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RESIDENTIAL BUILDING STOCK ASSESSMENT: MANUFACTURED HOME CHARACTERISTICS AND ENERGY USE

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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
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

HUD	U.S. Department of Housing and Urban Development
HUD MPS	HUD Minimum Property Standards
HVAC	heating, ventilation, and air conditioning
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
LPD	lighting power density
MAP	Manufactured Home Acquisition Project
n	number of observations
NEEA	Northwest Energy Efficiency Alliance
NEEM	Northwest Energy Efficient Housing Program
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
RCDP	Residential Construction Demonstration Project
RDD	random digit dial
R-value	thermal resistance value
SEER	Seasonal Energy Efficiency Ratio
SGC	Super Good Cents

SLF	supply leakage fraction
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
ZCTA	Zip Code Tabulation Area

Executive Summary

This report is the second 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 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). 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.

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. Of the 99 utilities represented in the overall RBSA study, 52 were represented in the manufactured home sample. Field surveys were conducted on more than 1,850 sites for three residence types across the Northwest, including more than 300 manufactured homes.

This second report summarizes the characteristics observed onsite and energy use data for the manufactured home component of the RBSA. The first report[1] (released in October 2012) summarized single-family homes (Baylon et al., 2012) and the third report will summarize multifamily homes.

[1] See the RBSA Single-Family Characteristics and Energy Use Report at http://neea.org/docs/reports/residential-building-stock-assessment-single-family-characteristics-and-energy-use.pdf?sfvrsn=8

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. To this end 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.

The RBSA survey is the first comprehensive assessment of the manufactured home sector aimed at characterizing the entire sector using a physical survey. Manufactured homes were addressed in both the 2007 Single-Family Residential Existing Construction Stock Assessment ((RLW 2007)[2] and the 1992 Pacific Northwest Residential Energy Survey (PNWRES92) (BPA 1993). However, the 2007 study did not include a statistically significant sample of manufactured homes and the sites were included in the analysis and summaries for the single-family sites. The PNWRES92 included about 3,000 manufactured homes and was the last in a series of four phone-survey-based residential characterization studies conducted by BPA. This study was the most comprehensive residential characteristics survey conducted prior to the RBSA. However, the data are now 20 years old and were collected using only phone surveys.

In addition to these more general studies, there have been a number of assessments of particular manufactured home vintages beginning in the late 1980s. For the most part these studies have focused on the current manufacturing specifications at the time of the study. The RBSA sample, on the other hand, spans the full range of manufactured home vintages beginning in the 1950s and continuing until the present. In this sense, the RBSA sample provides a more complete baseline for this sector than any study fielded in the region to date.

Study Objectives

The manufactured home RBSA includes four major objectives:

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

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

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.

Methodology

Ecotope designed the sample to be representative of manufactured homes from three geographic perspectives: by whole region, by state, and for the whole BPA service territory. The sample was designed to achieve a 90%/10% confidence/precision interval for each of the geographic perspectives. The sample design reflects a small oversample by BPA in order to achieve a statistically significant number of sample points in BPA's overall service territory. The RBSA manufactured homes sample was also enhanced by two utility oversamples.

The manufactured home sample frame was developed with a large, region-wide phone survey. Phone surveys were completed using a combination of random digit dial (RDD) and utility customer phone lists. Each housing type, utility type, and geographic sampling stratum was assigned a quota by the sample design. Approximately four phone surveys were completed for each field survey in the manufactured homes sample. Recruiters developed the final sample by randomly selecting from this list.

The survey data collected on this final sample 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. For this report, the populations of each state in the region were separately summarized as well as the region as a whole.

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 manufactured home report:

- Characteristics of Northwest manufactured homes exhibit a high degree of uniformity across the four Northwest states. This uniformity is largely due to the preemptive federal standards and the region's energy efficiency programs, which also use common standards across all factories and thus all new manufactured homes in the region.
- The review of overall conductive heat loss rates across all vintages of homes shows surprisingly small differences among the states and climates. When reviewing the overall heat loss rate by vintage, however, there are considerable differences between homes built to federal standards and homes built to regional utility program specifications for manufactured homes. Homes built to federal minimum standards average about twice the heat loss and twice the infiltration rate of the homes built under the utility programs.
- The lighting audit allowed us to develop an estimate of the impacts of the Energy Independence and Security Act (EISA) on the region's residential lighting programs.

Approximately 17% of all lamps are exempt from these standards and could be the basis for utility programs aimed at these types of lamps and fixtures.

- The overall lighting power density (LPD) for manufactured homes across the region is about 1.27 Watts/sq.ft. About 38% of all lamps are compact fluorescent lamps (CFL) or other types of fluorescent lamps.
- About 70% of homes report electricity as their primary fuel for space heating. Approximately 11% of homes surveyed report gas as their primary heating fuel. The saturation of gas heat in Montana is about five times the saturation in the rest of the region combined.
- Domestic hot water (DHW) fuel source is dominated by electricity with approximately 90% of the water heating use supplied by electric DHW tanks.
- An average of 1.3 refrigerators was observed in each manufactured home. About 58% of those refrigerators were manufactured since 2000.
- In the manufactured home sector, the saturation of horizontal axis clothes washers is about 20% of all clothes washers and about 40% of the washers purchased in the last six years.
- Across the region, manufactured homes have about 2.0 TVs and 1.5 set-top boxes. About 20% 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 20% of all manufactured homes have an electronic gaming system. The average number of gaming systems in manufactured homes with gaming systems is 1.2.
- About 77% of all manufactured homes surveyed have at least one computer.
- The average weather normalized, electric and gas energy use index (EUI) is 53 kBtu/sq.ft. per manufactured home in the region. Occupants report supplemental fuel use (wood, propane, oil, etc.) of about 14,300 kBtu/home or about a 20% increase in the energy use beyond the metered electric and natural gas usage.

1. Introduction

This report is the second 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.[3]

The RBSA was 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 manufactured home component of the RBSA. The first report (released in October 2012) summarized single-family homes (Baylon et al., 2012), and the third report will summarize 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.

[3] 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 since 1992 and, except for some small scale assessments, few comprehensive characteristics 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 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.

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. Table 1 illustrates the total number of utilities included in the final RBSA manufactured home sample relative to the total number of Northwest utilities. Of the 99 utilities represented in the overall RBSA study, 52 were represented in the manufactured home sample. The proportion of utilities represented in the manufactured home sample reflects the overall sample size for this building type and the fact that many utilities do not have significant manufactured home populations.

Table 1: RBSA Manufactured Home Sampled Utilities by State

Region	Total Utilities	Sampled Utilities	% of Total
Idaho	27	9	33%
Western Montana	10	7	70%
Oregon	25	23	92%
Washington	56	23	50%
Total	132	52	39%

1.2. Previous Studies

The RBSA survey is the first comprehensive assessment of manufactured homes aimed at characterizing the entire sector of such homes by using a physical survey. Although manufactured homes were addressed in two earlier studies that were conducted in 2007 and 1992, those studies have limitations as current baseline information for this sector.

The 2007 Single-Family Residential Existing Construction Stock Assessment (RLW 2007)[4] was the most recent regional residential characterization study. The report and databases were based

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

on a field sample completed between 2004 and 2006 involving 489 homes. Unfortunately, only 15 manufactured homes were included in the sample and they were not separated in the final analysis. As a result we have not considered that study.

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, 3,000 of which were surveys of manufactured homes. This survey 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, there have been a number of assessments of particular home vintages beginning in the late 1980s. For the most part, these studies have focused on the current manufacturing specifications at the time of the study:

- **Residential Construction Demonstration Project (RCDP), manufactured homes.** The RCDP program for manufactured homes was aimed at providing BPA with a comprehensive review of current construction practices (circa 1986–89) as a basis for designing energy efficiency programs for this sector (Harkreader et al., 1987). The study consisted of performance reviews of 150 homes, including a full field survey and billing analysis (Baylon et al., 1991).
- **Manufactured Home Acquisition Project (MAP) program evaluation.** The MAP program was a BPA initiative that resulted in an extensive improvement in all manufactured homes built from 1992 to 1995 (approximately 20,000 homes). The performance of the homes was evaluated by using a field sample of 178 homes across the region (Baylon et al., 1995).
- **MAP program reference manual.** This effort documented the performance of components of the manufactured homes built from 1989 to 1995 (Davis and Baylon, 1996).
- **Super Good Cents (SGC) manufactured homes, 1997-1998.** This effort documented the manufacturing standards that were implemented after the MAP program was disbanded. The review included a field study of 49 manufactured homes (Davis et al., 2000).
- **SGC manufactured homes, 2000-2001.** This study documented SGC construction practices for manufactured homes. The study included a field survey of 105 homes randomly selected from the 2000-2001 sitings under that program (Davis and Baylon, 2004).
- **Northwest Energy Efficient Housing Program (NEEM), 2006.** This study reviewed the performance of 100 randomly selected homes built under the NEEM program. The NEEM program was a follow-on program to the SGC program (Baylon et al., 2009).

These individual studies provide a picture of the trends in manufactured homes over the last 25 years. Much of the work on the RBSA manufactured home protocol and analysis leveraged these studies. On the whole, however, the level of effort and extent of the RBSA sample provide a unique summary of manufactured home construction and occupancy in the Northwest region.

1.3. Study Objectives

The manufactured home 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 manufactured homes 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 manufactured homes.** The region specified several geographic perspectives that would need to be represented at the same level of certainty: by whole region; by state; and by whole BPA service territory (public power customers of the BPA). In addition, NEEA requested a subsample of heat-loss assessments, including blower door and duct blaster testing for manufactured 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 manufactured 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. Two utilities requested an oversample of manufactured homes, 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. The result is that 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 limits 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 321 manufactured 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 across an individual sample stratum.

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 (EB), 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 manufactured homes from three geographic perspectives: by whole region, by state, and by whole BPA service territory. The sample design reflects a small oversample by BPA in order to achieve a statistically significant number of sample points in BPA's overall service territory. Table 2 presents the manufactured home sampling requirements. The RBSA manufactured homes sample was also enhanced by two utility oversamples. Samples in each of these sampling domains were designed to be representative within those domains.

Table 2: Manufactured Home Sampling Requirements

	Sampling Domains with 90%/10% Confidence/Precision
NWR	All residential utility customers in Washington, Oregon, Idaho, and western Montana (BPA region with NorthWestern Energy)
NWP	All BPA public (cooperative, Public Utility District [PUD], municipal, federal) residential utility customers in the Northwest
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)

In order to address the sampling requirements across the RBSA, Ecotope designed the sample using seven geographic strata and two utility strata (a total of nine strata). These strata were combined in the final analysis to include the four states and the two oversample utilities as well as the entire region and the entire population of the BPA service territories. The geographic strata included:

- Idaho
- Western Montana
- Western Oregon
- Eastern Oregon
- Puget Sound, Washington
- Western Washington (excluding Puget Sound)
- Eastern Washington

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 survey 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 the Form #861 certification filings with the Federal Energy Regulatory Commission (FERC) from 2009[5] 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 nine manufactured home sampling strata.

The ratio among single-family homes, manufactured homes, and multifamily units within each sampling stratum was established by using 2000 U.S. Census data (see U.S. Census Bureau, 2002a and 2002b) sorted by Census ZCTAs, 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. 1,226 manufactured home phone surveys were completed using a combination of RDD and utility customer phone lists. Each housing type, utility type, and geographic sampling stratum was assigned a quota by 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

[5] 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 manufactured homes field survey.

Table 3: Manufactured Home Field Survey Sample Frame

State	Total Manufactured Home Customers	Total Sample Frame
Idaho	79,945	246
Western Montana	52,974	247
Oregon	170,781	355
Washington	240,030	378
Total	**543,730**	**1,226**

2.1.3. Sample Distribution

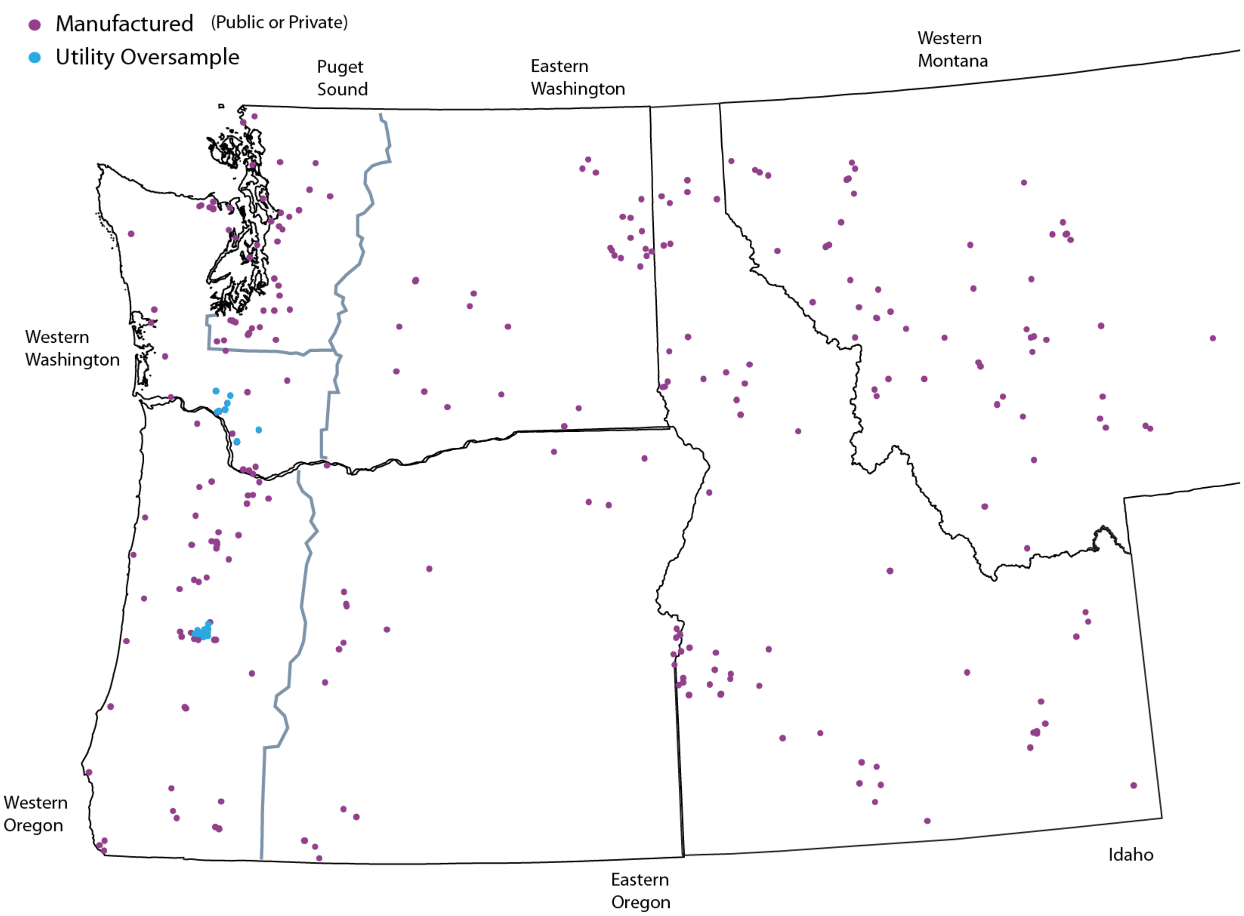
Phase 3 of the sampling process included recruitment of the field survey sample. Upon completion of the phone survey, the resulting list of contacts was assembled into the recruiting lists for the field surveys. A target was assigned to each of the nine strata in the sample design. Table 4 summarizes the distribution of the RBSA manufactured home field survey sample by state. The totals in Table 4 include approximately 75 extra sites above and beyond the number of sites required to meet the sampling criteria for each state. The extra sites were due to the BPA oversample (24 sites), the utility oversamples (32 sites), and a 6% field survey overshoot of manufactured homes (19 sites).

Table 4: Manufactured Home Sample Distribution

State	Total Sample
Idaho	66
Western Montana	61
Oregon	97
Washington	97
Total	**321**

Figure 1 is a map of the final manufactured home sample distribution. The widely distributed nature of the sample dots in Figure 1 demonstrates the broadly representative nature of the sample.

Figure 1: Map of Final Sample Distribution of Manufactured Home 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 (measuring air tightness of the building envelope), Duct Blaster® (measuring 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. Table 5 presents the final heat-loss assessment sample distribution. The heat-loss assessment included 156 manufactured homes.

Table 5: Final Distribution of Manufactured Home Heat-Loss Assessment Sample

State	Total Sample
Idaho	26
Western Montana	25
Oregon	43
Washington	62
Total	156

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 make sure that an unbiased estimate is produced as the data gathered at the individual home is combined to characterize the region or any particular sub-region of interest. Because the population varies dramatically between each geographic 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 geographic 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 321 manufactured 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 four 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 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 manufactured home onsite data collection protocol.

Data collected onsite included, but were not limited to:

- **Building envelope**
  - Age and construction standard
  - Windows
    - Evidence of upgrade
    - Replacement type
    - Replacement window area
    - Total window area
    - Percentage of south-facing windows
  - Walls
    - Evidence of increased insulation
    - Insulation R-value of replacement
    - Area
  - Roof
    - Area
    - Height
    - Evidence of increased insulation
    - Insulation R-value
  - Floors
    - Evidence of increased insulation
    - Insulation R-value
    - Insulation condition
    - Area
- **Ducts**
  - Evidence of mastic sealing
  - Duct material
  - Duct crossover present
  - Crossover condition

- **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)

2.3. 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 measures in Northwest manufactured homes.
- **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 make sure 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.

2.4. Characteristics Analysis

The RBSA manufactured 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 state and utility strata in the final database. As a result of various scheduling overlaps, some extra surveys were received and the case weights were developed for all 321 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 manufactured home residential sector. At the outset, the output from the electronic tablet PC software was disaggregated into 50 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 in this report.

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 321 manufactured homes.

2.5. 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 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 on supplemental (non-utility) fuel use 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 were 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 6 shows the utility response rate by utility and the site data submission rate (98% of sites received out of total sites requested). Ninety-five percent of utilities solicited provided data for the study.

Table 6: Utility Billing Solicitation Response Rate

Utility Service	Utility Response Rate	Site Data Submission Rate
Electric Service	94%	98%
Natural Gas Service	100%	95%
Total	95%	98%

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 were audited as they were received to verify that they were 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 PRInceton Scorekeeping Method (PRISM)[6]-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 possible. The billing analysis used the case weights for the overall RBSA manufactured home sample design.

2.6. Final Database

The RBSA manufactured home field survey generally collected about 500 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.[7] 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 321 individual surveys and provides a data dictionary for the variables and calculated fields. The final manufactured home database will be developed by using Microsoft Access.

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

[7] 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 manufactured homes as factory-built homes constructed in accordance with the Federal Manufactured Home Standards. The RBSA has evaluated these homes separately because they are built to different standards than other residence types and because they are more commonly electrically heated in the Northwest region.

The terms “single-wide,” “double-wide,” and “triple-wide” refer to homes built in a controlled environment on a permanent chassis and brought to the site in one, two, or three sections, respectively. The term “modular/prefab” refers to a home built in a controlled environment and assembled onsite, but not attached to a permanent chassis. Modular/prefab homes are built and inspected to local codes.

