	
	R0 Metal; R8 Flex	
	R2 - R4 Metal; R4 Flex	
	R2 - R4 Metal; R6 Flex	
	R2 - R4 Metal; R8 Flex	
	R7-R11 Metal; R4 Flex	
	R7-R11 Metal; R6 Flex	
	R7-R11 Metal; R8 Flex	
	na	
	unk	
90% Flex (spider system)		
	Insulation Type	
	R4 Flex	
	R6 Flex	
	R8 Flex	
	na	
	unk	

Tier 1	Tier 3	Tier 3
100% Duct Board		
	Insulation Type	
	1" Ductboard	
	2" Ductboard	
	na	
	unk	
Duct Board Plenum, Flex Runs		
	Type of Ductboard and flex	
	1" Ductboard R4 Flex	
	2" Ductboard R4 Flex	
	1" Ductboard R6 Flex	
	2" Ductboard R6 Flex	
	1" Ductboard R8 Flex	
	2" Ductboard R8 Flex	
	na	
	unk	
na		
unk		
Cavity used for air transport		
Yes		
No		
Insulation condition		
100%		
90%		
75%		
50%		
25%		
< 25%		
na		
unk		
% Supply in conditioned space		
0		
25		
50		
75		
100		
na		
unk		
% of supply ducts in accessible unconditioned space (attic, crawl, garage; do not include between floors)		
0		
25		
50		
75		
100		
unk		

Tier 1	Tier 3	Tier 3
% supply in inaccessible unconditioned space		
0		
25		
50		
75		
100		
na		
unk		
% of return ducts in conditioned space		
0		
25		
50		
75		
100		
unk		
Notes - Ducts		

4. Walls

Tier 1	Tier 2	Tier 3
Wall Type (enter multiple types if necessary)		
Framed		
	Type of framing	
	2X4	
		Insulation Level
		R0
		R2 - R7
		R11
		R13
		>R13
		na
		unk
		Insulation Type
		Batt
		Loose Fill
		na
		unk
		Rigid Insulation Sheathing
		None
		1"
		2"
		3"+
		na
		unk
		Wall area (above grade)
	2X6	
		Insulation level
		R0
		R1-R13
		R14-R20
		R21-R23
		>R23
		na
		unk

Tier 1	Tier 2	Tier 3
		Insulation Type
		Batt
		Loose Fill
		na
		unk
		Rigid Insulation Sheathing
		None
		1"
		2"
		3"+
		na
		unk
		Wall area (above grade)
	2X8	
		Insulation level
		<R-19
		R19 - R30
		>R30
		na
		unk
		Insulation Type
		Batt
		Loose Fill
		na
		unk
		Rigid Insulation Sheathing
		None
		1"
		2"
		3"+
		na
		unk
		Wall area (above grade)
	Alternative Framed Wall	
		Insulation level

Tier 1	Tier 2	Tier 3
		Insulation Type
		Batt
		Loose Fill
		na
		unk
		Rigid Insulation Sheathing
		None
		1"
		2"
		3"+
		na
		unk
		Alternative Wall Thickness
		9"
		10"- 13"
		>13"
		na
		unk
		Wall area (above grade)
Masonry		
	Masonry Type	
	Brick	
	Concrete Block	
	na	
	unk	
		Block filled w/ insulation
		No
		Yes
	Exterior Insulation Level	
	None	
	R5	
	R10	
	R15	
	R20	
	R21+	
	na	
	unk	

Tier 1	Tier 2	Tier 3
	Furred wall	
	No	
	Yes	
		Framing Size
		2X2
		2X4
		2X6
		2X8
		na
		unk
		Insulation Level
		R0
		R3-R6
		R7-R10
		R11-R20
		na
		unk
		Insulation Type
		Batt
		Loose Fill
		na
		unk
	Area	
	Notes	
ICF		
	ICF Type	
	EPS	
	Urethane	
	Thickness, nominal R	
	na	
	unk	
	Wall thickness	
	6"	
	8"	
	12"	
	na	
	unk	
	Area	
	Notes	

Tier 1	Tier 2	Tier 3
SIPs		
	Thickness	
	4"	
	6"	
	8"	
	10"	
	na	
	unk	
	Area	
	Notes	
Log		
	Thickness	
	6-9"	
	10-14"	
	>15"	
	na	
	unk	
	Area	
	Notes	
Other		
	Describe type	
	Est. Thickness (inches)	
	Area	
	Rigid Insulation Sheathing	
	None	
	1"	
	2"	
	3"+	
	na	
	unk	
	Type of framing	
	2x4	
	2x6	
	2x8	
	Alternative	
	na	
	unk	

Tier 1	Tier 2	Tier 3
	Insulation Type	
	Batt	
	Loose Fill	
	na	
	unk	
	Insulation Level	
	RO	
	R3-R6	
	R7-R10	
	R11-R20	
	unk	
	na	
	Notes	
Adiabatic		
	Adiabatic Type	
	Wall to other living space	
	Wall to heated nonresidential occupancy	
	Other	
	na	
	unk	
		If other, describe
	Wall type	
	Frame	
	Masonry	
	SIPs panel	
	Other	
	na	
	unk	
	Area	
	Notes	
Structural Steel		
	Furred Wall	
	No	
	Yes	

Tier 1	Tier 2	Tier 3
	Size of Framing	
	2X2	
	2X4	
	2X6	
	2X8	
	na	
	unk	
	Insulation Level	
	R0	
	R3-R6	
	R7-R10	
	R11-R20	
	na	
	unk	
	Insulation Type	
	Rigid	
	Fiberglass	
	na	
	unk	
	Area	
	Notes	
Infill Frame		
	Frame type	
	Wood	
	Steel	
	na	
	unk	
	Insulation Level	
	R0	
	R1-R13	
	R14-R20	
	R21-R23	
	>R23	
	na	
	unk	
	Insulation Type	
	Batt	
	Loose Fill	
	na	
	unk	

Tier 1	Tier 2	Tier 3
	Rigid Insulation Sheathing	
	None	
	1"	
	2"	
	3"+	
	na	
	unk	
	Area	
	Notes	
Door		
	Type	
	Wood panel	
	Wood flush	
	Wood hollow	
	Metal insulated	
	wood with 1/2 window	
	na	
	unk	
	Area	
	Notes	
Masonry (Basement)		
	Percent above grade	
	<5% (less than 6 inches)	
	5-10% (7-12 inches)	
	10-25% (13-24 inches)	
	25-50% (24-48 inches)	
	>50% (>48 inches)	
	na	
	unk	
	Insulation Level	
	None	
	R0	
	R5	
	R10	
	R15	
	R20	
	R21+	
	na	
	unk	
	Area	
	Notes	

5. Windows

5.1. Room-by-Room Characteristics

Tier 1	Tier 2	Tier 3
Area of windows (sq.ft. per room)		
Type of window		
Primary		
Secondary		
na		
unk		
Are windows south facing?		
Yes		
No		
Is there a skylight?		
Yes		
No		
	Number of panes in skylight	
	1	
	2	
	3	
	na	
	unk	
	Area of skylight	

5.2. Window Types

5.2.1. Primary Type

Tier 1	Tier 2	Tier 3
% of windows in home of this type		
Frame Type		
Metal		
Wood, Vinyl or Fiberglass		
na		
unk		
Glazing Type		
Single		
Double		
Triple		
na		
unk		
	Width of each air space	
	<1/2"	
	>=1/2"	
	na	
	unk	

Tier 1	Tier 2	Tier 3
Storm windows present		
Yes		
No		
	Effective storm window	
	Yes	
	No	
Low E Coating present?		
Yes		
No		

5.2.2. Secondary Type

Tier 1	Tier 2	Tier 3
Frame Type		
Metal		
Wood, Vinyl or Fiberglass		
na		
unk		
Glazing Type		
Single		
Double		
Triple		
na		
unk		
	Width of each air space	
	<1/2"	
	>=1/2"	
	na	
	unk	
Storm windows present		
Yes		
No		
	Effective storm window	
	Yes	
	No	
Low E Coating present?		
Yes		
No		