Home configuration includes the overall characteristics of the homes. Several dimensions are important, including residence type (see Section 3.1), vintage (see Section 3.2), age and standard (see Section 3.3), conditioned floor area (see Section 3.4), and room types (see Section 3.5).

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 from the entire population of manufactured homes.

3.1. Type of Residence

The homes surveyed for this study 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 321 manufactured home surveys that are the basis of this summary.

Table 7 shows the percentage of homes by type of manufactured home across all states and the region. Table 7 shows that about 59% of the surveys across the entire region are double-wide manufactured homes. Approximately 32% are in the single-wide category, and the modular/prefab and triple-wide categories each include approximately 4% to 5%. These distinctions, for the most part, are not important to any of the subsequent summaries in this report.

Table 7: Distribution of Homes by Type and State

Home Type		Percentage of Homes					
		ID	MT	OR	WA	Region	n
Single-Wide	%	33.3%	59.0%	22.8%	31.0%	31.5%	112
	EB	9.6%	10.4%	7.8%	8.3%	4.7%	
Double-Wide	%	62.1%	31.1%	61.2%	63.2%	59.3%	179
	EB	9.9%	9.8%	9.2%	8.6%	5.1%	
Triple-Wide	%	1.5%	1.6%	6.6%	3.9%	4.2%	11
	EB	2.5%	2.7%	4.7%	3.6%	2.2%	
Modular/Prefab	%	3.0%	8.2%	9.5%	0.9%	4.6%	18
	EB	3.5%	5.8%	5.4%	1.5%	2.0%	
Other[8]	%	—	—	—	0.9%	0.4%	1
	EB	—	—	—	1.5%	0.6%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	321

3.2. Vintage

As Table 8 and Figure 2 show, about 12% of the region's manufactured homes were built prior to 1971. Thereafter, the percent additions in each decade are reasonably consistent across the region until a decline after 2000. Within each state, however, growth rates vary by decade.

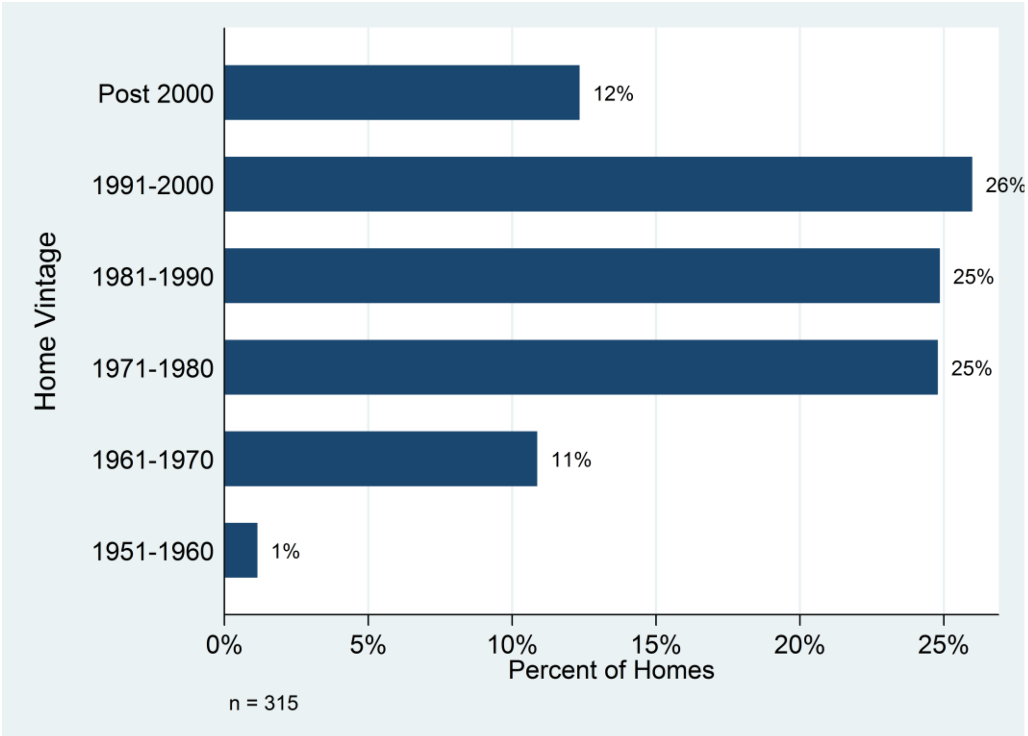
About 26% of the manufactured housing was built prior 1976 (when the U.S. Department of Housing and Urban Development [HUD] standards were put in place). This ratio is fairly uniform across all states except Montana, where about 45% of manufactured housing was built before the advent of the HUD standards. By 1990, when the BPA and local utilities began to focus on this sector, about 60% of the existing stock was already sited. All states except Montana saw significant declines in manufactured home sitings in the post-2000 period.

Table 8: Distribution of Homes by Vintage and State

Vintage		Percentage of Homes					
		ID	MT	OR	WA	Region	n
1951–1960	%	—	1.7%	1.4%	1.2%	1.1%	3
	EB	—	2.8%	2.2%	2.0%	1.2%	
1961–1970	%	9.4%	13.6%	9.7%	11.7%	10.9%	33
	EB	6.0%	7.4%	5.6%	5.9%	3.3%	
1971–1980	%	31.3%	35.6%	26.9%	18.8%	24.8%	91
	EB	9.6%	10.3%	8.3%	7.0%	4.4%	
1981–1990	%	21.9%	8.5%	18.7%	33.9%	24.9%	64
	EB	8.6%	6.0%	7.4%	8.6%	4.7%	
1991–2000	%	29.7%	20.3%	33.9%	20.2%	26.0%	86
	EB	9.5%	8.7%	8.8%	7.2%	4.5%	
Post 2000	%	7.8%	20.3%	9.4%	14.2%	12.3%	38
	EB	5.6%	8.7%	5.5%	6.4%	3.5%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	315

[8] Originally a double-wide with two substantial additions.

Figure 2: Distribution of Homes by Vintage



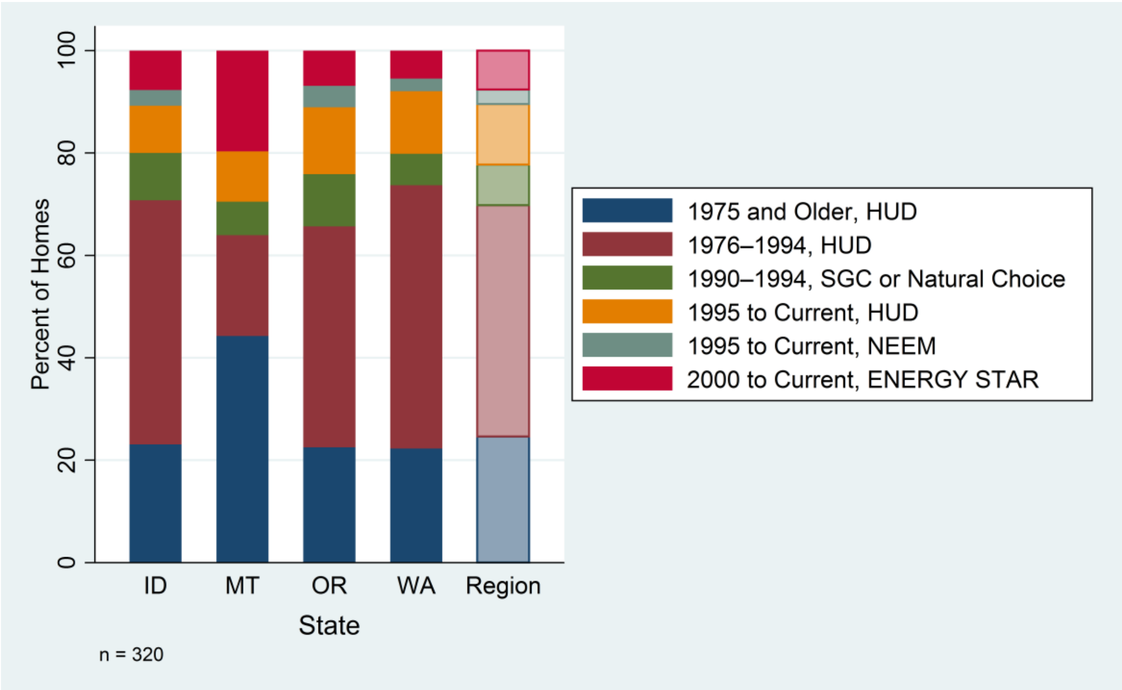
3.3. Age and Standard

In addition to the age of the home, surveyors collected information about the building standard of the homes from the HUD data plate of the home. Since 1976, HUD Code has required each manufactured home to have a data plate with information about the year of construction, factory-installed heating components, design parameters, component heat transfer rates, etc. Surveyors used this information to characterize the age and manufacturing standard of the home. The manufacturing standard refers to various code and efficiency programs over the years. Table 9 and Figure 3 each have a list of the age/standards used for this study. The most common age/standard across the region is 1976–1994 HUD. Energy-efficient design programs such as SGC, Natural Choice, NEEM, and ENERGY STAR were not a part of the market until after 1990. In general, these programs had significantly different standards. The surveyors were asked to identify homes that participated in one or another of these programs. About 20% of all manufactured homes in this region were manufactured and sited under these programs, representing about half of all the homes sited in the period after 1990.

Table 9: Distribution of Homes by Age/Standard and State

Age/Standard		Percentage of Homes					
		ID	MT	OR	WA	Region	n
1975 and Older, HUD	%	23.1%	44.3%	22.5%	22.3%	24.6%	87
	EB	8.7%	10.5%	7.8%	7.5%	4.4%	
1976–1994, HUD	%	47.7%	19.7%	43.1%	51.4%	45.2%	128
	EB	10.3%	8.4%	9.4%	9.0%	5.2%	
1990–1994, SGC or Natural Choice	%	9.2%	6.6%	10.2%	6.2%	7.9%	30
	EB	5.9%	5.3%	5.6%	4.2%	2.8%	
1995 to Current, HUD	%	9.2%	9.8%	13.0%	12.2%	11.8%	35
	EB	5.9%	6.3%	6.2%	5.9%	3.4%	
1995 to Current, NEEM	%	3.1%	—	4.2%	2.5%	2.9%	10
	EB	3.5%	—	3.8%	2.5%	1.7%	
2000 to Current, ENERGY STAR	%	7.7%	19.7%	6.9%	5.5%	7.6%	30
	EB	5.5%	8.4%	4.6%	4.0%	2.6%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	320

Figure 3: Distribution of Homes by Age/Standard and State



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. Surveyors measured conditioned floor area by using the outside dimensions of the home. Table 10 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.

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

Table 10: Average Conditioned Floor Area by State

State	Conditioned Floor Area (sq.ft.)		
	Mean	EB	n
ID	1,314	78	63
MT	1,248	109	61
OR	1,298	75	94
WA	1,265	79	95
Region	1,280	45	313

Figure 4: Average Conditioned Floor Area by State

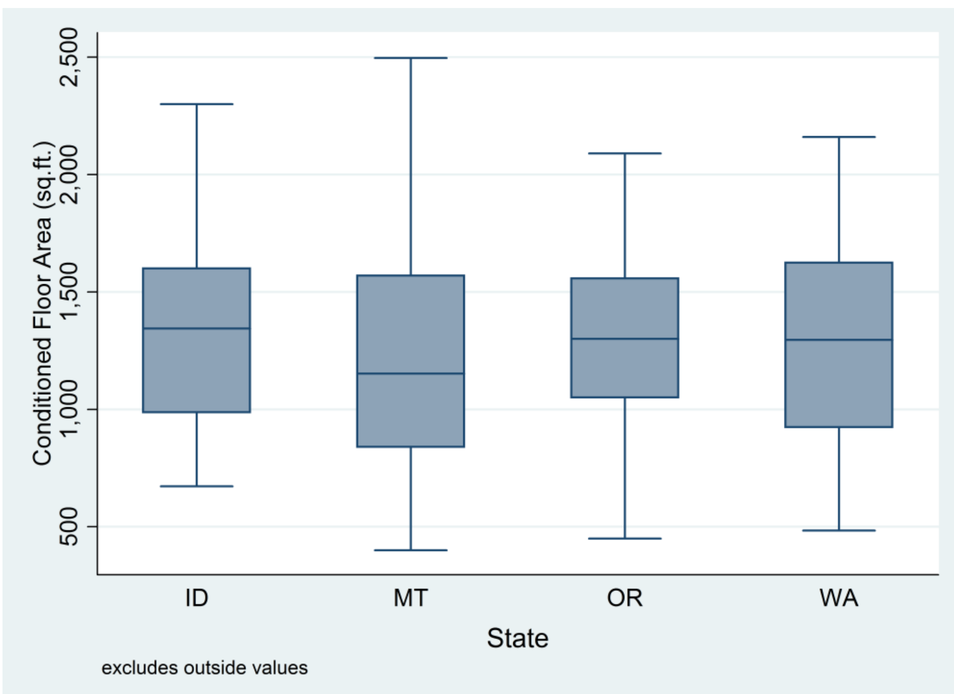


Table 11 shows the distribution of house size by vintage across the region. Manufactured home sizes have increased steadily over the last 30 years. Overall the conditioned floor area has increased about 80% across the region.

Table 11: Average Conditioned Floor Area by Vintage and State

Vintage		Conditioned Floor Area (sq.ft.)					
		ID	MT	OR	WA	Region	n
1951–1960	Mean	—	400	910	1,152	953	3
	EB	—				205	
1961–1970	Mean	1,008	960	916	861	907	33
	EB	165	262	172	197	112	
1971–1980	Mean	1,086	1,106	1,121	1,166	1,128	89
	EB	113	142	114	149	70	
1981–1990	Mean	1,281	1,014	1,279	1,234	1,244	63
	EB	148	148	136	100	72	
1991–2000	Mean	1,604	1,473	1,451	1,339	1,441	83
	EB	113	205	110	151	75	
Post 2000	Mean	1,471	1,687	1,751	1,757	1,717	37
	EB	210	258	238	210	129	
All Vintages	Mean	1,314	1,248	1,298	1,265	1,280	308
	EB	78	109	75	79	45	

3.5. Rooms

The real estate market has consistently used the number of bedrooms and bathrooms to characterize homes. Table 12 shows the average number of bedrooms per manufactured home by state. The average number of bedrooms per home for the region is about 2.6.

Table 12: Average Number of Bedrooms per Home by State

State	Bedrooms per Home		
	Mean	EB	n
ID	2.95	0.15	66
MT	2.72	0.18	61
OR	2.71	0.11	97
WA	2.47	0.11	97
Region	2.64	0.06	321

Table 13 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 Washington is 1.78, with slightly more in Oregon and Idaho and slightly less in Montana.

Table 13: Average Number of Bathrooms per Home by State

State	Bathrooms per Home		
	Mean	EB	n
ID	1.88	0.104	66
MT	1.66	0.115	61
OR	1.87	0.083	97
WA	1.78	0.086	97
Region	1.81	0.050	321

Almost 3,000 rooms were surveyed, and areas were measured on virtually all of them. Table 14 shows a distribution of room type and size. These rooms are summarized regardless of whether they were conditioned or unconditioned.

Table 14: Average Room Areas by Room Type

Room Type	Room Areas (sq.ft.)		
	Mean	EB	n
Bathroom	67	2	554
Bedroom	136	3	581
Closet	37	4	129
Dining Room	130	6	146
Family Room	251	18	86
Garage	654	96	57
Hall	50	3	255
Kitchen	172	7	303
Laundry Room	71	4	204
Living Room	262	9	297
Master Bedroom	191	6	206
Office	131	9	76
Other	219	58	73
All Room Types	140	4	2,967

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). For the manufactured homes sector, the consistency of manufacturing standards was used to set the insulation level appropriate to that manufacturing period. Table 9 shows the standards used in this report (see Section 3.3). Each component (walls, ceilings, floors, windows, and doors) was assigned an insulation level and U-value based on the particular "Age/Standard" observed by the surveyor. In the case of floor insulation, the surveyor assessed the condition of the insulation, and the U-value of that component was adjusted based on those observations.

In addition, the surveyor was asked to assess if any component had been upgraded beyond the original manufacturer's specifications. These observations were used to adjust the assumed U-values when evidence of retrofit was observed.

We summarize insulation values and component characteristics throughout this section using the age categories and any additional observations about insulation upgrades or deterioration in insulation quality the surveyor identified. 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 age of the home to develop the standard that would be applied to the summaries. Table 15 shows the baseline insulation assumptions. If no improvements were identified, these values became the basis of the heat-loss rates of each component. This information was gathered from the data plate on the home (required by HUD regulations) or information provided to the homeowner when the home was sited. In some cases (particularly for older homes), the occupant's response in the interview was used to make this assignment.[9]

[9] Prior to 1976, there were no building code standards that applied to the manufactured homes sector. Beginning in 1976, the federal government began to regulate this sector through the HUD Minimum Property Standards (HUD MPS). This became a uniform and preemptive standard that all manufacturers used. In return, the individual states were not allowed to permit these homes (except certain aspects of setup and zoning). The HUD MPS was updated in 1994 and is used currently throughout the country as a minimum standard. Starting in 1990 and continuing to the present, the Northwest has had many programs that incented higher standards. For the most part, these standards mimic the single-family standards used in the state codes and attempt to ensure that the performance of the manufactured homes built under the HUD MPS have at least equivalent performance to site-built homes of the same vintage.

Table 15: Baseline Component Assumptions by Age/Standard

Component	Pre-1976, pre-HUD	1976–1994, HUD	1990–1994, SGC	Post-1994, HUD	Post-1994, NEEM	Post-1999, ENERGY STAR
Ceiling	R7	R11	R38	R22	R 38	R 40
Floor	R7	R11	R 33	R22	R 33	R 33
Wall	R7	R11	R21	R11	R 21	R 21
Windows (U-value)	1.25	0.75	0.38	0.48	0.38	0.35

For each component, the surveyor was asked to assess whether some retrofit activity could be observed and, if so, what upgrade to the insulation could be observed. Generally, the survey did not identify upgrades unless the component was directly observable. Thus, window upgrades were more commonly identified. When necessary, 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. Overall, about 47% of the manufactured homes surveyed had some component upgrades, and 80% of those homes had a window upgrade.

4.1.1. Walls

Wall assessment typically presents a challenge for surveyors to identify insulation levels. 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. Generally, the wall insulation level was based on the age/standard assumption for the vintage of that particular home. Hence, the surveyors, using the techniques described above, assigned insulation levels into the categories shown in Table 15. Table 16 shows the overall distribution of wall insulation by home vintage. This table includes the effects of vintage as well as the cases where wall upgrades were identified. Only a small fraction of the older homes in the study showed some evidence of retrofit wall insulation.

Even in the oldest vintages, some wall insulation was generally installed at the factory. When insulation was installed at the factory typically an R-7 batt was used. Surveyors were not asked to record framing type, but some surveyors noted walls framed with 2x2s or 2x3s in homes built before the advent of the HUD Code (1976). With the advent of the HUD Minimum Property Standards (HUD MPS), all manufactured homes were built with R-11 walls in 2x4 framing by 1980. The higher levels of insulation were not really used until regional utility programs led by BPA began providing incentives and guidelines for 2x6 walls beginning in 1990. These programs influenced a significant amount of regional production and, coupled with increases in HUD standards in 1995, resulted in consistently higher levels of wall insulation.