6. Ceiling

Tier 1	Tier 2	Tier 3
Average Ceiling Height		
Notes		
Ceiling Type		
Attic/Cathedral		
	Insulation Type	
	Mixed	
	Blown FB	
	Blown Rock Wool	
	Blown Cellulose	
	Other	
	Batt Fiberglass	
	Batt Mineral Wool	
	Batt (other)	
	na	
	unk	
	Insulation Level	
	R0	
	R1 - R10	
	R11 - R15	
	R16-R20	
	R21-R25	
	R26-R30	
	R31-R40	
	R41-R50	
	R50+	
	na	
	unk	
	Insulation Condition	
	100%	
	90%	
	75%	
	50%	
	25%	
	na	
	unk	
	Estimate R-value improvement possible	
	Area	
	Notes	

Tier 1	Tier 2	Tier 3
Roof Deck		
	Insulation Level	
	2"	
	3.5"	
	6"	
	8"	
	na	
	unk	
	Area	
	Notes	
Vault		
	Framing	
	2x4	
	2x6	
	2x8	
	2x10	
	2x12	
	TJI	
	Open Web Truss	
	na	
	unk	
	Insulation Level	
	R0	
	R1 - R15	
	R16 - R20	
	R21-R25	
	R26-R30	
	R31-R40	
	R41-R50	
	na	
	unk	
	Area	
	Notes	

Tier 1	Tier 2	Tier 3
Adiabatic		
	Area	
	Type of area above ceiling	
	Non res occupancy	
	Parking	
	Storage	
	Other	
	na	
	unk	
	Ceiling Type	
	Frame	
	Slab (PT)	
	Other	
	na	
	unk	
	Insulation Type	
	Fiberglass-stapled	
	Fiberglass-tied, stays	
	Rigid	
	Blow-in Batt (BIBS)	
	None	
	na	
	unk	
	Insulation Level	
	R0	
	R5-R9	
	R10-R14	
	R15-R19	
	R20-R29	
	R30+	
	na	
	unk	
	Notes	

Tier 1	Tier 2	Tier 3
Other		
	Insulation value	
	R0	
	R1-R10	
	R11-R15	
	R16-R20	
	R21-R25	
	R26-R30	
	R31-R40	
	R41-R50	
	R50+	
	na	
	unk	
	Area	
	Notes	

7. Customer Interview

7.1. Basic Customer and House Data

Tier 1	Tier 2	Tier 3
Notes		
Name of Surveyor		
Name of person interviewed/person at home		
Billing History Release Form attached		
Yes No		
Billing History Release Form signed by account holder		
Year Built		
Number of bedrooms		
Number of bathrooms		
When did you move in?		
Do you have a CO_2 alarm?		
Yes No		

7.2. Home and Energy Use

Tier 1	Tier 2	Tier 3
Do you use fuels other than from the utility?		
Yes No		
	Quantity of Fuel oil/kerosene (gallons)	
	Quantity of Propane (gallons)	
	Quantity of Wood (cords)	
	Quantity of pellets (tons)	
When you heat your home, what temperature do you try to maintain?		
Do you block off part of your home and keep it at a lower temp? What share?		
No 25% 50% 75% na unk		
When you go to bed, what do you set the thermostat to for heating?		
Do you use any air conditioning equipment in your home?		
Yes **No**		
	When you cool your home, what temperature do you try to maintain?	
	What outdoor temperature triggers you to use cooling inside?	
	When you go to bed, what do you set the thermostat to for cooling?	

Tier 1	Tier 2	Tier 3
Clothes washer loads per week		
Dishwasher loads per week		
% of loads that go in dryer		
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
na		
unk		
% of loads washed in hot water		
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
na		
unk		
Do you have any indoor air quality problems?		
Yes		
No		
	Stuffy	
	Yes	
	No	
	Drafty	
	Yes	
	No	
	Mildew	
	Yes	
	No	
	Persistent Odor	
	Yes	
	No	

Tier 1	Tier 2	Tier 3
Which heating system do you use the most?		
Boiler or Hot Water Tank		
Ductless Mini-split Heat Pump		
Electric Forced Air Furnace		
Gas Forced Air Furnace		
Gas Wall/Zonal		
Heat Pump (Air)		
Heat Pump (air) Dual Fuel		
Heat Pump (Geothermal)		
Oil Forced Air Furnace		
Packaged Terminal Heat Pump		
Plug In Heater		
Space Heating Stove/Fireplace		
na		
unk		
Which 2 TVs do you use the most?		
How many hours per day is the primary TV on?		
What is the age of the primary TV?		
How many hours per day is the secondary TV on?		
What is the age of the secondary TV?		
Do you use portable heating equipment (that might not be visible during walkthrough)		
Yes		
No		
How many additional TVs do you have?		
About how many hours per day do you use these additional TVs?		
Do you use portable cooling equipment (that might not be visible during walkthrough)		
Yes		
No		
Which showerhead do you use the most?		
If you have game equipment, do you use it to play DVDs or Blu-ray movies?		
Yes		
No		
If you have game equipment, do you use it to access the internet (email, Netflix, video chat, etc)?		
Yes		
No		

7.3. Demographics

Tier 1	Tier 2	Tier 3
What are the ages of the people who live here?		
<1?		
1-5?		
6-10?		
11-18?		
19-45?		
46-64?		
65 or older?		
How many people work outside the home?		
Is there a business operated out of the home?		
Yes		
No		
Do you own or rent?		
Own/Buying		
Rent		
Occupied without rent		
na		
unk		
	Who pays the electric bill?	
	Occupant	
	Landlord	
	HOA	
	na	
	unk	
	Who pays the gas bill?	
	Occupant	
	Landlord	
	HOA	
	na	
	unk	
Is this your primary home?		
Primary		
Secondary		
Temporary Outpost		
na		
unk		
Energy bill assistance and weatherization assistance are available based on income criteria. Do you qualify for other kinds of assistance?		
Yes		
No		

Tier 1	Tier 2	Tier 3
	Does another entity pay part of your electric bill? What Share?	
	No	
	25%	
	50%	
	75%	
	100%	
	na	
	unk	
	Does another entity pay part of your gas bill? What Share?	
	No	
	25%	
	50%	
	75%	
	100%	
	na	
	unk	
In the last year, have you just moved in?		
Yes		
No		
…An occupant moved out?		
Yes		
No		
New occupant moved in?		
Yes		
No		
Planning to move soon?		
Yes		
No		
Notes		

7.4. Conservation Improvements

Tier 1	Tier 2	Tier 3
Did you participate in a utility conservation program in the last two years?		
Yes		
No		
	Audit	
	Yes	
	No	
	Lighting	
	Yes	
	No	
	Heating	
	Yes	
	No	

Tier 1	Tier 2	Tier 3
	Cooling	
	Yes	
	No	
	Water Heating	
	Yes	
	No	
	Major Appliance	
	Yes	
	No	
		What kind of major appliance?
		Refrigerator
		Freezer
		Dishwasher
		Clothes washer
		Dryer
		na
		unk
	Showerhead	
	Yes	
	No	
	Weatherization (Insulation)	
	Yes	
	No	
		Ceiling Insulation
		Yes
		No
		Wall Insulation
		Yes
		No
		Floor Insulation
		Yes
		No
		Replacement Windows
		Yes
		No
		Duct Insulation
		Yes
		No
		Duct Sealing
		Yes
		No
		Air Sealing
		Yes
		No

Tier 1	Tier 2	Tier 3
		Door (Replacement)
		Yes
		No
	Other	
	Yes	
	No	
	Did you receive a tax credit for this work?	
	Yes	
	No	
		Federal?
		Yes
		No
		State?
		Yes
		No
		Other Tax Credit?
		Yes
		No
Did you do any conservation on your own in the last few years?		
Yes		
No		
	Audit	
	Yes	
	No	
	Lighting	
	Yes	
	No	
	Heating	
	Yes	
	No	
	Cooling	
	Yes	
	No	
	Water Heating	
	Yes	
	No	
	Major Appliance	
	Yes	
	No	

Tier 1	Tier 2	Tier 3
		What kind of major appliance?
		Refrigerator
		Freezer
		Dishwasher
		Clothes washer
		Dryer
		na
		unk
	Showerhead	
	Yes	
	No	
	Weatherization (Insulation)	
	Yes	
	No	
		Ceiling Insulation
		Yes
		No
		Wall Insulation
		Yes
		No
		Floor Insulation
		Yes
		No
		Replacement Windows
		Yes
		No
		Duct Insulation
		Yes
		No
		Duct Sealing
		Yes
		No
		Air Sealing
		Yes
		No
		Door (Replacement)
		Yes
		No
	Other	
	Yes	
	No	

Tier 1	Tier 2	Tier 3
	Did you receive a tax credit for this work?	
	Yes	
	No	
		Federal?
		Yes
		No
		State?
		Yes
		No
		Other Tax Credit?
		Yes
		No
If you changed space or water heating system for any reason, did it replace existing system or is it an additional system?		
na		
Replace		
Additional		
unk		
What was changed?		
Space heat		
Water heat		
unk		
na		
If replaced, how did it differ?		
Similar to what was replaced		
Similar but more efficient		
After 2005		
Different system		
na		
unk		
Does the new equipment use a different heating fuel?		
Yes		
No		
	Describe old	
	Describe new	

7.5. Planned Purchase

Tier 1	Tier 2	Tier 3
Do you plan to upgrade your heating system in the next year?		
No		
Replace heating system		
Change fuels		
Add air conditioning		
Upgrade duct system		
na		
unk		

Tier 1	Tier 2	Tier 3
Do you plan to upgrade your water heater in the next year?		
No		
Electric Tank		
Electric Instant		
Gas Tank		
Gas Instant		
na		
unk		
Do you plan a major appliance purchase in the next year?		
Yes		
No		
	TV	
	Yes	
	No	
	Washer/Dryer	
	Yes	
	No	
	Refrigerator	
	Yes	
	No	
	Dishwasher	
	Yes	
	No	
	120v Space Heater	
	Yes	
	No	
	Window AC Unit	
	Yes	
	No	
	Other	
	Yes	
	No	
		"Other" planned purchase (Not in previous list)
Have you heard of Energy Star ratings for appliances?		
Yes		
No		
	Are you satisfied with the performance of Energy Star appliances?	
	Yes	
	No	
Notes		

8. Rooms

Tier 1	Tier 2	Tier 3
Room Type		
Bathroom		
Bedroom		
Master Bedroom		
Closet		
Dining Room		
Garage		
Hall		
Kitchen		
Laundry Room		
Living Room		
Family Room		
Office		
Other		
Exterior		
na		
unk		
Is room part of a conditioned area of home?		
Yes		
No		
Room Area		
Notes		

9. Lighting

Tier 1	Tier 2	Tier 3
Fixture Quantity		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
na		
unk		
Fixture Type		
Ceiling Fixture		
Chandelier (Hanging)		
Ceiling Fan		
Architectural		
Floor Lamp		
Torchiere		
Recessed Can		
Recessed - other		
Table		
Track		
Wall mount		
High bay		
Low bay		
Garage door opener		
Exit		
Exterior		
Other		
na		
unk		

Tier 1	Tier 2	Tier 3
Lamp Category		
Incandescent		
	Lamp Type	
	Standard A Lamp	
	Decorative	
	Globe	
	Clear	
	Reflector	
	Mini base	
	Heat Lamp	
	3-Way Incandescent	
	Colored	
	unk	
	Other	
	na	
	Watts Per Lamp	
	5	
	25	
	40	
	60	
	65	
	75	
	90	
	100	
	125	
	150	
	500	
	na	
	unk	
Compact Fluorescent		
	Lamp Type	
	Pin base	
	Twist	
	A shape bulb	
	Globe	
	Reflector	
	3-Way CFL	
	Flood	
	Circline (Screw Base)	
	Decorative	
	Mini base	
	Straight Tube	
	unk	
	Other	
	na	

Tier 1	Tier 2	Tier 3
	Watts Per Lamp	
	7	
	15	
	22	
	28	
	36	
	42	
	na	
	unk	
Halogen		
	Lamp Type	
	MR	
	PAR	
	Quartz Tube	
	unk	
	Other	
	na	
	Watts Per Lamp	
	20	
	30	
	50	
	75	
	100	
	150	
	na	
	unk	
Linear Fluorescent		
	Lamp Type	
	T-4	
	T-5	
	T-8	
	T-12	
	Fluorescent Unknown	
	Fluorescent Other	
	na	
	unk	
	Watts Per Lamp	
	16	
	20	
	32	
	40	
	60	
	100	
	na	
	unk	
	Lamp Length (feet)	

Tier 1	Tier 2	Tier 3
Other		
	Lamp Type	
	High Pressure Sodium	
	Low Pressure Sodium	
	Mercury Vapor	
	Metal Halide	
	LED Interior	
	LED Exterior	
	unk	
	Other	
	na	
	Watts Per Lamp	
	12	
	15	
	40	
	50	
	90	
	100	
	125	
	150	
	250	
	unk	
	na	
	Lamp Length (feet)	
na		
unk		
Lamps Per Fixture		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
na		
unk		

Tier 1	Tier 2	Tier 3
Control		
Manual		
Dimmer		
Motion		
Photo		
Photo/Motion		
Timer		
Other		
None		
na		
unk		
Notes		

10. Electronics - General

Tier 1	Tier 2	Tier 3
Number of electronics chargers plugged in		
0		
1		
2		
3		
4		
5		
na		
unk		
Number of TVs		
0		
1		
2		
na		
unk		
Number of Games		
0		
1		
2		
3		
na		
unk		
Number of Computers/Laptops		
0		
1		
2		
3		
na		
unk		
Number of pieces of Audio Equipment		
0		
1		
2		
3		
4		
5		
na		
unk		
Does Audio Equipment include a subwoofer		
No		
Passive		
Powered		
na		
unk		

Tier 1	Tier 2	Tier 3
Does subwoofer have indicator light or was it warm to the touch?		
Yes		
No		
Notes		

11. Television

Tier 1	Tier 2	Tier 3
Type		
CRT		
Other	**Model**	
na		
unk		
Is this one of two primary TVs		
No		
Primary	**Wattage (measured)**	
Secondary		
unk		
na		
Number of auxiliary items plugged in associated with TV		
Are auxiliary devices all plugged into a single strip?		
Yes		
No		
Brand		
AOC		
Epson		
Funai		
Haier		
Hitachi		
Insignia		
JVC		
LG		
Mitsubishi		
Optima		
Panasonic		
Phillips		
Polaroid		
Samsung		
Sanyo		
Sharp		
Sony		
Toshiba		
ViewSonic		
Vizio		
Westinghouse		
na		
unk		
Size (diagonal inches)		
Manufacture Date of TV		

Tier 1	Tier 2	Tier 3
Cable/Satellite STB Provider		
None		
Comcast		
Time Warner Cable		
Direct TV		
Dish Network		
Sky Angel		
Other		
na		
unk		
Year STB Issued		
Is STB full size or small device		
Full		
Small		
na		
unk		
Do they record shows on their STB?		
Yes		
No		
Notes		

12. Game System

Tier 1	Tier 2	Tier 3
Brand		
Playstation2		
Playstation3		
Xbox 360		
Nintendo Game Cube		
Nintendo Wii		
Other		
na		
unk		
	Release	
	Original	
	Slim	
	na	
	unk	
Is it used to play DVDs or Blu-ray movies?		
Yes		
No		
Is it used to access the internet (email, Netflix, video chat, etc)?		
Yes		
No		
Notes		