Table 16: Distribution of Wall Insulation Levels by Home Vintage

Vintage		Wall Insulation Levels					
		R0–R8	R9–R14	R15–R21	R22–R30	All Walls	n
1951–1960	%	100.0%	—	—	—	1.0%	3
	EB	0.0%	—	—	—	1.1%	
1961–1970	%	87.6%	8.1%	4.3%	—	9.0%	33
	EB	10.3%	9.1%	5.2%	—	2.9%	
1971–1980	%	34.6%	64.6%	0.7%	—	23.1%	91
	EB	9.4%	9.4%	1.0%	—	4.5%	
1981–1990	%	1.2%	95.3%	3.5%	—	24.1%	64
	EB	1.7%	4.0%	3.7%	—	4.8%	
1991–2000	%	1.7%	64.3%	33.2%	0.9%	28.8%	86
	EB	2.7%	11.2%	10.8%	1.5%	5.9%	
Post 2000	%	—	35.5%	64.5%	—	13.9%	38
	EB	—	15.1%	15.1%	—	4.0%	
All Vintages	%	18.2%	61.8%	19.7%	0.3%	—	315
	EB	3.8%	5.3%	4.2%	0.4%	—	

The U-value of each wall was developed using standardized calculations. The calculation was based on standardized framing and insulation assumptions used to evaluate the wall insulation in BPA programs and the manufactured home industry. Because of the uniformity of federal standards and the diverse geographic response to utility programs, there is virtually no difference by state in the wall heat-loss rate (see Table 17).

Table 17: Distribution of Wall U-value by State

State	Wall U-value		
	Mean	EB	n
ID	0.090	0.004	66
MT	0.090	0.006	61
OR	0.089	0.004	97
WA	0.091	0.003	97
Region	0.090	0.002	321

4.1.2. Floors

The manufactured home floor system is fairly uniform across manufacturers and the region as a whole. The standard technique is to build a frame floor on top of the steel chassis that is used to transport the home to its site. The wheels are removed and the chassis is supported on a series of piers placed under the home. The foundation consists of the concrete pads poured or placed under the piers that provide the ultimate bearing surface for the home. The insulation is installed during the manufacturing process by placing a fiberglass batt under the entire floor system (below the framing) prior to placing the floor on the chassis. In modern homes, the framing cavities are also at least partly filled with insulation. Wiring, plumbing, and ducting are placed under the floor during this step in the manufacturing process. Essentially all manufactured homes built under the HUD MPS are built in this way, although there are some subtle variations from factory to factory.

The RBSA sample of manufactured homes is dominated by this construction technique, with only two homes (less than 1% of the sample) built differently. The remaining sample used the typical manufactured home framing and insulation system summarized in Table 15 (see Section 4.1).

Table 18 reflects the nominal insulation values (with adjustments) by vintage. Table 19 shows the average floor heat-loss rate based on U-value for each state and across the entire sample. Across the sample, about 12% of all manufactured homes had insulation retrofit into the floor system. The fraction of retrofit floor insulation is similar in all states. The survey identified the insulation upgrade in these cases, and the floor U-value and overall heat-loss rate were calculated with this information. The surveyor was also asked to assess the condition of floor insulation. In some cases, the floor insulation had been damaged over the life of the house, and the surveyor was asked to assess this damage. For homes where damage was observed, this assessment was used to modify the heat loss calculation. About 20% of the sample had a reduction in floor insulation as a result of these observations.

Table 18: Distribution of Floor Insulation by Home Vintage

Vintage		Floor Insulation Levels						
		R0–R8	R9–R14	R15–R21	R22–R30	R31–R40	All Floors	n
1951–1960	%	100.0%	—	—	—	—	0.8%	3
	EB	0.0%	—	—	—	—	1.0%	
1961–1970	%	89.5%	5.6%	4.9%	—	—	7.6%	33
	EB	9.7%	6.2%	7.8%	—	—	2.6%	
1971–1980	%	52.2%	37.1%	9.8%	0.9%	—	21.7%	91
	EB	10.7%	10.5%	6.8%	1.0%	—	4.2%	
1981–1990	%	16.7%	68.2%	5.7%	5.5%	3.8%	24.6%	64
	EB	8.6%	10.6%	5.5%	4.3%	4.5%	4.8%	
1991–2000	%	6.9%	25.8%	6.2%	36.6%	24.6%	29.1%	86
	EB	6.4%	9.0%	4.5%	9.7%	9.0%	5.0%	
Post 2000	%	—	—	4.6%	38.7%	56.7%	16.2%	38
	EB	—	—	7.5%	15.7%	16.0%	4.6%	
All Vintages	%	26.1%	32.3%	6.3%	18.2%	17.2%	—	315
	EB	4.6%	5.1%	2.7%	4.3%	4.3%	—	

Table 19: Distribution of Floor U-value by State

State	Floor U-value		
	Mean	EB	n
ID	0.087	0.009	64
MT	0.072	0.008	61
OR	0.076	0.007	96
WA	0.078	0.006	97
Region	0.078	0.004	318

4.1.3. Ceiling/Attics

The manufactured homes ceiling insulation is installed in the factory. Generally the access to the ceiling space is very limited or non-existent. Like the walls and floors, insulation values were set by the vintage of the home and the manufacturing standards in place at the time. The surveyors attempted to establish if any ceiling insulation was installed after the initial manufacture of the home. Like floors, about 12% of the sample had evidence of retrofit ceiling insulation. In general, the surveyors were not able to directly observe the insulation quality in either the factory insulation or the retrofit insulation. Table 20 summarizes the distribution of ceiling insulation across the sample. The nominal R-values shown in Table 20 reflect the assumption that the original insulation values or the retrofit insulation values were uniform across the ceiling area.

Table 20: Distribution of Ceiling Insulation

Insulation Level		Ceiling Insulation Level						
		R0–R8	R9–R14	R15–R21	R22–R30	R31–R40	All Ceilings	n
1951–1960	**%**	33.5%	—	—	66.5%	—	0.9%	3
	EB	49.8%	—	—	49.8%	—	1.0%	
1961–1970	**%**	78.5%	2.7%	5.2%	13.6%	—	7.4%	33
	EB	15.5%	4.4%	5.7%	14.8%	—	2.5%	
1971–1980	**%**	33.3%	53.5%	7.2%	4.9%	1.1%	21.6%	91
	EB	9.6%	10.4%	4.7%	3.2%	1.6%	4.2%	
1981–1990	**%**	1.5%	83.3%	7.1%	4.3%	3.9%	24.8%	64
	EB	2.3%	7.4%	4.9%	3.9%	4.2%	4.8%	
1991–2000	**%**	1.7%	28.5%	—	28.1%	41.7%	28.4%	86
	EB	2.7%	9.4%	—	8.8%	10.2%	4.9%	
Post 2000	**%**	—	—	—	37.1%	62.9%	16.8%	38
	EB	—	—	—	16.1%	16.1%	4.8%	
All Vintages	**%**	14.6%	40.7%	3.6%	17.7%	23.4%	—	315
	EB	3.3%	5.4%	1.6%	4.4%	4.8%	—	

Table 21 shows the distribution of ceiling U-values across the sample. The overall ceiling U-value was calculated using standard techniques designed to take into account the constrained nature of the ceiling construction in this sector (Davis and Baylon, 1996). The insulation U-values in Table 21 reflect the values in Table 20 summarized by state.

Table 21: Distribution of Ceiling U-value by State

State	Ceiling U-value		
	Mean	EB	n
ID	0.080	0.007	64
MT	0.080	0.009	61
OR	0.078	0.007	94
WA	0.087	0.006	97
Region	0.083	0.004	316

4.1.4. Windows

The evaluation of windows used the same distinction as that used for the other heat loss components. Manufacturing standards shown in Table 15 (see Section 4.1) were used based on the observed vintage of the home. In the case of windows, however, a much higher fraction of the original installed windows have been replaced with more modern windows. This improvement occurred in about 40% of the sample. Overall, about half of all windows from homes built before 1990, when the BPA program began influencing the actual in-plant manufacturing standard, have been replaced with higher performing windows, even if no other insulation upgrades were present. Table 22 shows the distribution of the replacement windows by state.

Table 22: Percent of Homes with Replacement Windows by State

State	Percentage of Homes		
	%	EB	n
ID	34.4%	9.8%	64
MT	32.1%	10.4%	56
OR	40.2%	9.3%	96
WA	43.0%	9.2%	92
Region	39.8%	5.3%	308

The result of these replacements has been a decrease in the average U-values of the windows in the manufactured home sector. Table 23 shows the distribution of window U-values by state.

Table 23: Distribution of Window U-value by State

State	Window U-value		
	Mean	EB	n
ID	0.723	0.062	66
MT	0.792	0.078	61
OR	0.715	0.056	97
WA	0.699	0.046	97
Region	0.717	0.029	321

It is important to note that this sample includes a large fraction of homes from older vintages. About 61% of all homes in this sample were manufactured before 1990, and 25% of the sample was manufactured before 1976 when the HUD standard went into effect. In this entire period, window standards in the manufactured home sector lagged behind codes and building practices for site-built homes in the Northwest.

4.1.5. Overall Heat Loss

After establishing the insulation levels and characteristics of the home, Ecotope compiled the overall heat-loss rate.[10] U-values were assigned to each building envelope component where insulation levels were established. In calculating the UA of each home, the manufacturing standards in place at the time of manufacture were used to determine the insulation levels and component specifications for each home.[11] These standards are shown in Table 15 (see Section 4.1). As a result, all of the manufactured homes surveyed included a UA calculated for the components of the building.[12]

Table 24 shows the distribution of heat-loss rate by state and by vintage. The heat loss figures in this section 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 24 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]

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[10] 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 thermal conductivity (U-value) of each building component (e.g., wall) and the area of that component. The insulation levels summarized in the previous sections 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.

[11] For purposes of analysis, a *de facto* manufacturing standard was developed for homes built before the advent of the federal HUD standards (1976).

[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, manufacturing standards were used to establish the insulation level.

[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 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 24: Average Normalized Heat-Loss Rate by Vintage

Vintage		Heat-Loss Rate (UA/sq.ft.) per Home					
		ID	MT	OR	WA	Region	n
Pre 1981	Mean	0.491	0.503	0.433	0.470	0.467	124
	EB	0.051	0.047	0.035	0.038	0.021	
1981–1990	Mean	0.348	0.495	0.354	0.378	0.373	62
	EB	0.028	0.175	0.034	0.018	0.015	
1991–2000	Mean	0.276	0.247	0.281	0.294	0.282	86
	EB	0.042	0.041	0.042	0.043	0.024	
Post 2000	Mean	0.171	0.188	0.186	0.209	0.197	38
	EB	0.007	0.016	0.019	0.023	0.013	
All Vintages	Mean	0.372	0.387	0.339	0.371	0.363	310
	EB	0.034	0.042	0.026	0.023	0.015	

As Table 24 shows, when these data were analyzed across the entire range of vintages, the UA per square foot has been cut by a factor of 2.5 over the last 30 years. The percentage is consistent across the states, with slightly more reduction (but not statistically significant) in the colder regions. The uniformity across states suggests the impact of the federal standards. The standards are set for the entire region so that no state or local building practice impacts the component specifications separately.

Table 25 shows that there is essentially no difference between states in the overall heat-loss rate but there is a very substantial difference (about a factor of three) between the oldest vintages and the current standards and practices.

Table 25: Average Heat-Loss Rate by Age/Standard

Age/Standard		Heat-Loss Rate (UA/sq.ft.) per Home					
		ID	MT	OR	WA	Region	n
1975 and Older, HUD	Mean	0.523	0.527	0.491	0.538	0.522	85
	EB	0.038	0.049	0.043	0.040	0.023	
1976–1994, HUD	Mean	0.391	0.416	0.362	0.374	0.375	125
	EB	0.042	0.080	0.014	0.013	0.011	
1990–1994, SGC or Natural Choice	Mean	0.182	0.163	0.188	0.179	0.182	30
	EB	0.013	0.013	0.007	0.011	0.006	
1995 to Current, HUD	Mean	0.321	0.271	0.298	0.265	0.284	35
	EB	0.096	0.030	0.087	0.015	0.033	
1995 to Current, NEEM	Mean	0.176	—	0.177	0.252	0.206	10
	EB	0.003	—	0.014	0.104	0.046	
2000 to Current, ENERGY STAR	Mean	0.170	0.174	0.169	0.163	0.168	30
	EB	0.007	0.006	0.006	0.007	0.004	
All Age/Standards	Mean	0.372	0.387	0.339	0.371	0.363	315
	EB	0.034	0.042	0.026	0.023	0.015	

Figure 5 shows the declining heat-loss rate over the 30 years in which codes were implemented in the region.

Figure 5: Average Heat-Loss Rate by Vintage

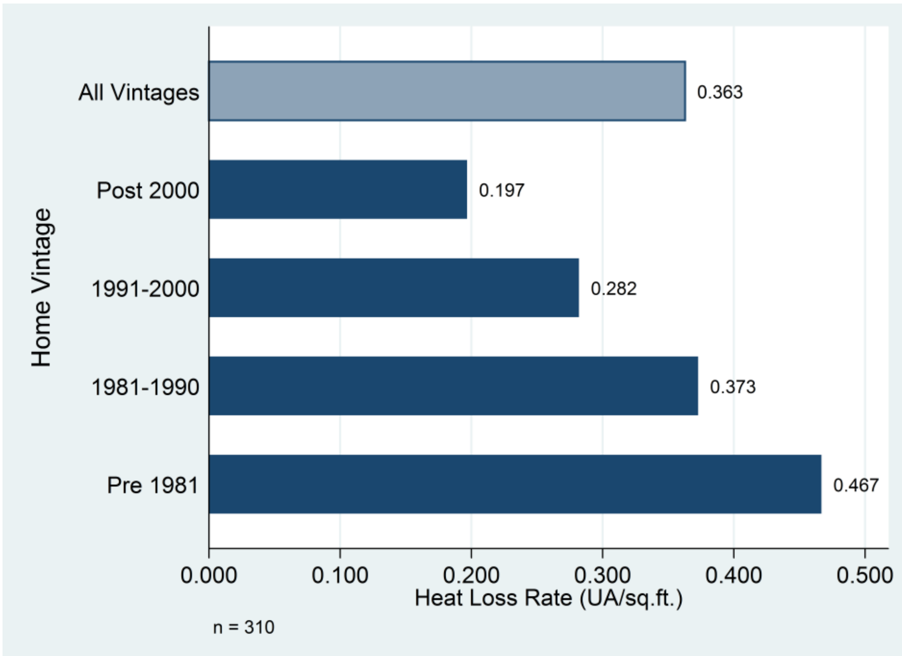


Table 26 shows the average total heat-loss rate (conductive only) distributed by vintage. The reduction in heat loss is about 40% from the earliest to the latest vintage bins. This compares with the reduction in normalized heat loss in Table 24 of almost twice that reduction. Similar to the single-family sector, some of the gains in envelope performance have been offset by an increase in house size. Since 1980, the average size of manufactured homes has increased about 60%. Table 26 also shows the trend in reduced heat loss by state. Like the other components, the overall effect on heat-loss rate is fairly uniform across states.

Table 26: Average Heat-Loss Rate by Vintage

Vintage		Heat-Loss Rate (UA) per Home					
		ID	MT	OR	WA	Region	n
Pre 1981	Mean	515	490	429	464	465	124
	EB	45	50	32	40	21	
1981–1990	Mean	440	508	469	459	461	62
	EB	63	220	64	36	29	
1991–2000	Mean	430	345	401	393	399	86
	EB	58	53	66	67	37	
Post 2000	Mean	251	309	329	359	334	38
	EB	32	41	66	52	33	
All Vintages	Mean	456	422	416	436	432	310
	EB	32	38	31	25	16	

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. The summaries include 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 27 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 27: Average Blower Door Air Flow by State

State	Blower Door Air Flow (CFM @ 50 Pa)		
	Mean	EB	n
ID	1,781	231	26
MT	2,048	472	25
OR	1,649	172	43
WA	1,773	303	62
Region	1,762	155	156

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 28 shows the average blower door air tightness across the states and within the region, through all vintages of the sample. This value is close to 12 ACH50, with all states showing similar results. This finding follows a similar pattern to the other components as these homes were all built with a similar set of standards and a similar set of construction techniques.

Table 28: Average Blower Door Air Tightness by State

State	Blower Door Air Tightness (ACH50)		
	Mean	EB	n
ID	12.1	2.0	26
MT	13.0	2.6	25
OR	11.0	1.7	43
WA	12.0	3.1	62
Region	11.8	1.5	156

Table 29 and Figure 6 show 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. Indeed in this sector, changes in technique show an increase in air tightness of almost a factor of four between the pre-1981 homes and the modern post-2000 homes.

Table 29: Average Blower Door Air Tightness by Home Vintage

Vintage	Blower Door Air Tightness (ACH50)		
	Mean	EB	n
1951–1960	16.5	6.6	2
1961–1970	22.5	10.7	17
1971–1980	14.8	1.7	40
1981–1990	10.8	1.8	34
1991–2000	7.7	0.8	37
Post 2000	4.8	0.5	23
All Vintages	11.8	1.5	156

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

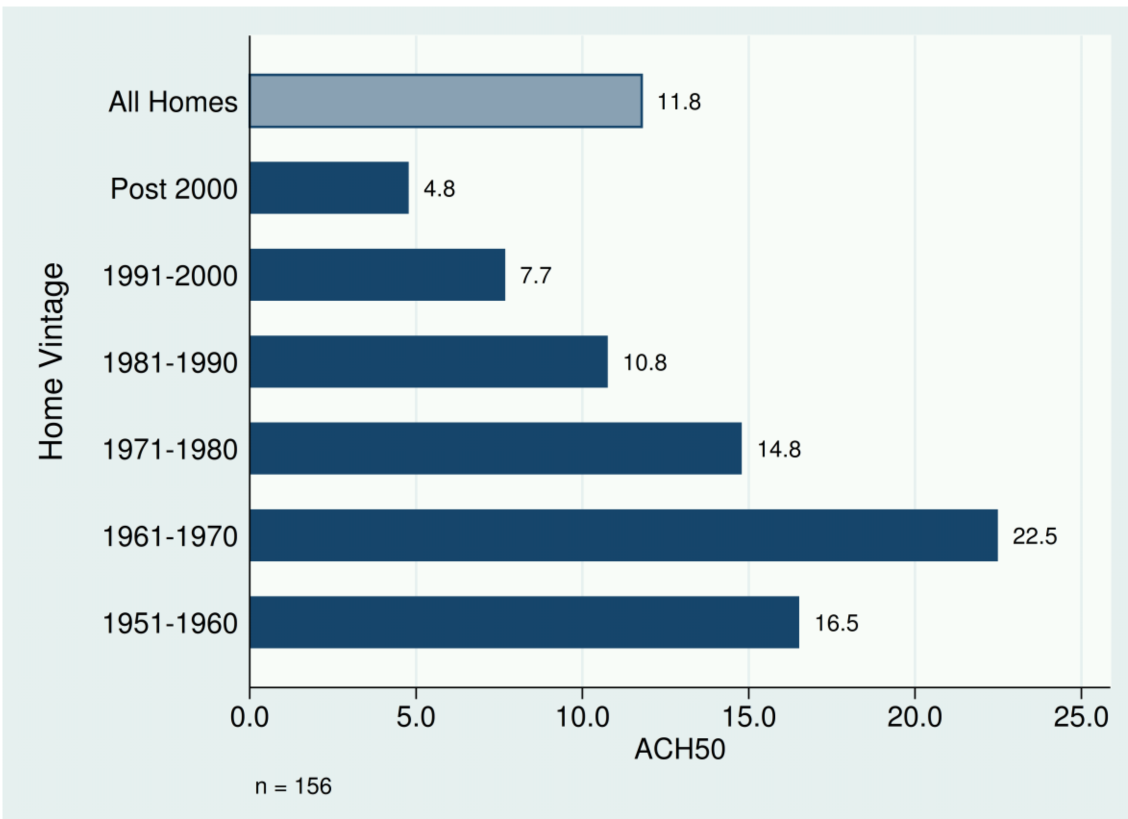


Table 30 and Table 31 show the effective natural infiltration rate inferred from the level of envelope tightness shown in Table 28. Overall, this level of convective heat loss suggests that infiltration accounts for about 25% of the overall heat loss of the average home. To use the test data (CFM at 50 Pa) for assessing air infiltration rates in normal conditions (typically less than 4 Pa of differential pressure), two analytical approaches are presented below:

1. The ACH50 divided by 20 used to calculate the values in Table 30 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).
2. Table 31 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 31 shows the results of applying this calculation procedure to the air tightness test results.