13. Computer

Tier 1	Tier 2	Tier 3
Type		
Desktop		
Notebook		
Integrated		
na		
unk		
	Number of screens	
	1	
	2	
	3	
		Size of screen 1
		Size of screen 2
		Size of screen 3
Number of other things plugged in associated with computer (Printers, etc)		
Are all items plugged into a single strip?		
Yes		
No		
Notes		

14. HVAC

Tier 1	Tier 2	Tier 3
Electric Forced Air Furnace		
	Primary heating system	
	Yes	
	No	
	KW	
	5	
	10	
	15	
	20	
	25	
	na	
	unk	
	Fan type	
	ECM	
	PSC	
	na	
	unk	
	Filter	
	Electronic air cleaner	
	Disposable thin	
	Disposable thick pleated	
	Other	
	None	
	na	
	unk	
	Controls	
	Programmable thermostat	
	Non-programmable thermostat	
	na	
	unk	
	Year of Manufacture	
	Distribution (repeat fields)	
	Ducted	
	Radiant slab	
	Radiators	
	na	
	unk	
	Notes	
Gas Forced Air Furnace		
	Primary heating system	
	Yes	
	No	

Tier 1	Tier 2	Tier 3
	Equipment Type	
	Atmospheric	
	Draft Assist	
	Condensing	
	Condensing Post 2005	
	na	
	unk	
		Ignition
		Intermittent
		Ignition
		Standing pilot
		na
		unk
		Model number
	Fan type	
	ECM	
	PSC	
	na	
	unk	
	Filter	
	Electronic air cleaner	
	Disposable thin	
	Disposable thick pleated	
	Other	
	None	
	na	
	unk	
	Distribution	
	Ducted	
	Radiant	
	Radiators	
	na	
	unk	
	Controls	
	Programmable Thermostat	
	Non-Programmable thermostat	
	na	
	unk	
	Year of Manufacture	

Tier 1	Tier 2	Tier 3
	Brand	
	Amana	
	American Standard	
	Armstrong	
	Bryant	
	Carrier	
	Climate Master	
	Coleman	
	Day&Night	
	Evcon	
	Frigidaire	
	General Electric	
	Goodman	
	Heil	
	Intertherm	
	Janitrol	
	Lennox	
	Nordyne	
	Ruud	
	Rheem	
	Sears	
	Tappan	
	Temp Star	
	Trane	
	unk	
	na	
	Input BTUs	
	Output BTUs	
	Notes	
Boiler or Hot Water Tank		
	Primary heating system	
	Yes	
	No	
	Fuel	
	Gas	
	Electric	
	Oil	
	na	
	unk	
		Ignition
		Standing pilot
		Ignition
		na
		unk

Tier 1	Tier 2	Tier 3
		Combustion Type
		Atmospheric
		Draft Assist
		Condensing
		na
		unk
		Input BTUs
		Output BTUs
		KW
	Controls	
	Programmable thermostat	
	Non-programmable thermostat	
	na	
	unk	
	Distribution	
	Ducted	
	Radiant Floor	
	Radiators	
	Fan Coils	
	Combo	
	na	
	unk	

Tier 1	Tier 2	Tier 3
	Brand	
	Amana	
	American Standard	
	Armstrong	
	Bryant	
	Carrier	
	Climate Master	
	Coleman	
	Day&Night	
	Evcon	
	Frigidaire	
	General Electric	
	Goodman	
	Heil	
	Intertherm	
	Janitrol	
	Lennox	
	Nordyne	
	Ruud	
	Rheem	
	Sears	
	Tappan	
	Temp Star	
	Trane	
	na	
	unk	
	Model number	
	Notes	
Gas Wall/Zonal		
	Primary heating system	
	Yes	
	No	
	Ignition	
	Standing Pilot	
	Intermittent Ignition	
	na	
	unk	
	Equipment Type	
	Atmospheric	
	Condensing	
	na	
	unk	
	Input Btus	
	Outputs Btus	
	Notes	

Tier 1	Tier 2	Tier 3
Space Heating Stove / Fireplace		
	Primary heating system	
	Yes	
	No	
	Equipment Type	
	Open Hearth	
	Glass Door Over Open Hearth	
	Rated Equipment	
	Enclosed Wood Stove	
	na	
	unk	
	Fuel	
	Natural Gas	
	Propane	
	Wood	
	Pellets	
	Oil	
	Coal	
	Other	
	na	
	unk	
		Ignition
		Standing pilot
		Ignition
		Manual
		na
		unk
		Input Btus
		Outputs Btus
	Controls	
	None	
	on/off	
	Thermostat	
	na	
	unk	
	Notes	
Electric Resistance Wall/Zonal		
	Primary heating system	
	Yes	
	No	
	Quantity	

Tier 1	Tier 2	Tier 3
	Controls	
	Programmable thermostat	
	Non-programmable thermostat	
	Manual	
	None	
	na	
	unk	
	Voltage	
	110	
	220	
	240	
	na	
	unk	
	Use	
	Seldom	
	A little	
	All the time	
	na	
	unk	
	Notes	
Plug in Heater		
	Primary heating system	
	Yes	
	No	
	Use	
	Seldom	
	A little	
	All the time	
	na	
	unk	
	Quantity	
	Notes	
Heat pump (Air)		
	Primary heating system	
	Yes	
	No	
	Outdoor Unit Model	
	Fan Type	
	ECM	
	PSC	
	unk	
	na	

Tier 1	Tier 2	Tier 3
	Filter	
	Electronic air cleaner	
	Disposable thin	
	Disposable thick pleated	
	Other	
	None	
	na	
	unk	
	Controls	
	Programmable thermostat	
	Non-programmable thermostat	
	na	
	unk	
	Outdoor Unit Manufacture Date	
	Brand	
	Amana	
	American Standard	
	Armstrong	
	Bryant	
	Carrier	
	Climate Master	
	Coleman	
	Day&Night	
	Evcon	
	Florida Heat pump	
	Frigidaire	
	General Electric	
	Goodman	
	Heil	
	Intertherm	
	Janitrol	
	Lennox	
	Nordyne	
	Ruud	
	Rheem	
	Sears	
	Tappan	
	Temp Star	
	Trane	
	na	
	unk	
	Size (Cooling Tons, ex 2.5)	
	Compressor works in heat mode	
	Yes	
	No	
	Notes	

Tier 1	Tier 2	Tier 3
Ductless Mini-split Heat Pump (Ductless Heat Pump)		
	Distribution	
	Zonal	
	Ducted	
	na	
	unk	
	Controls	
	Remote Control	
	Wall Mounted Thermostat	
	na	
	unk	
	Indoor Unit Brand	
	Carrier	
	Daikin	
	Fedders	
	Friedrich	
	Fujitsu	
	LG	
	Mitsubishi	
	Samsung	
	Sanyo	
	na	
	unk	
	Outdoor Unit Manufacture Date	
	Multi-head system	
	Yes	
	No	
	Indoor Unit Model	
	Size (Cooling Tons, ex 2,5)	
	Zones Served	
	Bathroom	
	Yes	
	No	
	Bedroom	
	Yes	
	No	
	Master Bedroom	
	Yes	
	No	
	Dining Room	
	Yes	
	No	
	Hall	
	Yes	
	No	

Tier 1	Tier 2	Tier 3
	Kitchen	
	Yes	
	No	
	Laundry Room	
	Yes	
	No	
	Living Room	
	Yes	
	No	
	Family Room	
	Yes	
	No	
	Office	
	Yes	
	No	
	Other	
	Yes	
	No	
Heat Pump (air) Dual Fuel		
	Primary heating system	
	Yes	
	No	
	Backup heat fuel	
	Gas	
	Propane	
	Oil	
	na	
	unk	
	Outdoor Unit Model	
	Fan Type	
	ECM	
	PSC	
	unk	
	na	
	Filter	
	Electronic air cleaner	
	Disposable thin	
	Disposable thick pleated	
	Other	
	None	
	na	
	unk	
	Controls	
	Programmable thermostat	
	Non-programmable thermostat	
	na	
	unk	