Table 30: Average Infiltration Rate by State, ACH50 Divided by 20

State	Infiltration Rate (ACH50/20)		
	Mean	EB	n
ID	0.604	0.10	26
MT	0.651	0.13	25
OR	0.548	0.08	43
WA	0.600	0.16	62
Region	0.589	0.08	156

Table 31: Average Infiltration Rate by State, ASHRAE 62.2

State	Infiltration Rate (ACH Natural, ASHRAE 62.2)		
	Mean	EB	n
ID	0.582	0.090	26
MT	0.811	0.187	25
OR	0.515	0.075	43
WA	0.634	0.159	62
Region	0.606	0.077	156

[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.

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. 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 the homeowner's designation to a "secondary" heating 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 a 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.

Approximately one full day of the four-day RBSA surveyor training 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. In manufactured homes, duct systems are very uniform because of housing type.

The surveyors were instructed to spend the 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 efficiency implications exist for the different types. The motor types include permanent split capacitors (PSC) found on older systems, and electronically commutated motors (ECM) found on some newer systems. Only a small percentage of systems in manufactured homes have ECM air handlers because these would not be installed at the manufacturing facility.

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 (AC) 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 coded and summarized as "primary."

Surveyors recorded the age and type of equipment. Ecotope categorized combustion appliances by type of combustion 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 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.

5.1. Heating Systems

Table 32 categorizes the primary heating equipment including forced air furnaces, electric and other zonal heating systems, ducted air-source heat pumps, and ductless heat pumps (DHP). The zonal systems are divided between electric baseboards/wall heaters and combustion stoves and heaters located in a single (usually central) zone. Table 33 shows the distribution of fuel choice in the primary systems in each state. Figure 7 and Figure 8 show the distribution of fuel choice in primary systems for the region and by state, respectively.

Approximately 79% of the primary heating systems are ducted forced air systems, including forced air furnaces and conventional (air-source) pumps. About 84% of these forced air systems use electricity (and these include air-source heat pumps). The remainder of the forced air systems is mostly gas-fueled, with a small percentage of propane and oil.

Most of the remaining primary systems are zonal (non-ducted) and are equally divided between electric zonal heating and combustion heating stoves. 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 in the central part of the home. Overall, 81% of primary heating systems are electric or natural gas (see Figure 7). More importantly, 70% of all primary heating in this sector is electric (usually electric resistance furnaces). About 14% of all primary heating systems use wood (not including pellets). The remainder is divided among oil, pellets, and propane.

Table 32: Distribution of Primary Heating System

Heating System Type	Primary Heating Systems		
	%	EB	n
Forced Air Furnace	64.3%	5.0%	206
Ductless Heat Pump	0.8%	0.8%	3
Baseboard Heater	1.5%	1.1%	6
Fireplace	1.3%	1.3%	3
Air Source Heat Pump	14.4%	3.6%	50
Heating Stove	16.0%	3.8%	49
Plug-In Heater	1.7%	1.5%	4
Total	100.0%	—	321

Table 33: Distribution of Fuel Choice for Primary Heating System

Fuel Type		Fuel Choice (Primary System)					
		ID	MT	OR	WA	Region	n
Electric	%	63.6%	16.4%	77.9%	78.5%	70.1%	207
	EB	9.8%	7.9%	7.2%	7.4%	4.3%	
Gas	%	15.2%	50.8%	6.6%	3.8%	10.9%	51
	EB	7.3%	10.6%	4.4%	3.5%	2.6%	
Oil	%	—	3.3%	1.2%	—	0.7%	3
	EB	—	3.8%	2.0%	—	0.7%	
Pellets	%	1.5%	—	2.6%	2.1%	2.0%	5
	EB	2.5%	—	3.0%	2.5%	1.5%	
Propane	%	1.5%	16.4%	—	0.9%	2.2%	12
	EB	2.5%	7.9%	—	1.5%	1.1%	
Wood	%	18.2%	13.1%	11.7%	14.7%	14.1%	43
	EB	7.9%	7.2%	6.0%	6.4%	3.6%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	321

Figure 7: Distribution of Fuel Choice for Primary Heating System

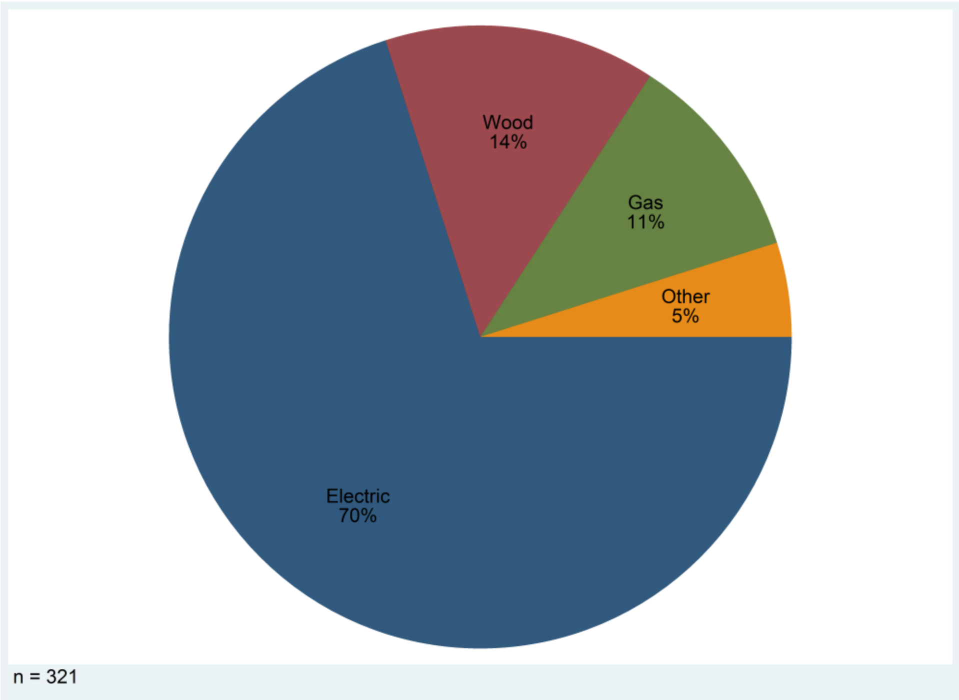


Figure 8: Distribution of Fuel Choice for Primary Heating Systems by State

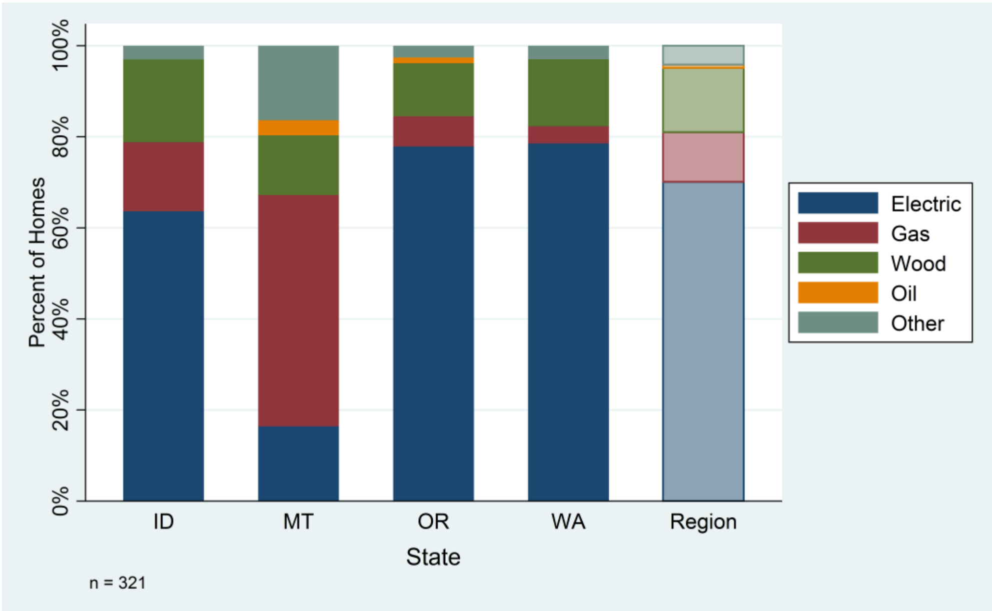


Table 34 shows the distribution of secondary heating systems. Secondary heating systems include all systems that were not designated as primary. Homes can have several secondary heating systems. The surveyors did not collect detailed information on the relative usage/importance of the secondary systems.

Table 35 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 34: Distribution of Secondary Heating Systems

Heating System Type	Secondary Heating Systems		
	%	EB	n
Forced Air Furnace	30.9%	7.5%	41
Ductless Heat Pump	1.0%	1.6%	1
Baseboard Heater	8.9%	4.3%	12
Fireplace	1.3%	2.1%	1
Air Source Heat Pump	7.2%	4.4%	7
Heating Stove	24.2%	6.3%	35
Plug-In Heater	26.6%	6.1%	35
Total	100.0%	—	132

Table 35: Distribution of Fuel Choice by Secondary Heating System and State

Fuel Type		Fuel Choice (Secondary Systems)					
		ID	MT	OR	WA	Region	n
Electric	%	64.0%	53.8%	73.2%	67.1%	67.6%	85
	EB	15.8%	18.5%	10.5%	12.1%	6.9%	
Gas	%	8.0%	11.5%	2.6%	5.8%	5.5%	8
	EB	9.2%	13.3%	4.2%	6.3%	3.6%	
Oil	%	—	—	2.6%	—	0.9%	1
	EB	—	—	4.0%	—	1.4%	
Pellets	%	4.0%	3.8%	0.3%	—	1.0%	3
	EB	6.3%	6.3%	0.5%	—	1.0%	
Propane	%	8.0%	11.5%	8.1%	6.2%	7.6%	11
	EB	8.8%	13.3%	7.4%	6.8%	4.3%	
Wood	%	16.0%	19.2%	13.2%	20.8%	17.4%	24
	EB	10.9%	12.9%	8.9%	11.2%	6.0%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	132

Electric systems are the most commonly used secondary system, accounting for almost 70% of all the secondary fuel. About half of these systems (39% of all secondary systems) are plug-in heaters, but the other half (36% of all secondary systems) consists of the home's original forced-air electric furnace system that has been displaced by a heating stove. This shows that many homeowners have decided to forgo a central system in lieu of another system (most commonly a wood stove). Wood is the other major fuel used by secondary systems, accounting for about 25% of the systems. These are largely wood stoves, although some fireplaces are also used.

Table 36 and Table 37 cross-tabulate the distribution of fuel choices for the two principal heating systems in this sample with the most diverse fuel selection: forced air furnaces and combustion heating stoves. Table 36 and Table 37 include both the primary and secondary systems. The tables illustrate the dominance of particular fuel types in these separate systems. Almost 80% of the forced air furnaces are electric, and more than 85% of the combustion stoves use wood or pellets.

Table 36: Distribution of Fuel Choice, Forced Air Furnaces

Fuel Type	Fuel Choice (Forced Air Furnaces)		
	%	EB	n
Electric	79.8%	3.7%	174
Gas	13.9%	3.2%	52
Oil	0.7%	0.9%	2
Propane	5.6%	2.3%	19
Total	100.0%	—	247

Table 37: Distribution of Fuel Choice, Combustion Heating Stoves

Fuel Type	Fuel Choice (Heating Stove)		
	%	EB	n
Gas	8.7%	5.9%	6
Oil	2.1%	2.6%	2
Pellets	9.0%	5.7%	8
Propane	4.6%	4.3%	4
Wood	75.6%	8.3%	64
Total	100.0%	—	84

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 subsequently 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 38 shows the distribution of gas furnace efficiency by vintage and state based on Annual Fuel Utilization Efficiency (AFUE). Federal standards for gas furnaces have not changed in the period between 1990 and 2011. These standards set a required efficiency for gas furnaces in manufactured homes at 78%. Over time these standards have migrated toward the standards used by the rest of the market. Nevertheless the efficiency of gas furnaces has remained constant in this industry. The advent of NEEM and ENERGY STAR standards has increased the average slightly in the last decade. Although in single-family homes the higher efficiency furnaces have come to dominate many markets, only a few manufactured homes have seen a significant increase in gas furnace efficiency.

Table 38: Average Gas Furnace Efficiency (AFUE) by Equipment Vintage and State

Vintage		Efficiency (AFUE)					
		ID	MT	OR	WA	Region	n
Pre 1990	**%**	80.3%	76.8%	—	78.0%	77.9%	9
	EB	0.3%	1.5%	—	0.0%	1.0%	
1990–1999	**%**	81.9%	80.7%	78.4%	82.1%	80.4%	17
	EB	0.3%	0.6%	2.2%	0.0%	1.0%	
2000–2005	**%**	80.0%	82.1%	81.4%	—	81.7%	11
	EB	0.0%	2.1%	0.0%	—	1.5%	
Post 2005	**%**	84.8%	80.0%	95.0%	80.0%	82.2%	8
	EB	6.1%	0.0%	0.0%	0.0%	2.9%	
All Vintages	**%**	82.3%	80.2%	79.5%	80.0%	80.5%	45
	EB	2.3%	0.9%	2.1%	1.7%	0.8%	

Heat pumps are generally a consumer choice upgrade and are not part of the manufacturer's specifications. As a result, the performance of heat pumps within the manufactured homes sector is similar to the entire residential market. Table 39 shows the average efficiency for air source heat pumps in manufactured homes. 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. In 2006, the federal minimum HSPF increased from 6.8 to 7.7. However, the average HSPF observed in the field after 2005 (8.4) is greater than 7.7, indicating that some consumers are buying heat pumps that have considerably better ratings than the federal minimum.

Table 39: Average Air Source Heat Pump Efficiency (HSPF) by Equipment Vintage (Post-1989)

Vintage*	Efficiency (HSPF)		
	Mean	EB	n
1990–1999	7.16	0.30	7
2000–2005	7.39	0.24	14
Post 2005	8.39	0.31	16
All Vintages	7.67	0.22	40

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

Table 40 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. Beginning in 2015 the federal standard will be increased to HSPF 8.2. As Table 40 illustrates, a majority of the heat pumps in this sector have an HSPF of 8.2 or less, and less than 10% meet the 2015 federal standard.

Table 40: Distribution of Air Source Heat Pump Efficiency (HSPF) by State

HSPF		Percentage of Homes				
		ID	OR	WA	Region	n
6.8–7.6	**%**	60.0%	60.4%	48.5%	57.4%	22
	EB	36.3%	18.2%	32.1%	14.8%	
7.7–8.2	**%**	40.0%	27.6%	48.9%	34.1%	13
	EB	36.3%	16.7%	32.0%	14.1%	
8.3–8.9	**%**	—	—	2.6%	0.6%	1
	EB	—	—	4.4%	1.1%	
≥9.0	**%**	—	12.0%	—	7.9%	5
	EB	—	11.6%	—	7.8%	
Total		100.0%	100.0%	100.0%	100.0%	41

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 41 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 cooling loads in various micro-climates throughout the region. The data in Table 41 are based on the presence of any cooling equipment; in general, this represents about 54% of all the homes. In Cooling Zone 3, the saturation of cooling equipment is more than twice that in Cooling Zone 1, reflecting the higher cooling loads in those locations.

Table 41: Percentage of Homes with Any Mechanical Cooling Equipment by Cooling Zone and State

Cooling Zone		Cooling Equipment per Home (All Systems)					
		ID	MT	OR	WA	Region	n
Cooling Zone 1	%	50.0%	32.6%	69.7%	21.9%	40.4%	209
	EB	18.5%	11.5%	10.7%	8.5%	5.9%	
Cooling Zone 2	%	65.0%	26.7%	68.2%	84.2%	70.2%	73
	EB	17.7%	18.9%	17.8%	14.0%	9.1%	
Cooling Zone 3	%	80.8%	—	100.0%	100.0%	90.5%	39
	EB	12.8%	—	0.0%	0.0%	6.8%	
All Cooling Zones	%	66.7%	31.1%	72.5%	41.0%	53.7%	321
	EB	9.6%	9.8%	8.4%	7.5%	4.6%	

Table 42 shows the distribution of cooling equipment types across all primary cooling systems observed. In general, the occupant identified their primary cooling in the interview with the surveyor. In a few cases where the home had a central cooling system associated with a working indoor air handler, that system was designated as the primary cooling system regardless of the occupants' assertions. In Table 42, 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.[15]

[15] 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 42 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 42: 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
Central AC	**%**	19.8%	36.7%	43.5%	25.1%	39
	EB	10.5%	14.1%	14.1%	6.1%	
Evaporative Cooler	**%**	16.8%	33.6%	49.6%	5.0%	11
	EB	18.3%	23.5%	25.7%	2.3%	
Air Source Heat Pump	**%**	58.1%	26.6%	15.2%	33.0%	57
	EB	11.9%	11.3%	8.7%	6.5%	
Ductless Heat Pump	**%**	72.5%	27.5%	—	1.5%	3
	EB	41.6%	41.6%	—	1.6%	
PTAC	**%**	77.6%	—	22.4%	1.9%	5
	EB	34.1%	—	34.1%	1.7%	
Window AC	**%**	58.4%	38.1%	3.5%	33.5%	58
	EB	11.1%	10.9%	4.1%	6.8%	
All HVAC Types	**%**	47.1%	32.9%	20.0%	—	173
	EB	5.0%	5.7%	5.3%	—	

The distribution of cooling equipment is dominated by central systems. More than half of all cooling systems are associated with either a central heat pump or a central air conditioning unit. About a third of the cooling systems are window AC units, with the balance mixed between various types of zone cooling systems.

Table 43 and Table 44 summarize the observed equipment efficiency for both central AC and heat pump cooling equipment. The SEER efficiencies are shown by vintage. The distribution of SEER does not change dramatically by vintage until the increase in federal efficiency standards in the post-2006 period.

Table 43: Average Cooling Efficiency (SEER) for Post-1989 Central AC Systems by Vintage

Vintage*	Efficiency (SEER)		
	Mean	EB	n
1990–1999	10.4	0.494	6
2000–2005	10.1	0.095	7
Post 2005	13.0	0.000	6
All Vintages	10.7	0.424	21

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

Table 44: Average Cooling Efficiency (SEER) for Central Air Source Heat Pump Systems by Vintage

Vintage*	Efficiency (SEER)		
	Mean	EB	n
Pre 1990	10.0	0.00	1
1990–1999	10.6	0.48	7
2000–2005	11.2	0.66	14
Post 2005	13.6	0.73	16
All Vintages	11.9	0.53	41

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

The 2006 federal standard set a minimum SEER of 13.0, and it appears from Table 43 that most central AC equipment was very close to the minimum standard. In contrast, Table 44 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 39) resulted in an increased cooling efficiency (Table 43). Note that Table 43 does not include SEER ratings for pre-1990 AC systems. Lookup model numbers and ratings for the few cases in this vintage range were not available.

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 45 shows that the regional saturation of this equipment is about 12%.

Table 45: Average Number of Portable Cooling Devices per Home by State

State	Number of Portable Cooling Devices per Home		
	Mean	EB	n
ID	0.138	0.075	58
MT	0.136	0.074	59
OR	0.163	0.086	64
WA	0.115	0.061	85
Region	0.133	0.039	266

6. Duct Systems

The review of duct systems in manufactured homes was less complex than for site-built structures. Manufactured homes are built in a factory, and the duct systems are also fabricated there and installed as part of the floor assembly. The amount of insulation in the floor system is determined largely by the vintage of the home (see Section 4.1). Most manufactured homes have some amount of insulation below the duct (in the “belly” area) and in some cases, insulation is also placed between the duct and the home’s subfloor. The duct typically runs most of the length of the home and delivers conditioned air to most rooms via short risers that are attached to the subfloor.

The amount of energy waste associated with the duct systems depends on the amount of insulation surrounding the duct (and its location relative to the crawlspace and home interior), duct leakage, and the overall air-tightness of the house. The duct insulation level is determined by the surveyor’s assignment of home vintage (plus visual inspection of the floor system insulation and crossover duct), and some of these homes received duct and house tightness tests plus a test of supply system static pressure and main heating system airflow rate so that a supply duct leakage fraction (SLF) could be calculated.

Surveyors were given a one-day classroom training followed by a one-day field training on use duct leakage and airflow measurement techniques as applied to manufactured homes. 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 (such as furnace operating conditions). Supply static pressure at normal operating conditions was also measured to allow for normalization of leakage to what is called the half-plenum pressure (an approach most notably used in the ASHRAE Standard 152 duct testing standard). The highest static pressure in a duct system is at the plenum, 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 the combination of system-wide static pressures acting on a combination of system-wide duct leaks, this procedure is accepted as a more targeted estimate of duct leakage than tests conducted at 25 or 50 Pa.

6.1. Duct Configuration

Manufactured homes are generally manufactured with a duct system connected to a forced air furnace. The duct is installed below the floor framing between the chassis for the home. This duct is centered on the individual home section at the factory. The registers for each room are installed at that duct, or in some cases a small flex duct is added to allow the register to be placed at the perimeter of the home. In single-wide homes, the single trunk duct (5x15) runs the length of the home with registers placed in the rooms, using short risers. The furnace is located above the duct in the utility room and supplies the duct from that one point. Very few manufactured homes in the Northwest have a ducted return system; return air comes directly from the house through a grille or louvered door located at the furnace. In effect, the home itself is a large return duct.

In multi-section homes, the factory-installed ducts are located in the center of each section. The ducts are the same as in a single-wide home but with the furnace located in only one of the sections. The other sections are connected to the furnace with a large flex-duct (usually 14-inch round), called a "crossover" duct, that is installed onsite during the home's setup. This installation involves two flexible connections in the crawlspace and is often the source of catastrophic duct failure as the homes age. In larger homes, and especially triple-wide homes, one or more additional crossover ducts are installed in the hope of improving the distribution of conditioning air throughout the home. In a few cases, a second furnace is added (especially in triple-wide homes) to cover the heat load of the home.

These duct systems and heating systems are very straightforward and very inexpensive. They are, however, prone to substantial leakage due to the number of connection and field additions required. Crossover ducts are particularly vulnerable to failure. Surveyors observed and reported on crossover duct conditions when access to crawl spaces was available. Table 46 summarizes these results.

Table 46: Crossover Duct Condition in Multi-Section Homes

Unit Type		Crossover Duct Condition			
		Connected	Partially Connected	Disconnected	n
Modular/Prefab	%	87.1%	12.9%	—	10
	EB	19.6%	19.6%	—	
Double Wide	%	93.6%	5.5%	0.8%	155
	EB	3.3%	3.2%	1.0%	
Triple Wide	%	100.0%	—	—	10
	EB	0.0%	—	—	
Other	%	100.0%	—	—	1
	EB	0.0%	—	—	
All Types	%	93.7%	5.6%	0.7%	176
	EB	3.1%	3.0%	0.9%	

6.2. Duct Leakage Tests

Approximately 150 manufactured home surveys (almost 50% of the sample) included a supply duct leakage, system airflow, and duct static pressure test. The summary tables in the next section show various statistics based on these data; in most cases, the total number of cases summarized will be less than 150 because some of the tests did not meet accuracy requirements. The duct leakage tests reflect duct leakage to outside (as opposed to total duct leakage). "Leakage to outside" means that a blower door was used to back-pressure the house to the same pressure measured in the ducts (with respect to outside) during the duct leakage test so that leakage from the ducts back to conditioned space (which does not result in energy waste) is zeroed out. Appendix C includes a description of the leakage testing procedure.

Table 47 presents average supply leakage to outside in CFM at a test pressure of 25 Pa (0.1-inch water column), and Table 48 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. In Table 49 and Table 50 results are presented that express the leakage at a higher test pressure of 50 Pa (0.2-inch water column), because this measure is still commonly used in the Northwest and possibly elsewhere.

Table 49 shows the values measured in the field at 50 Pa reference pressure. 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.[16]

Table 47: Exterior Supply Duct Leakage at 25 Pa

State	Duct Leakage Total Flow (CFM @ 25 Pa)		
	Mean	EB	n
ID	145	68	15
MT	156	47	22
OR	119	27	32
WA	138	23	54
Region	135	16	123

Table 48: Exterior Supply Duct Leakage (25 Pa) Normalized by House Size

State	Duct Leakage Total Flow (CFM/sq.ft. @ 25 Pa)		
	Mean	EB	n
ID	0.152	0.087	15
MT	0.151	0.048	22
OR	0.096	0.019	32
WA	0.130	0.033	54
Region	0.125	0.020	123

Table 49: Exterior Supply Duct Leakage at 50 Pa

State	Duct Leakage Total Flow (CFM @ 50 Pa)		
	Mean	EB	n
ID	220	105	15
MT	237	69	22
OR	184	42	32
WA	212	35	54
Region	207	25	123

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

Table 50: Exterior Supply Duct Leakage (50 Pa) Normalized by House Size

State	Duct Leakage Total Flow (CFM/sq.ft. @ 50 Pa)		
	Mean	EB	n
ID	0.234	0.134	15
MT	0.231	0.072	22
OR	0.149	0.029	32
WA	0.200	0.052	54
Region	0.192	0.031	123

All homes that received a duct tightness test also had their furnace flow measured with an Energy Conservatory TrueFlow® Air Handler flow meter. Supply leakage to outside at half-plenum pressure is ratioed to the measured furnace flow and expressed as a "supply leakage fraction" (SLF) in Table 51. The SLF is the percentage of conditioned air that does not make it into the house directly; the SLF is also a primary input into models of overall house energy usage.

Table 51: Supply Duct Leakage Fraction

State	Supply Duct Leakage Fraction (Half Plenum Pressure)		
	%	EB	n
ID	12.8%	3.8%	14
MT	17.3%	6.3%	20
OR	13.0%	3.9%	29
WA	14.0%	2.6%	50
Region	14.0%	1.9%	113

7. Lighting

A detailed lighting audit was specified as part of the manufactured home survey. The lighting 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 fixture review, which included fixture types, lamps per fixture, and fixture count. Lamps were characterized by lamp type and lamp wattage. All types of fixtures (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 52 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 35 lamps per home. In contrast, the lamp count in a previous study included about 50 lamps per home in 2006 manufactured homes (Baylon et al., 2009). These 2006 homes averaged 1,740 square feet of conditioned area compared to 1,280 square feet for this sample. By comparison, the RBSA single-family sample observed about 63 lamps per home with an average house size of 2,006 square feet.

Table 52: Average Number of Lamps per Home by State

State	Lamps per Home		
	Mean	EB	n
ID	33.2	2.9	66
MT	29.9	3.5	61
OR	37.1	3.2	97
WA	34.1	3.1	97
Region	34.5	1.8	321

Table 53 shows the average total number of fixtures per home. Although this average is relatively consistent from one state to the next, the Montana results are somewhat lower than the other states. In this case, a slight downward bias due to missing exterior fixtures in some Montana homes would account for most of the difference in overall fixture count for this state.

Based on these lighting audit data, a total of 21 fixtures could be expected in each home, with a total of about 35 lamps in those fixtures. For reference, single-family homes had a total of 40 fixtures per home with a total of 63 lamps in those fixtures.

Table 53: Average Number of Fixtures per Home

State	Fixtures per Home		
	Mean	EB	n
ID	20.7	1.7	66
MT	18.0	1.8	61
OR	22.8	1.8	97
WA	20.8	1.5	97
Region	21.1	0.9	321

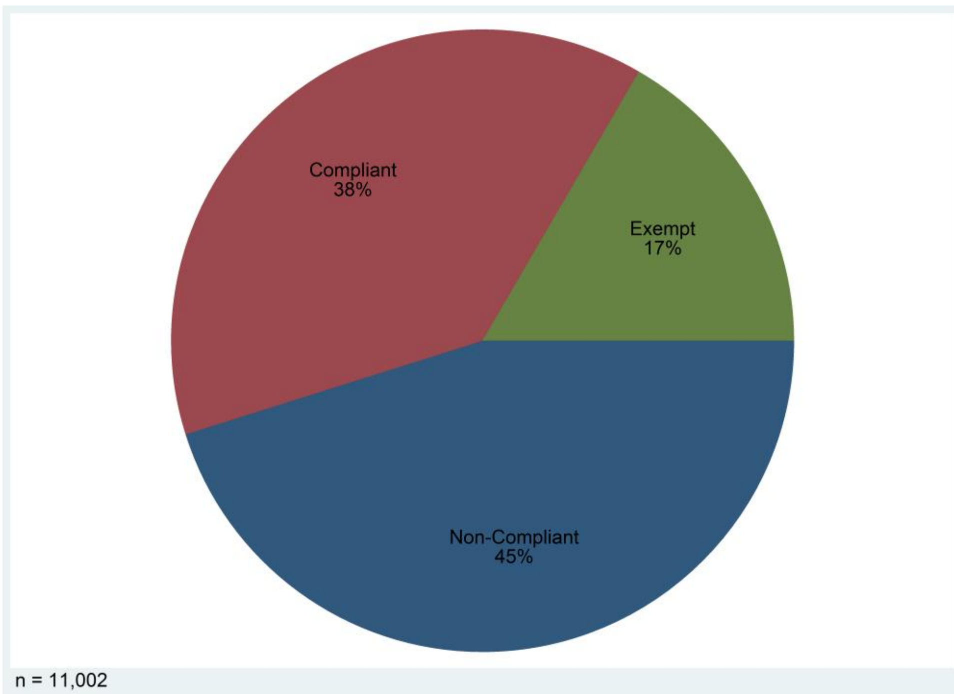
Table 54 and Figure 9 show the distribution of EISA exempt, non-compliant, and compliant lamps. The EISA compliant lamps currently meet or exceed the EISA standards for lighting efficacy (lumens per watt). About 38% of all the lamps observed are currently in compliance with the EISA standards. Most of 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 17% of all lamps will be exempt from the fully implemented EISA standard. Slightly more than 45% 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 54: Distribution of Lamps by EISA Category and State

EISA Category		Percentage of Lamps					
		ID	MT	OR	WA	Region	N
Exempt	%	18.5%	11.8%	17.0%	16.6%	16.6%	1,756
	EB	3.3%	3.0%	2.8%	2.6%	1.6%	
Non-Qualified, Non-Exempt	%	47.6%	51.4%	45.8%	42.6%	45.1%	5,090
	EB	6.0%	5.8%	3.9%	4.6%	2.6%	
Qualified or Not Affected	%	33.9%	36.8%	37.2%	40.8%	38.2%	4,156
	EB	6.1%	5.6%	4.4%	4.8%	2.7%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	11,002

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 55, the mean saturation of CFLs throughout the manufactured homes in the region is about 28% 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 manufactured home sample as a percentage of the total number of lamps in the individual sampling regions. The error bound on this estimate is 2.6%. The distribution of CFLs in the states remains reasonably comparable by state and reflects the uniformity in this population across the region.

Table 55: Distribution of Lamps by Type and State

Lamp Type		Percent of Lamps					
		ID	MT	OR	WA	Region	n
Compact Fluorescent	%	26.0%	26.6%	25.9%	29.7%	27.7%	2,961
	EB	5.8%	5.9%	4.3%	4.5%	2.6%	
Halogen	%	3.0%	0.6%	2.0%	2.3%	2.2%	242
	EB	1.7%	0.6%	1.0%	0.9%	0.6%	
Incandescent	%	62.8%	62.6%	60.8%	56.7%	59.4%	6,588
	EB	6.1%	5.8%	4.6%	5.0%	2.8%	
Linear Fluorescent	%	7.8%	10.2%	11.3%	10.8%	10.5%	1,185
	EB	2.0%	3.6%	2.4%	1.8%	1.2%	
Other	%	0.4%	—	0.0%	0.4%	0.3%	26
	EB	0.3%	—	0.1%	0.2%	0.1%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	11,002

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

The largest lamp type category is incandescent, representing 59% of the lamps observed. Only in Washington is there a lower saturation of incandescent lamps (though not statistically significant), presumably because of the greater emphasis on CFL lighting among the state's utilities.

Table 56 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 is 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 56: Distribution of Lamps by Type and Room

Lamp Type		Percent of Lamps					n
		Compact Fluorescent	Halogen	Incandescent	Linear Fluorescent	Other	
Bathroom	%	24.8%	0.5%	72.3%	2.4%	0.1%	2,048
	EB	4.2%	0.5%	4.4%	1.1%	0.1%	
Bedroom	%	31.4%	0.6%	64.9%	3.1%	—	1,569
	EB	4.1%	0.6%	4.2%	1.2%	—	
Closet	%	21.9%	0.4%	68.6%	9.1%	—	181
	EB	7.3%	0.6%	8.7%	5.7%	—	
Dining Room	%	17.8%	—	78.8%	3.4%	—	609
	EB	5.6%	—	6.3%	4.1%	—	
Exterior	%	27.9%	8.9%	56.7%	4.2%	2.2%	757
	EB	4.9%	3.3%	5.5%	2.5%	1.2%	
Family Room	%	34.7%	3.5%	60.4%	0.7%	0.7%	384
	EB	8.2%	2.8%	8.2%	1.1%	0.8%	
Garage	%	9.2%	1.5%	25.8%	63.5%	0.2%	544
	EB	4.4%	1.3%	7.5%	8.2%	0.2%	
Hall	%	34.5%	1.5%	62.2%	1.7%	0.2%	381
	EB	6.3%	2.3%	6.8%	1.5%	0.3%	
Kitchen	%	30.4%	5.7%	36.4%	27.4%	0.0%	1,656
	EB	4.3%	2.5%	4.2%	3.9%	0.1%	
Laundry Room	%	27.3%	—	55.5%	17.2%	—	366
	EB	6.1%	—	7.0%	6.8%	—	
Living Room	%	31.2%	1.7%	65.3%	1.8%	0.1%	1,297
	EB	4.2%	1.3%	4.3%	0.8%	0.1%	
Master Bedroom	%	30.4%	0.3%	67.7%	1.2%	0.3%	725
	EB	5.4%	0.3%	5.6%	1.0%	0.6%	
Office	%	39.2%	2.6%	45.9%	12.4%	—	229
	EB	9.3%	1.9%	8.5%	7.0%	—	
Other	%	20.9%	—	36.0%	43.1%	0.1%	256
	EB	9.6%	—	12.9%	15.6%	0.2%	
All Room Types	%	27.7%	2.2%	59.4%	10.5%	0.3%	11,002
	EB	2.6%	0.6%	2.8%	1.2%	0.1%	

The lighting audit identified lamps divided into the five categories shown in Table 55:

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

Table 57 through Table 61 show the average number of lamps in each category in each home. All 321 homes in this sample 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 57: Average Number of CFLs Installed per Home by State

State	Number of Lamps		
	Mean	EB	n
ID	8.61	2.1	66
MT	7.95	1.8	61
OR	9.61	1.5	97
WA	10.13	1.7	97
Region	9.53	1.0	321

Table 58: Average Number of Halogen Lamps Installed per Home by State

State	Number of Lamps		
	Mean	EB	n
ID	1.000	0.60	66
MT	0.180	0.17	61
OR	0.749	0.40	97
WA	0.789	0.31	97
Region	0.748	0.21	321

Table 59: Average Number of Incandescent Lamps Installed per Home by State

State	Number of Lamps		
	Mean	EB	n
ID	20.8	2.6	66
MT	18.7	2.9	61
OR	22.5	2.7	97
WA	19.3	2.4	97
Region	20.5	1.4	321

Table 60: Average Number of Linear Fluorescent Lamps Installed per Home by State

State	Number of Lamps		
	Mean	EB	n
ID	2.59	0.76	66
MT	3.03	1.23	61
OR	4.17	1.04	97
WA	3.69	0.78	97
Region	3.62	0.50	321

Table 61: Average Number of Other Lamps Installed per Home by State

State	Number of Lamps		
	Mean	EB	n
ID	0.136	0.086	66
MT	0.082	0.135	61
OR	0.040	0.049	97
WA	0.149	0.076	97
Region	0.106	0.041	321

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 62 summarizes the average number of CFLs stored at these sites. The number of stored lamps is consistent across most states, with Idaho slightly lower.

Table 62: Average Number of Stored Compact Fluorescent Lamps by State

State	Stored Compact Fluorescent Lamps		
	Mean	EB	n
ID	2.33	0.84	66
MT	3.00	0.86	61
OR	2.98	0.56	97
WA	2.73	0.65	97
Region	2.78	0.37	321

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 manufactured home and is summarized in Table 63. In this calculation, Idaho and Washington show a lower storage rate than the other states, although this result is not statistically significant.

Table 63: Percentage of All CFLs that Are Stored

State	CFLs		
	%	EB	n
ID	19.8%	5.9%	56
MT	29.2%	7.1%	48
OR	26.6%	4.8%	88
WA	18.9%	4.5%	89
Region	22.4%	2.8%	281

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 fixture and lamp 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 the LPD for each room and for the building as a whole. 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 LPD is calculated by dividing the total wattage by the square foot area of the room.