Tier 1	Tier 2	Tier 3
	Outdoor Unit Manufacture Date	
	Brand	
	Amana	
	American Standard	
	Armstrong	
	Bryant	
	Carrier	
	Climate Master	
	Coleman	
	Day&Night	
	Evcon	
	Florida Heat pump	
	Frigidaire	
	General Electric	
	Goodman	
	Heil	
	Intertherm	
	Janitrol	
	Lennox	
	Nordyne	
	Ruud	
	Rheem	
	Sears	
	Tappan	
	Temp Star	
	Trane	
	na	
	unk	
	Size (cooling Tons, ex 2.5)	
	Compressor works in heat mode	
	Yes	
	No	
	Backup equipment type	
	Atmospheric	
	Draft Assist	
	Condensing	
	Condensing post 2005	
	na	
	unk	
		Backup ignition
		Standing pilot
		Intermittent Ignition
		na
		unk
		Backup Model
	Backup Manufacture date	

Tier 1	Tier 2	Tier 3
	Backup Input BTUs	
	40000	
	60000	
	80000	
	100000	
	120000	
	na	
	unk	
	Backup Output BTUs	
	40000	
	60000	
	80000	
	100000	
	120000	
	na	
	unk	
	Backup brand	
	Amana	
	American Standard	
	Armstrong	
	Bryant	
	Carrier	
	Climate Master	
	Coleman	
	Day&Night	
	Evcon	
	Florida Heat pump	
	Frigidaire	
	General Electric	
	Goodman	
	Heil	
	Intertherm	
	Janitrol	
	Lennox	
	Nordyne	
	Ruud	
	Rheem	
	Sears	
	Tappan	
	Temp Star	
	Trane	
	na	
	unk	
	Notes	

Tier 1	Tier 2	Tier 3
Heat pump (Geothermal)		
	Open or closed loop	
	Open	
	Close	
	na	
	unk	
	Water or ground loop	
	Ground	
	Water	
	na	
	unk	
	Back up heat type	
	Gas	
	Electric	
	None	
	na	
	unk	
	Fan Type	
	ECM	
	PSC	
	na	
	unk	
	Distribution	
	Ducts/Forced air	
	Hot Water distribution	
	Both	
	na	
	unk	
	Filter	
	Electronic air cleaner	
	disposable thin	
	disposable thick pleated	
	other	
	None	
	na	
	unk	
	Controls	
	Programmable thermostat	
	Non-programmable thermostat	
	na	
	unk	

Tier 1	Tier 2	Tier 3
	GSHP Brand	
	Amana	
	American Standard	
	Armstrong	
	Bryant	
	Carrier	
	Climate Master	
	Coleman	
	Day&Night	
	Evcon	
	Florida Heat pump	
	Frigidaire	
	General Electric	
	Goodman	
	Heil	
	Intertherm	
	Janitrol	
	Lennox	
	Nordyne	
	Ruud	
	Rheem	
	Sears	
	Tappan	
	Temp Star	
	Trane	
	na	
	unk	
	Model	
	Notes	
Packaged Terminal Heat Pump		
	Is this the Primary system	
	Yes	
	No	
	Equipment type	
	Through wall	
	Window Shaker	
	na	
	unk	
	Number of units	
	Brand	
	Model #	
	Cooling Capacity	
	Manufacture Date	
	Energy Star Label Present?	
	Yes	
	No	
	Notes	

Tier 1	Tier 2	Tier 3
Oil Forced Air furnace		
	Oil furnace present	
	Yes	
	No	
	Primary heating system	
	Yes	
	No	
	Notes	
Fireplace		
	Primary heating system	
	Yes	
	No	
	Fuel	
	Wood	
	Propane	
	na	
	unk	
Wood / Propane Stove		
	Primary heating system	
	Yes	
	No	
	Fuel	
	Wood	
	Propane	
	na	
	unk	

14.1. Cooling

Tier 1	Tier 2	Tier 3
Cooling Type		
Central Air		
	Fan Type	
	ECM	
	PSC	
	unk	
	na	
	Filter	
	Electronic air cleaner	
	Disposable thin	
	Disposable thick pleated	
	Other	
	None	
	unk	
	na	

Tier 1	Tier 2	Tier 3
	Controls	
	Programmable thermostat	
	Non-programmable thermostat	
	unk	
	na	
	Brand	
	Amana	
	American Standard	
	Armstrong	
	Bryant	
	Carrier	
	Climate Masters	
	Coleman	
	Day & Night	
	Evcon	
	Florida Heat Pump	
	Frigidaire	
	General Electric	
	Goodman	
	Heil	
	Intertherm	
	Janitrol	
	Lennox	
	Nordyne	
	Ruud	
	Rheem	
	Sears	
	Tappan	
	Temp Star	
	Trane	
	na	
	unk	
	Size (Cooling Tons)	
	Model # of outdoor unit	
	Manufacture Date	
	Notes	
PTAC		
	Equipment type	
	Through wall	
	Window Shaker	
	na	
	unk	
	Primary heating system	
	Yes	
	No	
	Number of units	
	Days of use per year	

Tier 1	Tier 2	Tier 3
	Brand	
	Amana	
	American Standard	
	Armstrong	
	Bryant	
	Carrier	
	Climate Masters	
	Coleman	
	Day & Night	
	Evcon	
	Florida Heat Pump	
	Frigidaire	
	General Electric	
	Goodman	
	Heil	
	Intertherm	
	Janitrol	
	Lennox	
	Nordyne	
	Ruud	
	Rheem	
	Sears	
	Tappan	
	Temp Star	
	Trane	
	na	
	unk	
	Model	
	Notes	
Evaporative Cooler		
	Evaporative scale	
	Zonal	
	Central	
	Both	
	unk	
	na	
	Size (CFM)	
	Notes	
Ductless Mini-split Air Conditioner (Ductless Heat Pump)		
	Distribution	
	Zonal	
	Ducted	
	na	
	unk	

Tier 1	Tier 2	Tier 3
	Controls	
	Remote control	
	Wall mounted thermostat	
	na	
	unk	
	Indoor Unit Brand	
	Carrier	
	Daikin	
	Fedders	
	Friedrich	
	Fujitsu	
	LG	
	Mitsubishi	
	Samsung	
	Sanyo	
	na	
	unk	
	Outdoor Unit Manufacture Date	
	Multihead System	
	Yes	
	No	
	Model	
	Size (Cooling Tons, ex 2.5)	
	Zones Served	
	Bathroom	
	Yes	
	No	
	Bedroom	
	Yes	
	No	
	Master Bedroom	
	Yes	
	No	
	Dining Room	
	Yes	
	No	
	Hall	
	Yes	
	No	
	Kitchen	
	Yes	
	No	
	Laundry Room	
	Yes	
	No	

Tier 1	Tier 2	Tier 3
	Living Room	
	Yes	
	No	
	Family Room	
	Yes	
	No	
	Office	
	Yes	
	No	
	Other	
	Yes	
	No	

14.2. Ventilation

Tier 1	Tier 2	Tier 3
Ventilation Types		
Bathroom Vent		
	Equipment Grade	
	Builder Grade	
	Panasonic or equivalent	
	na	
	unk	
	Working	
	Yes	
	No	
	Controls	
	Manual switch	
	Continuous	
	Timer	
	na	
	unk	
	Hours per day	
	Notes	
Central Vent		
	Equipment Type	
	Builder Grade	
	Panasonic or equivalent	
	Remote fan with multiple pickups	
	na	
	unk	
	Working	
	Yes	
	No	