Table 64 shows the distribution of average LPD across various room types. The LPD for each room was based on the rooms' interior area and calculated separately. The list of rooms is from a "pick list" that the surveyors used to assign rooms during the survey. Table 64 shows about an 18% 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 64: Average Lighting Power Density (LPD) by Room Type

Room Type	Room LPD (W/sq.ft.)		
	Mean	EB	n
Bathroom	2.52	0.18	554
Bedroom	0.89	0.06	581
Closet	2.03	0.28	129
Dining Room	1.47	0.18	146
Family Room	0.82	0.12	86
Garage	0.66	0.08	57
Hall	1.61	0.18	255
Kitchen	1.23	0.09	303
Laundry Room	1.13	0.09	204
Living Room	0.79	0.07	297
Master Bedroom	0.85	0.10	206
Office	0.92	0.14	76
Other	2.55	1.66	73
All Room Types	1.41	0.07	2,967

The LPDs in Table 64 are summarized based on the interior area of the individual rooms. The total number of room audits conducted in this sample was about 3,000, or slightly more than nine rooms per home. The patterns shown in the table are not surprising; the highest LPD was observed in the bathrooms, with at least two sets of lamps for vanity mirrors, etc. The lowest LPDs occur in the garage, living room, family 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.

The lighting summary in Table 64 does not include exterior lamps, only lamps observed in individual rooms. Table 65 summarizes the total exterior wattage observed. This wattage represents about 14% of the total wattage observed in these homes. The surveyors did not collect exterior lighting data in about 40% of the manufactured homes in the sample. Thus, to prevent a bias in the overall lighting, an adjustment was made in the total lighting power. Similar adjustments could not be made in fixture or lamp counts.

Table 65: Average Exterior Lighting Power (Watts) by State

State	Exterior Lighting Power (Watts)		
	Mean	EB	n
ID	195	36	52
MT	240	93	17
OR	244	52	71
WA	227	38	59
Region	227	25	199

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 overall lighting power (including exterior lamp watts) was the basis for assessing LPD throughout the home.

Given the shortfall in the assessment of exterior lamps in the lighting audit, a correction was made to account for the potential bias introduced. To estimate the adjustment, the homes without exterior lighting were assigned the average wattage shown in Table 65. This wattage was added to the overall wattage calculated for the interior lamps, and the LPD was calculated using this new wattage.

Approximately 4.7% of the surveys were not included 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. Table 66 shows the LPD calculated from the unadjusted total wattage in the lighting audit.

Table 67 and Figure 10 show the LPD calculated from the total wattage adjusted by the exterior lighting wattage in cases where the survey included no exterior lamps. As the table shows, this correction raises the LPD by about 7% across the entire sample. For the cases where the adjustment was made, more than a 12% increase in wattage was observed.

Table 67 shows a regional LPD of 1.27, which is somewhat lower than the 1.4 W/sq.ft. LPD observed in the review of 2006 new manufactured homes (Baylon et al., 2009). The observed LPD in this study is consistent with the Council's assumption given the presence of 28% high-efficacy CFLs in our sample. In addition, a 10% saturation of linear florescent lamps was observed. When compared to the lamp type saturations of these technologies in the earlier study

(18% and 5% respectively), the reduced LPD is consistent with the increased saturations in this review.

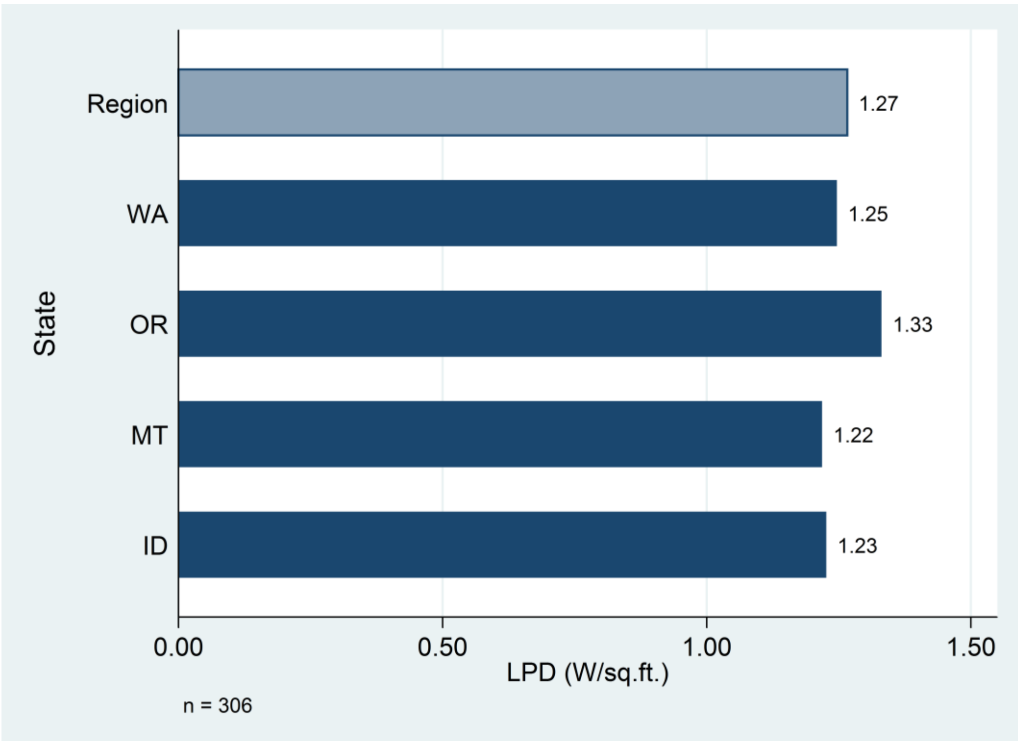
Table 66: Average Lighting Power Density (LPD) by State

State	Home LPD (W/sq.ft.)		
	Mean	EB	n
ID	1.19	0.108	61
MT	1.06	0.109	61
OR	1.27	0.092	91
WA	1.17	0.093	93
Region	1.19	0.054	306

Table 67: Average Adjusted Lighting Power Density (LPD) by State

State	Home LPD (W/sq.ft.)		
	Mean	EB	n
ID	1.23	0.110	61
MT	1.22	0.107	61
OR	1.33	0.088	91
WA	1.25	0.095	93
Region	1.27	0.054	306

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



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.

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 68 shows the average number of the household appliances per home for the total region. With the exception of freezers and dishwashers, virtually every home in the region has a full complement of appliances.

Table 68: Average Number of Appliances per Home by Type

Appliance	Number of Appliances per Home (n = 321)	
	Mean	EB
Clothes Washer	0.989	0.013
Dryer	0.950	0.024
Dishwasher	0.770	0.043
Freezer	0.428	0.063
Refrigerator	1.210	0.048
Water Heater	1.002	0.012

8.1. Refrigerator/Freezers

The survey of refrigerators focused on vintage and style. About 80% of all households have only one refrigerator; over 30% of those households have at least one standalone freezer.

Table 69 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 to 12 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.

Table 69: Distribution of Refrigerator/Freezers by Vintage

Vintage	Refrigerators		
	%	EB	n
Pre 1980	2.7%	1.2%	17
1980–1989	13.3%	3.1%	63
1990–1994	19.3%	3.6%	85
1995–1999	14.2%	3.0%	75
2000–2004	21.6%	3.3%	106
2005–2009	23.8%	3.8%	109
Post 2009	5.0%	2.0%	28
Total	100.0%	—	483

Table 70 shows the distribution of refrigerator types by position of the refrigerator doors and freezers. This table does not include standalone freezers.

Table 70: Distribution of Refrigerators by Type

Refrigerator Type	Refrigerators		
	%	EB	n
Full Size Refrigerator Only	2.2%	1.3%	10
Mini Refrigerator	2.2%	1.3%	8
Refrigerator with Bottom Freezer	13.5%	3.4%	42
Refrigerator with Side-by-Side Freezer	20.3%	3.8%	87
Refrigerator with Top Freezer	60.5%	4.9%	235
Side-by-Side Refrigerator with Bottom Freezer	1.3%	1.0%	5
Total	100.0%	—	387

Surveyors generally recorded the volumes for refrigerators and freezers from the information provided in the model number and manufacturer’s literature. Table 71 shows the average refrigerator volume by type of refrigerator across the region. The average refrigerator size is approximately 20 cubic feet (cu.ft.).

Table 71: Average Refrigerator Volume by Type

Refrigerator Type	Volume (cu.ft.)		
	Mean	EB	n
Full Size Refrigerator Only	20.1	3.98	10
Mini Refrigerator	4.5	1.00	8
Refrigerator with Bottom Freezer	21.4	0.63	42
Refrigerator with Side-by-Side Freezer	22.2	0.47	87
Refrigerator with Top Freezer	18.9	0.33	235
Side-by-Side Refrigerator with Bottom Freezer	24.6	1.65	5
All Types	19.7	0.36	387

Table 72 shows the distribution of standalone freezer type divided between upright and chest freezers. Table 73 shows the distribution of freezer volumes by type of freezer observed. The average freezer volume is 17 cu.ft.

Table 72: Distribution of Freezers by Type in Homes with Freezers

Freezer Type	Freezers		
	%	EB	n
Chest Freezer	39.8%	8.0%	53
Upright Freezer	60.2%	8.0%	85
Total	100.0%	—	138

Table 73: Average Freezer Volume by Type

Freezer Type	Freezer Volume (cu.ft.)		
	Mean	EB	n
Chest Freezer	15.1	1.24	53
Upright Freezer	18.7	0.81	85
All Types	17.3	0.77	138

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 74 shows the distribution of clothes washer vintages observed in this sample. The bulk of these washers were manufactured since 2000. This amounts to about 60% of the washers observed. The average age of the washers in this sample is less than 10 years.

Table 74: Distribution of Clothes Washers by Vintage

Vintage	Clothes Washers		
	%	EB	n
Pre 1980	1.0%	0.9%	4
1980–1989	8.1%	3.0%	24
1990–1994	14.0%	3.8%	43
1995–1999	16.5%	3.9%	56
2000–2004	21.2%	4.3%	66
2005–2009	31.5%	5.0%	93
Post 2009	7.7%	2.9%	23
Total	100.0%	—	309

Table 75 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 (front-loading) or vertical axis (top-loading) washing machines as well as stacked and combination washer/dryers. As shown, the majority of washing machines are vertical axis washing machines, with approximately 20% 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 25% of the current stock, compared to almost 40% for single-family homes.

Table 76 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.

Table 75: Distribution of Clothes Washers by Type and State

Clothes Washer Type		Percentage of Clothes Washers					
		ID	MT	OR	WA	Region	n
Horizontal Axis	%	16.9%	17.2%	18.5%	23.7%	20.4%	60
	EB	7.6%	8.2%	7.4%	7.7%	4.3%	
Stacked Washer/Dryer	%	3.1%	1.7%	—	6.6%	3.5%	8
	EB	3.5%	2.8%	—	4.6%	2.1%	
Vertical Axis (with Agitator)	%	75.4%	79.3%	77.1%	65.7%	72.2%	228
	EB	9.3%	8.8%	8.0%	8.8%	4.8%	
Vertical Axis (without Agitator)	%	4.6%	1.7%	4.4%	3.9%	3.9%	13
	EB	4.3%	2.8%	3.9%	3.5%	2.1%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	309

Table 76: Distribution of Clothes Washers by Type and Vintage

Clothes Washer Type		Vintage							
		Pre 1980	1980–1989	1990–1994	1995–1999	2000–2004	2005–2009	Post 2009	n
Horizontal Axis	%	—	—	—	6.0%	18.3%	61.7%	14.0%	60
	EB	—	—	—	5.2%	9.2%	11.5%	8.0%	
Stacked Washer/Dryer	%	—	32.4%	4.8%	13.4%	32.4%	17.0%	—	8
	EB	—	30.5%	8.1%	15.5%	30.5%	24.9%	—	
Vertical Axis (with Agitator)	%	1.3%	9.6%	19.8%	20.8%	21.8%	23.7%	2.9%	223
	EB	1.3%	3.8%	5.2%	5.1%	5.1%	5.4%	2.1%	
Vertical Axis (without Agitator)	%	1.2%	5.9%	—	5.9%	25.4%	36.5%	25.0%	13
	EB	2.0%	9.7%	—	9.7%	25.2%	26.3%	22.5%	
All Clothes Washer Types	%	1.0%	8.3%	14.3%	16.9%	21.6%	31.9%	6.0%	304
	EB	0.9%	3.1%	3.9%	3.9%	4.4%	5.0%	2.5%	

Surveyors asked participants about the number of washer loads performed each week in the home. Table 77 summarizes these results and shows an average of about 4.5 loads of washing per week (slightly less than the single-family sector).

Table 77: Average Number of Clothes Washer Loads per Week by State

State	Clothes Washer Loads per Week		
	Mean	EB	n
ID	4.54	0.91	65
MT	3.72	0.49	60
OR	4.29	0.54	96
WA	4.74	0.67	94
Region	4.47	0.37	315

8.3. Clothes Dryers

Surveyors recorded only the vintage and usage for clothes dryers. Table 78 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 78: Distribution of Clothes Dryers by Vintage

Vintage	Clothes Dryer		
	%	EB	n
Pre 1980	5.3%	2.4%	16
1980–1989	9.2%	3.2%	27
1990–1994	15.3%	4.0%	47
1995–1999	16.9%	4.1%	53
2000–2004	24.1%	4.6%	70
2005–2009	26.8%	4.9%	77
Post 2009	2.5%	1.4%	10
Total	100.0%	—	300

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 79 shows the responses to this question. Approximately 90% of all washer loads become dryer loads across the region, and this percentage is very similar to the single-family results.

Table 79: Percentage of Dryer Loads per Washer Load by State

State	Dryer Loads per Washer Load		
	%	EB	n
ID	84.9%	6.1%	63
MT	86.2%	5.5%	58
OR	88.6%	4.9%	94
WA	90.9%	3.9%	90
Region	88.8%	2.6%	305

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 80 shows that almost 60% of the dishwashers were purchased since the year 2000.

Table 80: Distribution of Dishwashers by Vintage

Vintage	Dishwashers		
	%	EB	n
Pre 1980	0.6%	0.7%	2
1980–1989	11.6%	4.0%	23
1990–1994	10.8%	3.6%	29
1995–1999	17.8%	4.6%	42
2000–2004	27.7%	5.3%	64
2005–2009	27.4%	5.5%	62
Post 2009	4.1%	2.4%	11
Total	100.0%	—	233

Surveyors asked participants how many loads per week they ran through the dishwasher. Table 81 summarizes the average number of dishwasher loads per week by state.

Table 81: Average Number of Dishwasher Loads per Week

State	Dishwasher Loads per Week		
	Mean	EB	n
ID	1.91	0.48	57
MT	2.27	0.75	48
OR	2.21	0.49	94
WA	2.31	0.49	90
Region	2.22	0.29	289

8.5. Cooking Appliances

Table 82 shows the distribution of cook top fuel for the entire region, and Table 83 shows the distribution of oven fuel. As with water heaters (see Section 8.6), the manufactured homes in this sample have a high saturation of electric-fueled cooking appliances.

Table 82: Distribution of Cook Top Fuel by Type

Fuel Type	Cook Top Fuel		
	%	EB	n
Electric	88.9%	3.0%	277
Gas	6.9%	2.3%	29
Propane	4.2%	2.0%	15
Total	100.0%	—	321

Table 83: Distribution of Oven Fuel by Type

Fuel Type	Oven Fuel		
	%	EB	n
Electric	90.2%	2.8%	282
Gas	6.0%	2.2%	25
Propane	3.8%	1.9%	14
Total	100.0%	—	321

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 84 shows the distribution of water heater fuel across the states. In general, this distribution reflects a much higher saturation of electric energy for the domestic hot water (DHW) system than for gas fuel. However, gas and electric are almost equally preferred in Montana, whereas electric accounts for almost 90% or more of water heaters in the other states. When natural gas is combined with propane, roughly half of the households in the Montana sample choose gas fuel for water heating. In the region as a whole, around 11% of the households choose gas or propane, compared to around 45% for single-family homes

Table 84: Distribution of Water Heater Fuel by State

Water Heater Fuel Type		Water Heaters					
		ID	MT	OR	WA	Region	n
Electric	**%**	86.4%	52.5%	92.1%	95.2%	88.9%	270
	EB	7.0%	10.6%	4.9%	3.9%	2.7%	
Gas	**%**	10.6%	39.0%	5.2%	3.9%	8.6%	39
	EB	6.3%	10.3%	3.8%	3.6%	2.4%	
Propane	**%**	3.0%	8.5%	2.7%	0.9%	2.5%	10
	EB	3.5%	6.0%	3.1%	1.5%	1.4%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	319

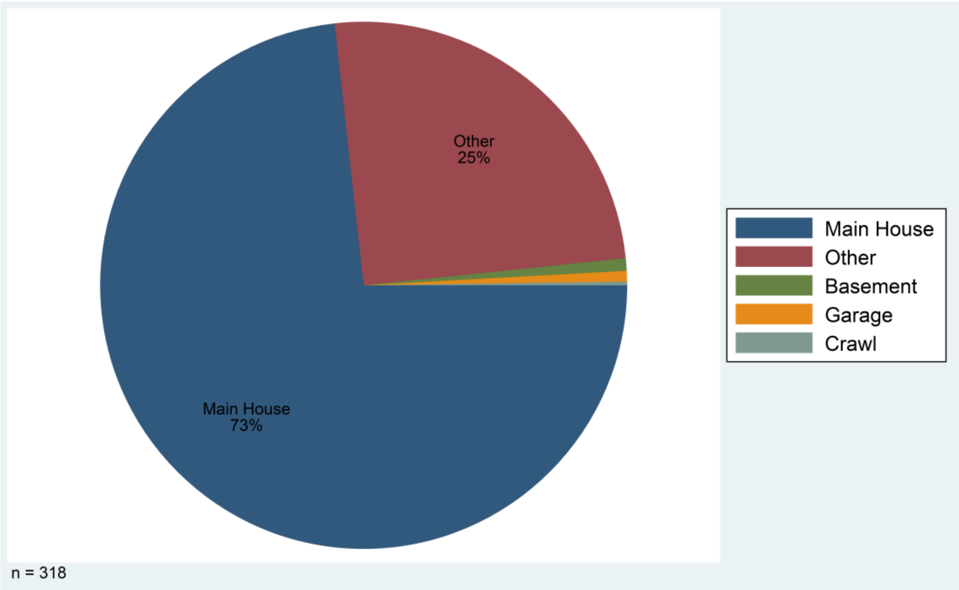
Nearly all water heaters in manufactured homes are storage water heaters, accounting for 99.2% of all water heaters. The remaining 0.8% is instantaneous water heaters.

Table 85 and Figure 11 show the distribution of water heater location in the home by state. Overall, the water heaters located in the main living area of the home represent more than three-quarters of the water heaters in the region, and this finding is fairly uniform across the states. The other popular location, accounting for about a quarter of the water heaters, is "Other." This water heater location is typically an exterior closet of the home outside of the thermal boundary but inside the shell of the home.

Table 85: Distribution of Water Heater Location by State

Water Heater Location		Water Heaters					
		ID	MT	OR	WA	Region	n
Basement	%	3.1%	3.4%	—	—	0.8%	4
	EB	3.6%	3.8%	—	—	0.6%	
Crawlspace	%	1.5%	—	—	—	0.2%	1
	EB	2.5%	—	—	—	0.4%	
Garage	%	—	—	—	1.5%	0.6%	2
	EB	—	—	—	2.2%	0.9%	
Main House	%	69.2%	74.6%	66.5%	79.3%	73.2%	233
	EB	9.3%	9.2%	8.7%	7.3%	4.6%	
Other	%	26.2%	22.0%	33.5%	19.2%	25.1%	78
	EB	8.9%	9.0%	8.7%	7.1%	4.5%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	318

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 86 shows all storage tank locations as they distribute across all primary space fuels.

Table 86: Distribution of All Water Heater Locations by Space Heating Fuel Type

Water Heater Location		All Water Heaters by Space Heating Fuel					
		Electric	Natural Gas	Oil	Pellets	Wood	n
Unknown	%	82.6%	17.4%	—	—	—	3
	EB	29.7%	29.7%	—	—	—	
Basement	%	50.0%	50.0%	—	—	—	4
	EB	42.0%	42.0%	—	—	—	
Crawlspace	%	100.0%	—	—	—	—	1
	EB	0.0%	—	—	—	—	
Garage	%	87.9%	—	—	—	12.1%	2
	EB	24.7%	—	—	—	24.7%	
Main House	%	70.6%	12.2%	1.0%	2.2%	14.0%	232
	EB	5.2%	3.3%	1.0%	1.9%	4.3%	
Other	%	67.6%	13.5%	—	1.6%	17.3%	77
	EB	9.1%	4.9%	—	2.6%	8.2%	
All Locations	%	70.1%	12.7%	0.7%	2.0%	14.5%	319
	EB	4.3%	2.6%	0.7%	1.5%	3.8%	

In addition to water heater fuel type and location, the size of the water tank constrains the potential market for high efficiency HPWHs. The tank size is divided into two categories. In manufactured homes, 100% of the water heaters were the smaller size, 0–55 gallons.

Table 87 shows the regional distribution of water heater vintage. As Table 87 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 that is less than 10 years on average, given that about 60% of the water heaters were installed prior to 2004.

Table 87: Distribution of Water Heaters by Vintage

Vintage	Water Heaters		
	%	EB	n
Pre 1990	8.6%	3.3%	21
1990–1999	30.9%	5.1%	88
2000–2004	23.7%	4.8%	67
2004–2009	31.9%	5.0%	98
Post 2009	4.8%	2.3%	14
Total	100.0%	—	288

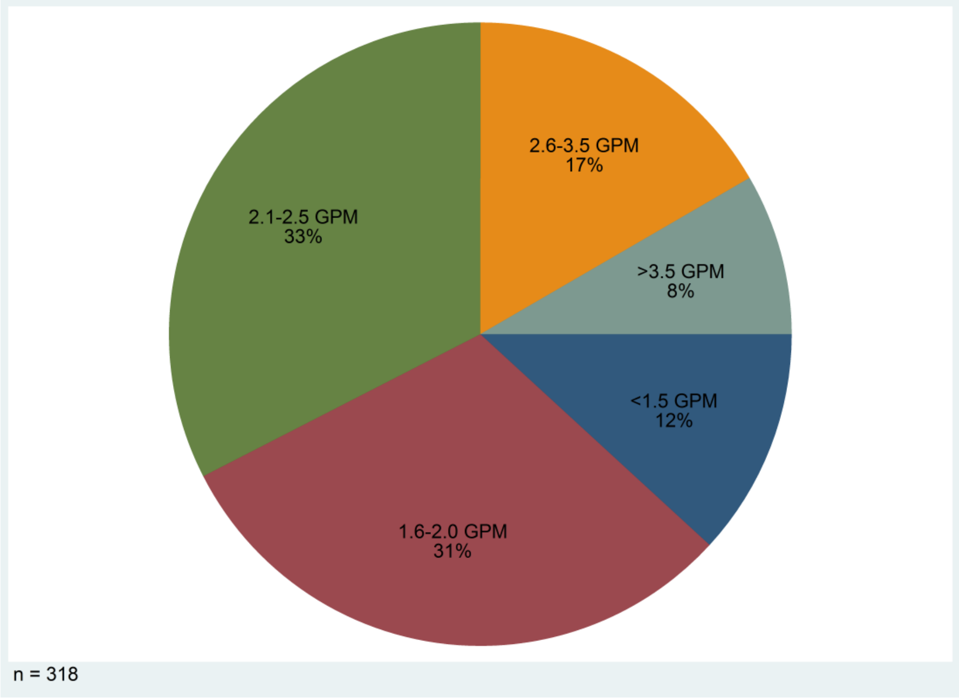
8.7. Showerheads

The surveyors took a census of showerheads in each home and used a Micro-Weir™ to measure the flow rate of the main showerhead when the faucets were turned on full. Table 88 and Figure 12 show the distribution of flow rates in these showerheads across the states. It should be noted that just over 40% 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 88: Distribution of Showerhead Flow Rate by State

Flow Rate (GPM)		Showerheads					
		ID	MT	OR	WA	Region	N
≤1.5 GPM	%	12.1%	24.6%	12.4%	8.4%	11.8%	46
	EB	6.7%	9.1%	6.3%	4.6%	3.1%	
1.6–2.0 GPM	%	25.8%	41.0%	25.4%	33.7%	30.6%	101
	EB	8.9%	10.4%	8.3%	8.6%	4.9%	
2.1–2.5 GPM	%	56.1%	21.3%	13.0%	41.1%	32.5%	100
	EB	10.1%	8.7%	6.3%	8.8%	4.7%	
2.6–3.5 GPM	%	4.5%	8.2%	26.1%	15.8%	16.6%	49
	EB	4.2%	5.8%	8.2%	6.3%	3.9%	
>3.5 GPM	%	1.5%	4.9%	23.0%	0.9%	8.4%	22
	EB	2.5%	4.6%	8.0%	1.5%	2.7%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	318

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 89 shows that the overall number of TVs across the region is slightly more than two TVs per home. This compares to 2.3 TVs per home in the single-family sector.

Table 89: Average Number of Televisions per Home by State

State	Televisions per Home		
	Mean	EB	n
ID	2.20	0.23	66
MT	1.87	0.21	61
OR	2.08	0.20	97
WA	2.01	0.22	97
Region	2.05	0.12	321

When the information was accessible, the surveyors also recorded television power in Watts for primary televisions. Primary TVs were classified as TVs that were plugged in at the time of the audit and identified by the participant as primary TVs. Table 90 shows the television power for the measured TVs by TV vintage. The surveyors measured TV power on approximately 66% of the TVs observed in the sample.

Table 90: Average Television Power by Vintage

Vintage	Television Power (W)		
	Mean	EB	n
Pre 1990	83.9	11.4	4
1990–1994	79.2	7.6	29
1995–1999	86.9	7.6	70
2000–2004	84.1	8.5	89
2005–2009	121.8	11.0	170
Post 2009	107.3	9.6	68
All Vintages	102.7	5.1	440

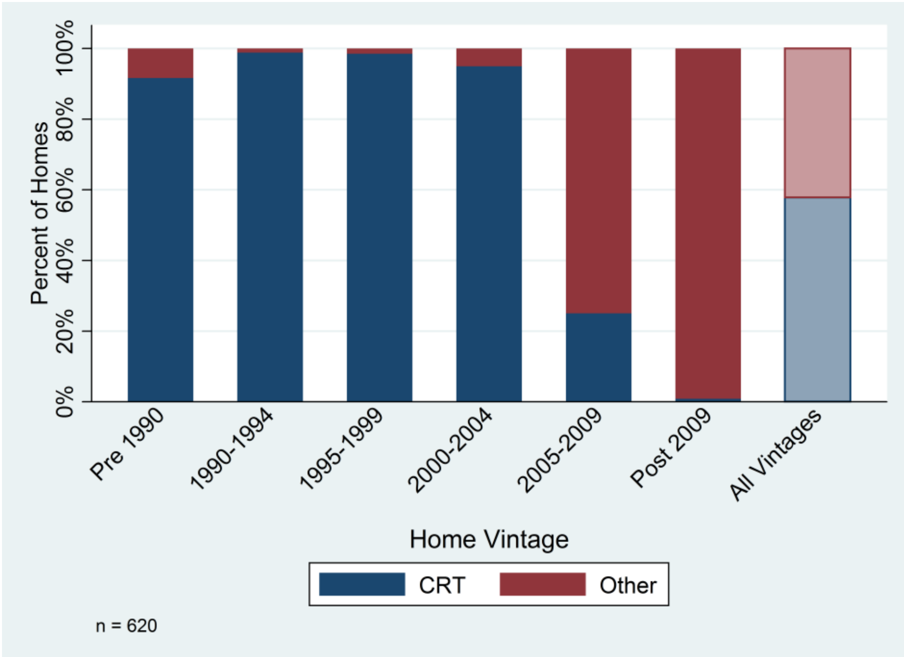
Table 91 and Figure 13 show the percentage of TVs in each vintage bin. As Table 91 shows, TVs were categorized into two types. CRT denotes conventional tube-type TVs that for the most part were made obsolete in the last eight years. Nevertheless, this type of TV was dominant in the earlier time periods. The “Other Type” refers to flat screen TVs. 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[17]. 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 91: Distribution of Television Screens by Type and Vintage

Vintage		Television Screens		
		CRT	Other	n
Pre 1990	%	91.6%	8.4%	8
	EB	13.7%	13.7%	
1990–1994	%	98.8%	1.2%	56
	EB	1.6%	1.6%	
1995–1999	%	98.5%	1.5%	105
	EB	2.2%	2.2%	
2000–2004	%	94.9%	5.1%	142
	EB	3.6%	3.6%	
2005–2009	%	25.1%	74.9%	223
	EB	5.2%	5.2%	
Post 2009	%	0.9%	99.1%	86
	EB	1.4%	1.4%	
All Vintages	%	57.8%	42.2%	620
	EB	4.0%	4.0%	

[17] Note that in the pre-1995 category, “Other” generally refers to rear projection televisions.

Figure 13: Distribution of Television Screens by Type and Vintage



The flat screen TVs have achieved penetration of about 99% of the market in the most recent cohort summarized, compared to just over 1% throughout the 1990s.

Table 92 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 92: Distribution of Televisions by Room Type

Room	Televisions		
	%	EB	n
Bathroom	0.7%	0.8%	5
Bedroom	31.4%	3.1%	195
Closet	0.3%	0.4%	2
Dining Room	0.6%	0.5%	4
Family Room	9.4%	1.9%	58
Garage	0.2%	0.2%	3
Kitchen	1.7%	0.9%	13
Laundry Room	0.3%	0.4%	2
Living Room	38.8%	3.0%	261
Master Bedroom	13.4%	1.9%	94
Office	2.5%	1.2%	16
Other	0.6%	0.5%	5
Total	100.0%	—	658

Surveyors also asked participants to report the number of hours the primary TV was turned on per day. Table 93 summarizes these reports by state. The number of hours of TV "on time" in this sector is about 35% longer than observed in the single-family RBSA sample. This difference is statistically significant.

Table 93: Average Primary Television On-Time Hours per Day per Home by State

State	Television On-Time per Home (hours/day)		
	Mean	EB	n
ID	8.38	1.06	65
MT	7.34	0.95	61
OR	6.39	0.93	83
WA	7.66	1.01	90
Region	7.37	0.56	299

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 and were summarized separately. The surveyors also noted the type of set-top box and digital video recorder (DVR) capability.

Table 94 summarizes the average number of set-top boxes per home. Table 95 shows the saturation of set-top boxes in households across the region. Table 96 shows the percentage of set-top boxes with DVR capability such as a TiVo. Unlike single-family homes where most of the TVs and accessories summaries had very little difference between states on these characteristics, however, in Montana manufactured homes had significantly less prevalence of DVRs than the other states.

Table 94: Average Number of Set-Top Boxes per Home by State

State	Set-Top Boxes per Home		
	Mean	EB	n
ID	1.73	0.21	66
MT	1.36	0.24	61
OR	1.72	0.21	97
WA	1.32	0.20	97
Region	1.51	0.12	321

Table 95: Percentage of Homes with Set-Top Boxes

State	Homes with Set-Top Boxes		
	%	EB	n
ID	87.9%	6.7%	66
MT	77.0%	8.9%	61
OR	85.4%	6.7%	97
WA	71.9%	8.1%	97
Region	79.0%	4.4%	321

Table 96: Percentage of Set-Top Boxes with DVR Capability by State

State	Set-Top Boxes with DVR		
	%	EB	n
ID	21.9%	8.3%	114
MT	10.8%	6.9%	83
OR	24.5%	6.7%	179
WA	24.2%	6.4%	130
Region	22.7%	3.8%	506

9.3. Gaming Systems

Table 97 and Table 98 summarize gaming system in the region. Table 97 shows the percentage of homes with gaming systems by state. About 27% of homes in this sample have gaming systems, which is slightly lower than the level observed in the single-family sector. The error bounds on this estimate make inference by state problematic. Nevertheless, it does appear that the Washington sample has a lower saturation of gaming systems than the rest of the region.

Table 98 shows the average number of gaming systems that are present in homes that have gaming systems. The regional average is about 1.4 gaming systems in homes that have gaming systems.

Table 97: Percentage of Homes with Gaming Systems

State	Homes with Gaming Systems		
	%	EB	n
ID	31.8%	9.5%	66
MT	27.9%	9.5%	61
OR	32.7%	8.9%	97
WA	21.8%	7.4%	97
Region	27.3%	4.6%	321

Table 98: Average Number of Gaming Systems per Home with Gaming Systems

State	Gaming Systems per Home		
	Mean	EB	n
ID	1.52	0.29	21
MT	1.24	0.17	17
OR	1.50	0.24	31
WA	1.18	0.14	22
Region	1.36	0.12	91

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 99 presents the saturation of computers per home across the four states.

Table 100 shows the percentage of homes with computers by state. The percentage of manufactured homes with computers does not vary greatly across the region, averaging about 75% of households with at least one computer. In contrast, the saturation of computers in single-family homes was about 90%.

Table 99: Average Number of Computers per Home by State

State	Computers per Home		
	Mean	EB	n
ID	1.03	0.19	66
MT	1.03	0.19	61
OR	1.43	0.43	97
WA	0.97	0.13	97
Region	1.13	0.15	321

Table 100: Percentage of Homes with Computers by State

State	Homes with Computers		
	%	EB	n
ID	68.2%	9.5%	66
MT	72.1%	9.5%	61
OR	77.3%	7.9%	97
WA	74.6%	7.9%	97
Region	74.3%	4.6%	321

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 101 and Table 102 describe the average number of audio systems and subwoofers in the sample.

Table 101: Average Number of Audio Systems per Home by State

State	Audio Systems per Home		
	Mean	EB	n
ID	1.06	0.21	66
MT	0.97	0.22	61
OR	1.99	0.36	97
WA	0.95	0.16	97
Region	1.30	0.14	321

On average, each home in the region has just over one audio system; Oregon, however, has almost two audio systems per home. 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 102 shows the saturation of subwoofers per home by type. The saturation is around 12% for all subwoofers, and less than half of these are powered subwoofers.

Table 102: Average Number of Subwoofers per Home by Type

Subwoofer Type	Subwoofers per Home (n = 321)	
	Mean	EB
Passive	0.146	0.040
Powered	0.101	0.033
All Subwoofers	0.123	0.025

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 and heating systems in the sections describing those components. This section focuses on demographic and behavior responses such as occupancy and energy use patterns.

10.1. Occupancy

The participants provided information on the number and age of occupants in the home. Table 103 shows the average occupant age per home. Both Montana and Oregon have an average occupant age per home of about 55 years old, whereas the average age per home in Idaho and Washington is slightly lower, 47 years old and 50 years old, respectively.

Table 104 summarizes the average number of occupants per home. The average number of occupants per home for the region is about 2.5, which is slightly less than the 2.7 found in single-family homes.

Table 103: Average Occupant Age per Home by State

State	Occupant Age		
	Mean	EB	n
ID	46.6	4.1	66
MT	55.6	3.6	60
OR	54.4	3.5	95
WA	50.3	3.8	93
Region	51.6	2.1	314

Table 104: Average Number of Occupants per Home by State

State	Occupants per Home		
	Mean	EB	n
ID	2.95	0.39	66
MT	2.27	0.26	60
OR	2.16	0.21	95
WA	2.67	0.39	95
Region	2.51	0.19	316

The ACS data suggest 2.48 occupants per home, which is within the error bounds of this survey. The ACS survey includes all building types. Multifamily households tend to have a smaller average number of occupants, and single-family households tend to have a larger average number of occupants. This would explain the similarity of values for manufactured homes to the overall average.

Table 105 breaks out the average number of occupants by age category. Across the region, each home has about 1.2 adults (18–64 years), about .7 seniors (65 and older), and about .7 children (0–17 years).

Table 105: Average Number of Occupants by Age Category by State

Age Category		Number of Occupants (n = 316)				
		ID	MT	OR	WA	Region
Children (0 to 17)	Mean	0.985	0.333	0.383	0.885	0.688
	EB	0.30	0.16	0.17	0.32	0.16
Adults (18 to 64)	Mean	1.364	1.217	1.058	1.172	1.169
	EB	0.22	0.23	0.17	0.21	0.11
Seniors (65 and Over)	Mean	0.606	0.717	0.718	0.614	0.656
	EB	0.16	0.17	0.16	0.13	0.08

Table 106 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. There are no homes in the latter category for manufactured homes and just a few for single-family homes.

Table 106: Distribution of Homes by Ownership Type and State

Ownership Type		Percentage of Homes					
		ID	MT	OR	WA	Region	n
Own/Buying	%	90.9%	88.5%	89.2%	84.4%	87.3%	287
	EB	5.9%	6.8%	5.9%	6.6%	3.6%	
Rent	%	9.1%	11.5%	10.8%	15.6%	12.7%	34
	EB	5.9%	6.8%	5.9%	6.6%	3.6%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	321

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 107 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 107: Percentage of Homes as Primary Residence by State

State	Homes as Primary Residence		
	%	EB	n
ID	100.0%	0.0%	66
MT	98.4%	2.7%	61
OR	98.6%	2.2%	97
WA	96.2%	3.5%	97
Region	97.7%	1.7%	321

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 108 summarizes the percentage of these types of home offices. Oregon and Idaho homes have the highest percentage of homes with home offices at about 18% and 12%, respectively. Montana and Washington both have less than 8%.

Table 108: Percentage of Homes with Home Offices by State

State	Homes with a Home Office/Business		
	%	EB	n
ID	12.1%	6.7%	66
MT	6.6%	5.3%	61
OR	17.5%	7.2%	97
WA	7.9%	4.7%	97
Region	11.4%	3.3%	321

10.2. Fuel Assistance

Surveyors asked participants whether they receive fuel financial assistance from either the utility or federal fuel bill assistance grants. Although fuel assistance was rarely reported, about 10% of the homes reported some form of electric bill paying assistance. About 3% of all homes reported gas heating assistance. Only about 11% of all homes use gas as a primary heating fuel. This translates as almost 25% of these participants. However, this finding represents a very small proportion of this sample and has a large error bound. Table 109 and Table 110 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. Residents in this study were three to four times more likely to participate in those programs than in the single-family sample.