Tier 1	Tier 2	Tier 3
	Controls	
	Manual switch	
	Continuous	
	Timer	
	Other	
	na	
	unk	
	# Hours	
	Notes	
Central Vent with Return		
	Equipment Type	
	Controlled	
	Non-controlled	
	na	
	unk	
	Controls	
	Manual switch	
	Continuous	
	Timer	
	Other	
	na	
	unk	
		If Timer. # Hours
	Notes	
ERV / HRV		
	Manufacturer	
	Model	
	Hours	
	Equipment Type	
	Stand-alone ducts	
	Attached to duct system	
	na	
	unk	
	Working	
	Yes	
	No	
	Rated CFM	
	Controls	
	Manual switch	
	Continuous	
	Timer	
	na	
	unk	
	Notes	

Tier 1	Tier 2	Tier 3
Kitchen Vent		
	Equipment Type	
	High Capacity Exhaust Range Hood	
	Small Capacity Exhaust	
	Recirculating only	
	na	
	unk	
	Notes	

15. Appliances

15.1. Water Heater

Tier 1	Tier 2	Tier 3
Fuel		
Gas		
Oil/Kerosene		
Electricity		
Wood		
Propane		
na		
unk		
	Standing Pilot	
	Yes	
	No	
System type		
Storage		
Instantaneous		
na		
unk		
	Equipment type	
	Tank	
	Condensing	
	na	
	unk	
		Tank Size (Gallons)
		Tank Wrap
		Yes
		No
	Input Capacity (BTUs. Gas water heaters only, ex. 40000, no comma)	
	Input Capacity (kW, Electric water heaters only)	
Serves whole house		
Yes		
No		
Manufacture Date		
Solar water heating		
Yes		
No		

Tier 1	Tier 2	Tier 3
Location		
Garage		
Main House		
Basement		
Crawl		
Other		
na		
unk		
	If in garage, can it obtain supply air from inside of house (is it within 6 unobstructed feet of the house/garage wall?)	
In conditioned space		
Yes		
No		
	If in house, can it exhaust to the garage? (is it within 6 unobstructed feet of the house/garage wall?)	
Is the room it's in greater than 1000 cubic ft?		
Yes		
No		
Is it within 4 feet of a drain		
Yes		
No		
	Type of drain	
	Floor Drain	
	Plumbed Drain	
	unk	
	na	
Clearance: is there 8 feet of vertical space available for the equipment?		
Yes		
No		

15.2. Showerheads

Tier 1	Tier 2	Tier 3
Number of showerheads		
Flow rate of primary		
Notes		

15.3. Clothes Washer

Tier 1	Tier 2	Tier 3
Clothes Washer Type		
Vertical Axis (with agitator)		
Vertical Axis (without agitator)		
Horizontal Axis		
Combined Washer/Dryer in one drum		
Stacked Washer/Dryer		
na		
unk		
Brand		
Amana		
AKSO		
Bosch		
Fisher & Paykel		
General Electric		
Hot Point		
IKEA		
Kirkland		
Kitchen Aid		
LG		
Litton		
Maytag		
Neptune		
Sears		
Kenmore		
Sub-Zero		
Tappan		
Whirlpool		
White/Westinghouse		
unk		
Year of Manufacture		
Notes		

15.4. Clothes Dryer

Tier 1	Tier 2	Tier 3
Year of Manufacture		
Fuel		
Gas		
Electric		
Propane		
na		
unk		

15.5. Refrigerator/Freezer

Tier 1	Tier 2	Tier 3
Energy Star label		
Yes		
No		
Style		
R/F Side by Side		
R/F Bottom freezer		
R/F Top freezer		
Freezer, chest		
Freezer, upright		
Full Size Single Refrigerator Only		
Side By Side w/ Bottom Freezer		
na		
unk		
	Icemaker type	
	Through Door	
	In Freezer	
	None	
	na	
	unk	
	Icemaker working	
	Yes	
	No	
Volume (cu ft)		
Year of manufacture		
Brand		
Amana		
AKSO		
Bosch		
Fisher & Paykel		
General Electric		
Hot Point		
IKEA		
Kirkland		
Kitchen Aid		
LG		
Litton		
Maytag		
Neptune		
Sears		
Kenmore		
Sub-Zero		
Tappan		
Whirlpool		
White/Westinghouse		
unk		
na		

Tier 1	Tier 2	Tier 3
Model Number		
% of year used		
25%		
50%		
75%		
100%		
na		
unk		
Location		
Conditioned		
Unconditioned		
na		
unk		
Notes		

15.6. Cooking

Tier 1	Tier 2	Tier 3
Oven Fuel		
Electric		
Gas		
Propane		
No Oven		
Other		
na		
unk		
Cooktop Fuel		
Electric		
Gas		
Propane		
Other		
na		
unk		
Notes		

15.7. Dishwasher

Tier 1	Tier 2	Tier 3
Year of manufacture		
Notes		

15.8. Large Unusual Loads

Tier 1	Tier 2	Tier 3
Notes		
Large Unusual Load		
	Equipment Type	
	Chicken heat lamp	
	Engine block heater	
	Freshwater Pump (i.e. House supply)	
	Heated pool	
	Heated waterbed	
	Hot tub	
	Hot water circ pump	
	Irrigation pump	
	Kiln (Electric)	
	Kiln (Gas)	
	Kiln (other fuel)	
	Pipe Heater	
	Sauna	
	Septic pump	
	Standalone Ice Maker	
	Stock tank heaters	
	Water feature	
	Welder (electric)	
	na	
	unk	
	Quantity	
	Location	
	Notes	

September 18, 2012

RESIDENTIAL BUILDING STOCK ASSESSMENT: SINGLE-FAMILY CHARACTERISTICS AND ENERGY USE

Appendix B: Breakout Tables for Electrically Heated Homes

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LIST OF TABLES

Appendix B: Breakout Tables for Electrically Heated Homes

Table B - 1: Distribution of Electrically Heated Homes by Vintage and State

Vintage		Percentage of Homes					
		ID	MT	OR	WA	Region	n
Pre 1951	%	18.0%	15.3%	19.5%	15.7%	17.0%	98
	EB	10.0%	12.3%	8.2%	3.3%	3.3%	
1951–1960	%	4.4%	14.9%	13.7%	7.8%	9.4%	48
	EB	4.8%	13.3%	7.0%	3.3%	2.9%	
1961–1970	%	11.5%	3.1%	13.0%	10.3%	11.0%	61
	EB	7.8%	5.2%	6.1%	3.0%	2.6%	
1971–1980	%	30.5%	32.9%	26.4%	25.6%	26.6%	116
	EB	11.9%	17.0%	8.6%	5.8%	4.4%	
1981–1990	%	9.0%	12.2%	7.7%	18.1%	13.9%	51
	EB	7.5%	11.4%	5.1%	5.4%	3.6%	
1991–2000	%	10.7%	18.5%	9.7%	13.4%	12.1%	65
	EB	7.7%	13.0%	5.6%	4.1%	3.0%	
Post 2000	%	15.9%	3.1%	10.1%	9.2%	10.0%	53
	EB	8.9%	5.2%	5.3%	3.2%	2.6%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	492

Table B - 2: Distribution of Electrically Heated Homes by Ground Contact Type and State

Ground Contact Type		Percentage of Homes					
		ID	MT	OR	WA	Region	n
Adiabatic Space Below	%	2.6%	6.3%	0.9%	2.0%	1.8%	8
	EB	4.3%	9.9%	1.0%	1.8%	1.2%	
Mixed Crawlspace and Conditioned Basement	%	9.5%	9.6%	5.4%	7.1%	6.9%	33
	EB	7.3%	11.1%	4.8%	3.4%	2.5%	
Mixed Crawlspace and Room Over Garage	%	2.6%	—	8.8%	2.3%	4.2%	15
	EB	4.3%	—	6.0%	1.8%	2.1%	
Mixed Crawlspace and Slab	%	6.1%	6.3%	9.2%	5.0%	6.4%	31
	EB	6.1%	9.9%	5.7%	2.2%	2.2%	
Mixed Crawlspace and Unconditioned Basement	%	0.8%	—	—	0.4%	0.3%	3
	EB	1.4%	—	—	0.5%	0.3%	
>90% Crawlspace	%	33.7%	26.0%	60.2%	53.6%	52.5%	90
	EB	11.9%	15.9%	9.7%	6.2%	4.8%	
>90% Slab	%	25.2%	9.6%	7.0%	10.0%	10.8%	90
	EB	11.1%	11.1%	5.1%	4.1%	3.1%	
>90% Conditioned Basement	%	18.7%	42.3%	8.2%	19.0%	16.4%	90
	EB	8.9%	18.0%	5.6%	5.4%	3.7%	
>90% Unconditioned Basement	%	0.8%	—	0.4%	0.8%	0.7%	90
	EB	1.4%	—	0.7%	0.7%	0.5%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	450

Table B - 3: Average Conditioned Floor Area by State, Electrically Heated Homes

State	Conditioned Floor Area (sq.ft.)		
	Mean	EB	n
ID	2,014	237	54
MT	1,977	383	24
OR	1,694	156	131
WA	1,900	104	289
Region	1,854	80	498

Table B - 4: Average Conditioned Floor Area by Vintage and State, Electrically Heated Homes

Vintage		Conditioned Floor Area (sq.ft.)					
		ID	MT	OR	WA	Region	n
Pre 1951	Mean	1,805	1,688	1,636	1,545	1,610	98
	EB	403	678	444	168	181	
1951–1960	Mean	1,160	1,307	1,311	1,517	1,401	48
	EB	356	496	324	335	208	
1961–1970	Mean	1,927	996	1,771	1,842	1,820	61
	EB	529	—	433	200	192	
1971–1980	Mean	1,760	1,884	1,791	1,904	1,852	115
	EB	333	611	375	214	167	
1981–1990	Mean	2,144	1,274	1,670	1,975	1,919	50
	EB	737	192	183	251	197	
1991–2000	Mean	2,058	2,798	2,140	2,196	2,196	65
	EB	762	357	481	256	214	
Post 2000	Mean	3,215	6,414	1,839	2,542	2,491	51
	EB	747	—	289	352	289	
All Vintages	Mean	2,014	1,977	1,694	1,900	1,854	498
	EB	237	383	156	104	80	

Table B - 5: Distribution of Frame Wall Insulation Levels, Electrically Heated Homes

Wall Framing Type		Frame Wall Insulation Levels						
		R0	R1–R10	R11–R16	R17–R22	>R22	All Insulation Levels	n
2x4	%	14.2%	12.1%	69.1%	4.6%	—	63.0%	348
	EB	3.9%	3.8%	5.5%	2.7%	—	4.7%	
2x6	%	2.7%	—	9.0%	88.3%	—	36.7%	177
	EB	1.9%	—	3.6%	4.1%	—	4.7%	
2x8	%	—	—	—	47.3%	52.7%	0.3%	2
	EB	—	—	—	58.0%	58.0%	0.4%	
All Frame Types	%	9.9%	7.6%	46.8%	35.5%	0.2%	—	526
	EB	2.6%	2.5%	4.7%	4.7%	0.3%	—	

Table B - 6: Percentage of Electrically Heated Homes with Basements by State

State	Homes with Basements		
	%	EB	n
ID	29.8%	10.8%	54
MT	54.9%	17.7%	24
OR	14.7%	7.0%	132
WA	29.5%	5.7%	292
Region	25.8%	4.1%	502

Table B - 7: Percentage of Electrically Heated Homes with Floor Area over Crawlspace by State

State	Homes with Floor Area over Crawlspace		
	%	EB	n
ID	52.7%	12.4%	54
MT	39.2%	17.4%	24
OR	81.9%	7.6%	132
WA	67.1%	6.0%	292
Region	69.1%	4.4%	502

Table B - 8: Distribution of Floor Insulation, Electrically Heated Homes

Floor Insulation Levels		Percentage of Homes									
		R1–R3	R4–R10	R11–R15	R16–R22	R23–R27	R28–R35	R38+	None	All Insulation Levels	n
Pre 1981	%	1.3%	4.9%	9.0%	41.6%	9.8%	8.0%	0.2%	25.2%	58.2%	237
	EB	1.1%	3.6%	4.1%	7.4%	3.3%	3.8%	0.4%	6.6%	5.8%	
1981–1990	%	—	—	4.1%	71.1%	8.6%	—	—	16.2%	12.5%	34
	EB	—	—	4.7%	14.6%	8.1%	—	—	12.0%	4.2%	
1991–2000	%	—	—	1.3%	28.0%	46.8%	13.4%	0.1%	10.4%	13.9%	47
	EB	—	—	2.2%	15.7%	16.3%	7.9%	0.1%	8.5%	4.2%	
Post 2000	%	—	—	—	29.3%	22.1%	41.4%	1.2%	5.9%	15.4%	42
	EB	—	—	—	15.6%	12.2%	15.2%	2.1%	5.5%	4.4%	
All Vintages	%	0.7%	2.8%	5.9%	41.3%	17.1%	12.7%	0.3%	19.2%	—	365
	EB	0.6%	2.1%	2.5%	5.8%	4.2%	3.6%	0.4%	4.5%	—	

Table B - 9: Distribution of Attic Insulation Levels, Electrically Heated Homes

Insulation Level	Attic Insulation Level		
	%	EB	n
R0	1.3%	0.7%	12
R1–R10	3.2%	1.8%	17
R11–R15	7.5%	2.3%	50
R16–R20	9.8%	2.8%	55
R21–R25	11.8%	3.2%	59
R26–R30	17.3%	3.9%	84
R31–R40	38.7%	5.0%	167
R41–R50	7.9%	2.7%	36
R50+	2.6%	1.4%	13
Total	100.0%	—	493

Table B - 10: Distribution of Vault Ceiling Insulation Level, Electrically Heated Homes

Insulation Level	Vault Ceiling Insulation Level		
	%	EB	n
R0	0.9%	0.8%	4
R1–R15	14.0%	5.6%	32
R16–R20	24.5%	11.5%	21
R21–R25	11.9%	6.9%	12
R26–R30	23.4%	9.7%	25
R31–R40	22.2%	8.7%	20
R41–R50	3.2%	2.7%	4
Total	100.0%	—	118

Table B - 11: Distribution of Window Types by State, Electrically Heated Homes

Window Type		Windows					
		ID	MT	OR	WA	Region	n
Double Glazed Metal Frame	**%**	19.7%	8.4%	15.4%	20.7%	18.8%	106
	EB	9.3%	8.1%	6.0%	5.4%	3.7%	
Single Glazed Metal Frame	**%**	2.8%	—	7.7%	3.9%	4.8%	47
	EB	3.8%	—	4.6%	1.6%	1.7%	
Double Glazed Wood/Vinyl/Fiberglass Frame	**%**	70.3%	72.2%	74.5%	71.5%	72.3%	407
	EB	11.0%	18.8%	6.5%	5.7%	4.0%	
Single Glazed Wood/Vinyl/Fiberglass Frame	**%**	7.1%	6.4%	2.4%	3.1%	3.4%	45
	EB	6.6%	6.1%	1.9%	1.8%	1.4%	
Triple Glazed Wood/Vinyl/Fiberglass Frame	**%**	—	13.0%	—	0.7%	0.7%	5
	EB	—	19.2%	—	0.6%	0.6%	
All Window Types	**%**	10.2%	2.4%	28.9%	58.5%	—	612
	EB	2.3%	0.9%	4.2%	4.4%	—	

Table B - 12: Average Normalized Heat-Loss Rate by Vintage and State, Electrically Heated Homes

Vintage		Heat Loss Rate (UA/sq.ft.) per Home					
		ID	MT	OR	WA	Region	n
Pre 1981	Mean	0.351	0.318	0.365	0.382	0.371	293
	EB	0.067	0.065	0.039	0.034	0.023	
1981–1990	Mean	0.259	0.245	0.302	0.264	0.270	47
	EB	0.063	0.047	0.038	0.018	0.016	
1991–2000	Mean	0.230	0.192	0.197	0.220	0.214	64
	EB	0.030	0.035	0.010	0.014	0.010	
Post 2000	Mean	0.195	0.159	0.208	0.203	0.203	51
	EB	0.035	0.000	0.024	0.012	0.011	
All Vintages	Mean	0.303	0.280	0.322	0.322	0.318	462
	EB	0.045	0.049	0.032	0.022	0.016	

Table B - 13: Average Heat-Loss Rate by Vintage and State, Electrically Heated Homes

Vintage		Heat Loss Rate (UA) per Home					
		ID	MT	OR	WA	Region	n
Pre 1981	Mean	578	482	594	612	599	293
	EB	96	106	87	40	37	
1981–1990	Mean	495	359	510	508	505	47
	EB	82	87	117	51	43	
1991–2000	Mean	503	523	428	456	457	64
	EB	234	64	108	54	49	
Post 2000	Mean	607	1,018	392	499	492	51
	EB	152	—	96	67	58	
All Vintages	Mean	554	501	537	559	550	462
	EB	71	82	67	27	26	

Table B - 14: Average Blower Door Air Tightness by State, Electrically Heated Homes

State	Blower Door Air Tightness (ACH50)		
	Mean	EB	n
ID	6.73	1.2	19
MT	7.77	3.5	9
OR	9.52	1.0	40
WA	10.25	1.2	70
Region	9.54	0.8	138

Table B - 15: Average Heating Thermostat Setpoint by State, Electrically Heated Homes

State	Heating Thermostat Setpoint (°F)		
	Mean	EB	n
ID	69.8	1.19	51
MT	68.7	0.95	24
OR	68.4	0.79	132
WA	68.7	0.39	288
Region	68.7	0.35	495

Table B - 16: Percentage of Electrically Heated Homes Reporting a Heating Setback by State

State	Homes Reporting Heating Setback		
	%	EB	n
ID	54.3%	12.4%	54
MT	63.1%	16.5%	24
OR	59.1%	9.4%	132
WA	70.2%	5.2%	292
Region	65.0%	4.4%	502

Table B - 17: Average Weather Normalized kWh per Home by State, Electrically Heated Homes

State	kWh per Home		
	Mean	EB	n
ID	19,157	2,399	51
MT	17,022	2,735	26
OR	14,792	1,045	126
WA	18,579	979	296
Region	17,488	714	499

September 18, 2012

RESIDENTIAL BUILDING STOCK ASSESSMENT: SINGLE-FAMILY CHARACTERISTICS AND ENERGY USE

Appendix C: Air and Duct Leakage Testing Procedures

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Appendix C: Air and Duct Leakage Testing Procedures

1. 2-Point Blower Door Test

Depressurize to near 50 and 25 Pa with respect to outside. Note the house pressure WRT outside doesn't have to be exactly 50 or 25 Pa; the actual values will be corrected to 50 Pa during analysis.

1.1. Blower Door (BD) Depressurization Test Procedure:

1. Close all windows and doors to the outside. Open all interior doors and supply registers.
2. Close all dampers and doors on wood stoves and fireplaces. Seal fireplace or woodstove as necessary to prevent ash disaster.
3. Make sure furnace and water heater cannot come on during test. Put water heater and/or gas fireplace on "pilot" setting. Make sure all exhaust fans and clothes dryer are off. Make sure any other combustion appliances will not be back drafted by the blower door.
4. Make sure doors to interior furnace cabinets are closed. Also make sure crawlspace hatch is on, even if it is an outside access. Check attic hatch position. Put garage door in normal position.
5. Set fan to depressurize house. Run pressure tap out through door shroud.
6. Depressurize house to –50 Pa or thereabouts. Record house pressure, BD flow pressure, and BD ring (below). If you cannot reach –50 Pa, get as close as possible and record information.
7. Now take the house down to –25 Pa WRT outside and record information.

Blower Door Tests	House P near 50 Pa (P_{50})	BD fan pressure	BD Ring	BD flow near 50 Pa (Q_{50})	House P near 25 Pa (P_{25})	BD fan pressure	Ring	BD flow near 25 Pa (Q_{25})
Test 1								
Test 2								

8. To check test, calculate the flow exponent, n. Use the following formula, $n = \ln(Q_{50}/Q_{25})/\ln(P_{50}/P_{25})$. Note Q_{50} and Q_{25} are the flows through the blower door at the testing pressures (which are denoted P_{50} and P_{25}. Depending on the test, you may not get the house to exactly –50 or –25 Pa WRT outside. Use the exact ΔP you measure when checking the flow exponent. For example, if the house gets to –48 Pa for the high ΔP, use this as the P_{50} in the equation. If the flow exponent is not between 0.50 and 0.75, repeat the test.
9. Note testing conditions (if windy, inaccessible room(s), garage door open or closed, etc.).

2. Exterior Duct Leakage Test

2.1. Exterior Duct Leakage Test Procedure

1. Exterior house doors and garage doors should be closed for exterior duct leakage test.
2. Pressurize the house to about 50 Pascals WRT outside.
3. Pressurize tested part of duct system to about 50 Pascals with smallest flow ring possible.
4. Measure pressure of ducts WRT house. Make sure blower door flow does not impinge on pressure tap measuring house pressure.
5. Adjust duct tester speed controller so that duct pressure WRT house is zero or very close.
6. Re-check pressure of ducts WRT outside.
7. Measure duct tester fan pressure. Look up flow in table, use gauge (make sure gauge is paired with the right duct tester) or use flow equation. Record duct pressure WRT out, DB fan pressure, DB fan ring.
8. If you cannot reach 50 Pa or 25 Pa, test to the highest pressure you can reach and enter this in the "50 Pa" column. Use a test pressure of half this pressure for the low pressure test.
9. Repeat steps 2–7 with house and ducts at about 25 Pa WRT outside.
10. Check flow exponent (as above).
11. Note any unusual testing conditions (wind, etc.).

2.2. Duct Leakage to Outside Data

1. Note duct pressure WRT outside may not be exactly 50 or 25 Pa.

	Both sides		Supply or Return (circle one)	
	50 Pa	25 Pa	50 Pa	25 Pa
Duct P	____	____	____	____
Ring	____	____	____	____
Fan P	____	____	____	____
Flow	____	____	____	____

2. To check test, calculate the flow exponent, n. Use the following formula, n = $\ln(Q_{50}/Q_{25})/\ln(P_{50}/P_{25})$. Note Q_{50} and Q_{25} are the flows through the blower door at the testing pressures (which are denoted P_{50} and P_{25}. Depending on the test, you may not get the house to exactly –50 or –25 Pa WRT outside. Use the exact ΔP you measure when checking the flow exponent. For example, if the house gets to –48 Pa for the high ΔP, use this as the P_{50} in the equation. If the flow exponent is not between 0.50 and 0.75, repeat the test.

3. TrueFlow® Test

Set-up: Turn on air handler (by using fan-only switch or by turning on heat/AC). Drill access hole as needed and point hooked end of static tap into airflow. Do not drill into the duct at any point where you are concerned with hitting something. Repeat test if needed to get flows at both low and high stage; record first stage readings to left of "/" in blanks below and second stage readings to right of "/."

Measure pressure in return plenum and record: _____/_____ Measure pressure in supply plenum. Record pressure below as Normal System Operating Pressure (NSOP). Place appropriate plate and spacers into filter slot. Turn on air handler and record supply static pressure with TrueFlow® in place (TFSOP) and pressure drop across plate.

Plate used (14 or 20) _____/_____

Normal System Operating Pressure (NSOP) _____/_____Pa

Plate pressure drop _____/_____Pa

True Flow System Operating Pressure (TFSOP) _____/_____Pa

Raw Flow (CFM) _____/ _____

Correction Factor* √(NSOP/TFSOP) _____/_____

Corrected Flow (CFM)______/______