Table 109: 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
100% Utility Bill Assistance	**%**	—	1.7%	—	4.8%	2.3%	5
	EB	—	2.7%	—	3.9%	1.7%	
75% Utility Bill Assistance	**%**	—	1.7%	—	2.6%	1.3%	3
	EB	—	2.7%	—	3.0%	1.3%	
50% Utility Bill Assistance	**%**	—	6.7%	0.3%	0.9%	1.1%	7
	EB	—	5.3%	0.3%	1.5%	0.8%	
25% Utility Bill Assistance	**%**	13.6%	6.7%	4.5%	3.5%	5.6%	24
	EB	7.0%	5.3%	3.6%	3.3%	2.2%	
No Utility Bill Assistance	**%**	86.4%	83.3%	95.2%	88.2%	89.7%	279
	EB	7.0%	8.0%	3.6%	5.8%	3.1%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	318

Table 110: 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
100% Utility Bill Assistance	%	—	—	—	1.3%	0.6%	1
	EB	—	—	—	2.1%	0.9%	
75% Utility Bill Assistance	%	—	3.3%	—	—	0.3%	2
	EB	—	3.8%	—	—	0.4%	
50% Utility Bill Assistance	%	—	8.3%	—	—	0.8%	5
	EB	—	5.9%	—	—	0.6%	
25% Utility Bill Assistance	%	1.6%	1.7%	0.1%	1.2%	1.0%	4
	EB	2.6%	2.7%	0.2%	2.0%	1.0%	
No Utility Bill Assistance	%	98.4%	86.7%	99.9%	97.5%	97.3%	306
	EB	2.6%	7.3%	0.2%	2.9%	1.5%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	318

10.3. Thermostat Settings

The surveyors asked participants about their heating and cooling thermostat behavior. Table 111 summarizes the self-reported thermostat heating setpoint by state. Table 112 provides the percentage of homes that use night heating setback on a regular basis.[18] Table 113 shows the amount of thermostat setback that occupants said they used.

Table 111: Average Heating Thermostat Setpoint by State

State	Heating Thermostat Setpoint (°F)		
	Mean	EB	n
ID	71.2	0.81	65
MT	69.6	0.59	61
OR	70.1	0.73	97
WA	68.3	0.87	94
Region	69.5	0.46	317

[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 112: Percentage of Homes Reporting a Heating Setback by State

State	Homes Reporting Heating Setback		
	%	EB	n
ID	50.0%	10.2%	66
MT	68.9%	9.8%	61
OR	63.8%	9.1%	97
WA	61.9%	8.7%	97
Region	61.4%	5.1%	321

Table 113: Average Size of Heating Setback by State

State	Heating Setback (°F)		
	Mean	EB	n
ID	6.73	1.50	33
MT	5.62	0.87	42
OR	8.60	1.24	59
WA	7.13	0.85	57
Region	7.39	0.59	191

Table 114 presents the average setpoints for cooling in households that have cooling.[19] Table 115 shows instances when occupants used a cooling setup that increased the cooling setpoint when the home was not occupied in the daytime.

Table 114: Average Cooling Thermostat Setpoint by State

State	Cooling Thermostat Setpoint (°F)		
	Mean	EB	n
ID	73.8	1.3	43
MT	73.5	1.8	33
OR	72.6	0.8	65
WA	72.1	1.2	35
Region	72.7	0.6	176

[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 115: Percentage of Homes Reporting a Cooling Thermostat Setup by State

State	Homes Reporting Cooling Setup		
	%	EB	n
ID	6.1%	4.9%	66
MT	3.3%	3.8%	61
OR	15.9%	6.9%	97
WA	9.7%	4.9%	97
Region	10.5%	3.2%	321

Although heating thermostat setbacks were quite common (with more than 60% 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. However, this summary applies to all households in the survey and only about half of them report any cooling equipment. Regardless, the cooling setup behavior is much less common than the corresponding heating setback behavior.

10.4. Fuel Use

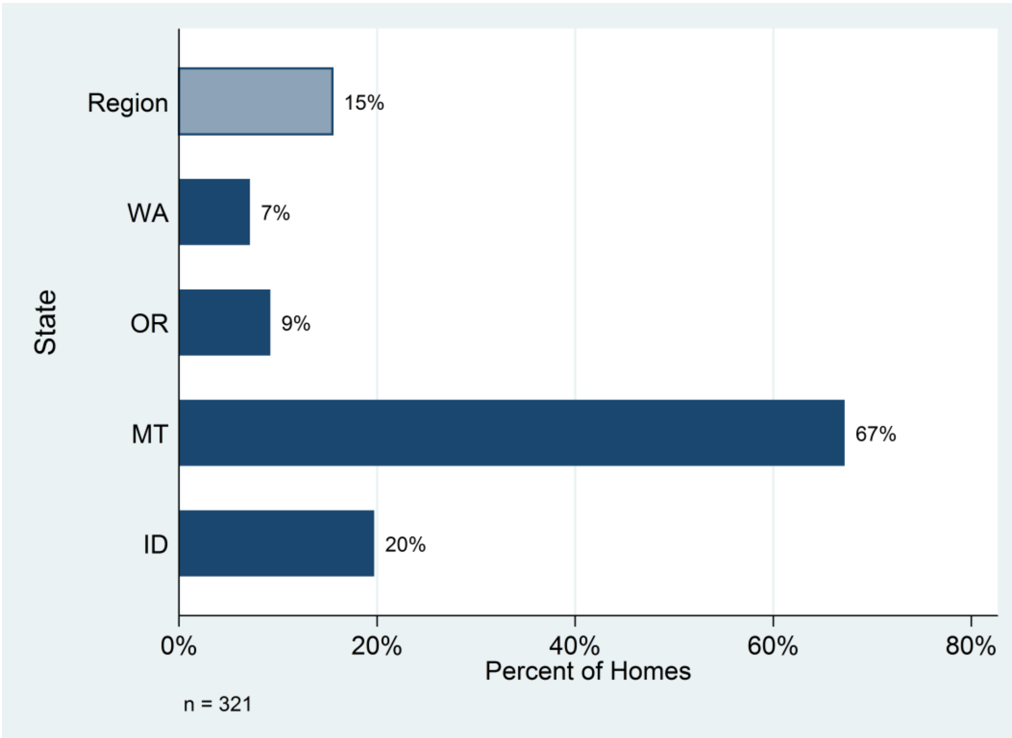
While they were onsite, the surveyors obtained billing releases for both electric and gas utility billing records. Table 116 and Figure 14 summarize the percentage of gas customers by state. The regional average is around 16%, which is much lower than the 57% reported for single-family homes. Oregon and Washington have a relatively similar percentage of gas customers and are slightly less than the regional average. Idaho has about 4% more gas customers than the region as a whole and Montana has more than three times the saturation of gas usage than the manufactured home sector as a whole.

Table 116: Percentage of Households Reporting Gas Service by State[20]

State	Households Reporting Gas Service		
	%	EB	n
ID	19.7%	8.1%	66
MT	67.2%	10.0%	61
OR	9.2%	5.2%	97
WA	7.1%	4.7%	97
Region	15.5%	3.1%	321

[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 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 117 and Figure 15 summarize the use of wood fuel for home heating. As Table 117 shows, about 22% of the sample reported wood use across the entire region. In the Montana sample, two-thirds of those who use wood used more than three cords[21] a year, while in Washington, almost two-thirds of the wood users used less than three cords per year. Figure 15 shows the distribution of reported wood fuel use graphically for those homes that reported wood use.

[21] A cord of wood is a unit of wood cut for fuel equal to a stack 4 x 4 x 8 feet or 128 cubic feet.

Table 117: Distribution of Wood Use as Heating Fuel by State

Annual Wood Use		Homes Using Wood Fuel					
		ID	MT	OR	WA	Region	n
1–3 Cords	%	4.5%	6.6%	10.5%	14.5%	11.0%	28
	EB	4.2%	5.3%	5.9%	6.4%	3.5%	
4–6 Cords	%	16.7%	6.6%	7.7%	8.7%	9.4%	30
	EB	7.6%	5.3%	4.9%	5.1%	3.0%	
>6 Cords	%	4.5%	6.6%	1.2%	—	1.7%	8
	EB	4.2%	5.3%	2.0%	—	1.0%	
None	%	74.2%	80.3%	80.5%	76.8%	77.9%	255
	EB	8.9%	8.4%	7.3%	7.6%	4.4%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	321

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

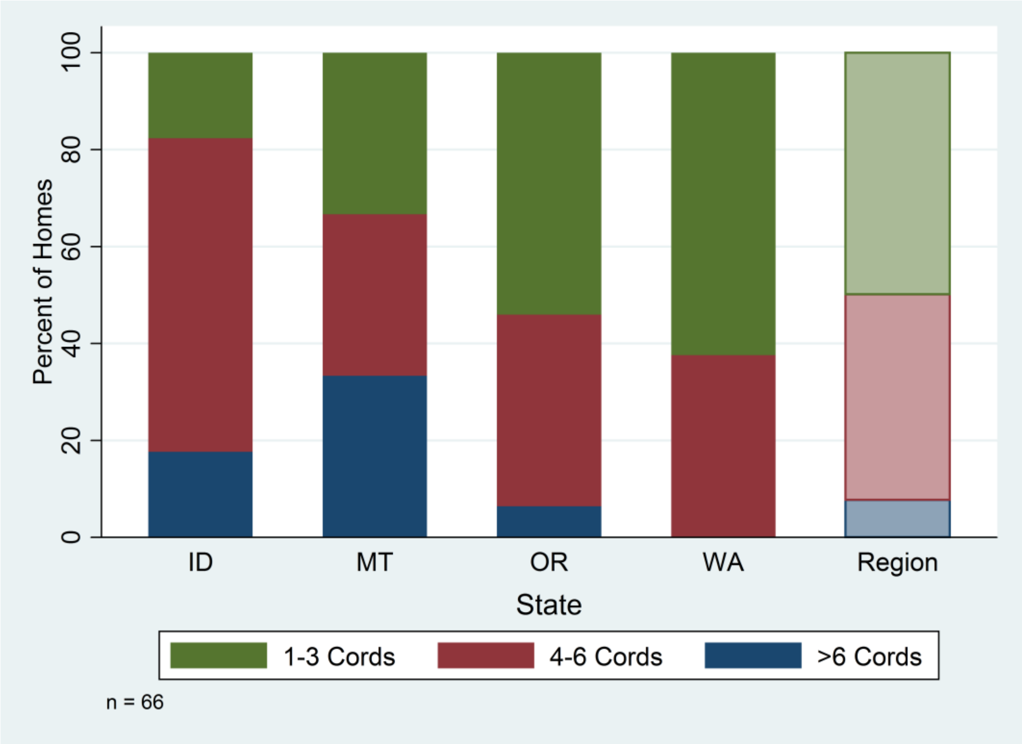


Table 118 shows the distribution of pellet fuel use by state. The data indicate that the use of pellet fuel for home heating is not significant; only 4% of the sample used pellets.

Table 118: Distribution of Pellet Fuel Use by State

Annual Pellet Fuel Use		Homes Using Pellet Fuel					
		ID	MT	OR	WA	Region	n
1–2 Tons	%	1.5%	1.6%	4.1%	2.1%	2.6%	8
	EB	2.5%	2.7%	3.7%	2.5%	1.7%	
3–4 Tons	%	1.5%	—	1.4%	1.3%	1.2%	3
	EB	2.5%	—	2.2%	2.1%	1.2%	
>4 Tons	%	1.5%	—	—	—	0.2%	1
	EB	2.5%	—	—	—	0.4%	
None	%	95.5%	98.4%	94.5%	96.6%	96.0%	309
	EB	4.2%	2.7%	4.3%	3.2%	2.1%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	321

Table 119 and Table 120 summarize the use of oil and propane in the sample. Only 1.3% of the population uses oil. About 9% of the survey population use propane fuel, and less than a quarter of those households used propane in quantities that were sufficient to provide primary heating.

Table 119: Distribution of Oil Fuel Use by State

Annual Oil Fuel Use		Homes Using Oil Fuel					
		ID	MT	OR	WA	Region	n
100–250 Gallons	%	1.5%	—	2.5%	—	1.0%	3
	EB	2.5%	—	2.8%	—	1.0%	
251–500 Gallons	%	—	3.3%	—	—	0.3%	2
	EB	—	3.8%	—	—	0.4%	
None	%	98.5%	96.7%	97.5%	100.0%	98.7%	316
	EB	2.5%	3.8%	2.8%	0.0%	1.0%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	321

Table 120: Distribution of Propane Fuel Use by State

Annual Propane Fuel Use		Homes Using Propane Fuel					
		ID	MT	OR	WA	Region	n
<50 Gallons	%	6.1%	—	—	1.2%	1.4%	5
	EB	4.9%	—	—	2.0%	1.1%	
50–250 Gallons	%	7.6%	8.3%	5.2%	3.9%	5.3%	18
	EB	5.4%	5.9%	4.2%	3.5%	2.3%	
251–500 Gallons	%	1.5%	6.7%	—	—	0.9%	5
	EB	2.5%	5.3%	—	—	0.6%	
501–1000 Gallons	%	—	8.3%	—	0.9%	1.2%	6
	EB	—	5.9%	—	1.5%	0.9%	
None	%	84.8%	76.7%	94.8%	94.0%	91.2%	286
	EB	7.3%	9.1%	4.2%	4.2%	2.7%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	320

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 121 summarizes the percentage of households that implemented self-funded efficiency improvements without utility incentives. About 33% of the sample responded positively to this question. Table 122 summarizes the percentage of households that used utility program incentives to fund efficiency measures. About 23% of the overall population said that they had used utility incentives, with Idaho and Oregon closer to 30%. Table 123 summarizes the percentage of households reporting the use of conservation tax credits, either for self-funded or utility program measures. Only 4% of the overall population claimed a state or federal tax credit for their conservation improvements.

Table 121: Percentage of Households Reporting Recent Self-Funded Conservation by State

State	Households Reporting Recent Self Funded Conservation Improvements		
	%	EB	n
ID	30.3%	9.4%	66
MT	52.5%	10.6%	61
OR	27.8%	8.4%	97
WA	33.6%	8.3%	97
Region	33.1%	4.8%	321

Table 122: Percentage of Households Reporting Recent Use of Utility Conservation Programs by State

State	Households Reporting Use of Utility Incentives		
	%	EB	n
ID	30.3%	9.4%	66
MT	19.7%	8.4%	61
OR	26.7%	8.2%	97
WA	19.6%	7.1%	97
Region	23.4%	4.4%	321

Table 123: Percentage of Households Reporting Use of Conservation Tax Credit

State	Households Reporting Recent Conservation Tax Credits		
	%	EB	n
ID	3.0%	3.5%	66
MT	8.2%	5.8%	61
OR	8.4%	5.1%	97
WA	0.4%	0.4%	97
Region	4.0%	1.8%	321

Table 124 shows the percentage of participants that used both tax credits and utility incentives to help fund their conservation investments. Overall, less than 1% 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, but still the fraction of participants in the manufactured home sector is negligible.

Table 124: 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	0.0%	0.0%	66
MT	0.0%	0.0%	61
OR	1.9%	2.3%	97
WA	0.2%	0.3%	97
Region	0.7%	0.7%	321

11. Energy Benchmarking

This section presents the results of the billing analysis and energy benchmarking for the manufactured home 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 individual state populations while maintaining the statistical integrity of the energy use estimates. Ecotope requested electric and gas bills for all participants in the manufactured home 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 303 electric customers and 44 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 (see for example, Baylon et al., 1991). This energy benchmark also provides planners with 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 local 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[22].

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

[22] Weather normalization is not useful if there is no space heating estimated and thus no seasonality to the billing record.

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

Table 125 shows the average per home total electricity use by state. This summary is based on annualized and normalized bills for 2010-2011. 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 homes with supplemental (non-electric) space heat from other fuels such as wood, propane, and oil. The distribution of electric energy use by state is shown in Figure 16.

Table 125: Average Annual kWh per Home by State

State	kWh per Home		
	Mean	EB	n
ID	17,454	1,545	62
MT	12,048	1,356	57
OR	14,808	1,054	92
WA	17,973	1,575	92
Region	16,333	816	303

Figure 16: Average Annual kWh per Home by State

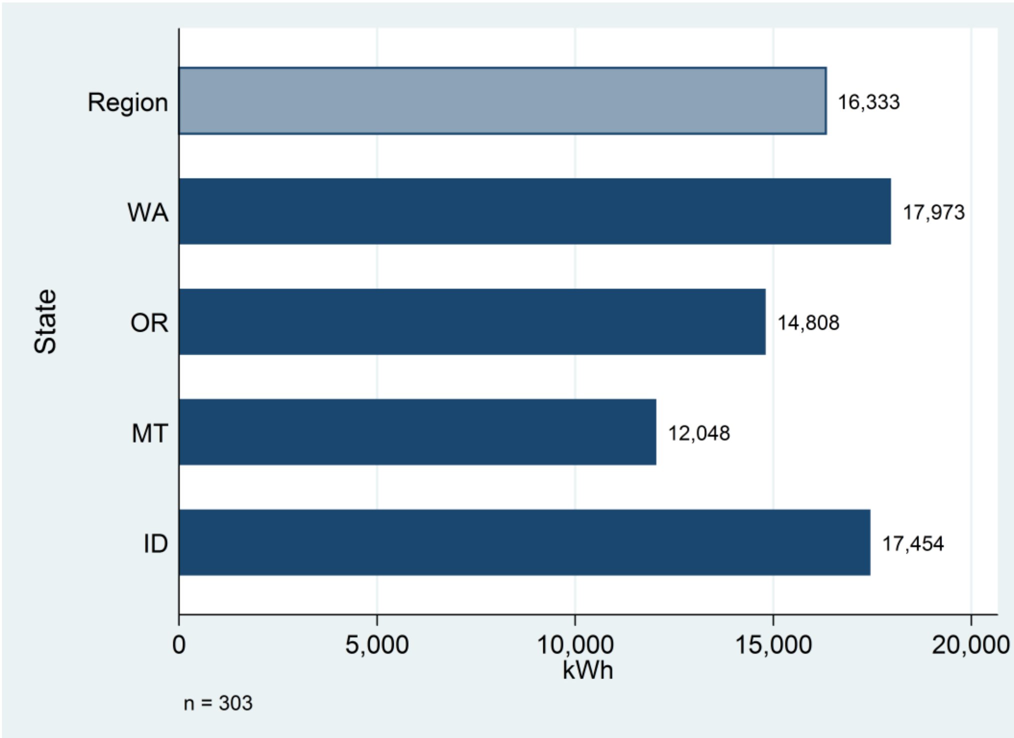


Table 126 and Figure 17 summarize the average per home total electricity use by state, but in this case the heating estimates for each site have been weather-normalized to the long-term weather for the weather station assigned. In aggregate, the impact of weather normalization across these larger geographic 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 126: Average Weather Normalized kWh per Home by State

State	kWh per Home		
	Mean	EB	n
ID	16,798	1,735	64
MT	11,949	1,394	59
OR	14,193	1,039	92
WA	17,653	1,853	94
Region	15,901	932	309

Figure 17: Average Weather Normalized kWh per Home by State

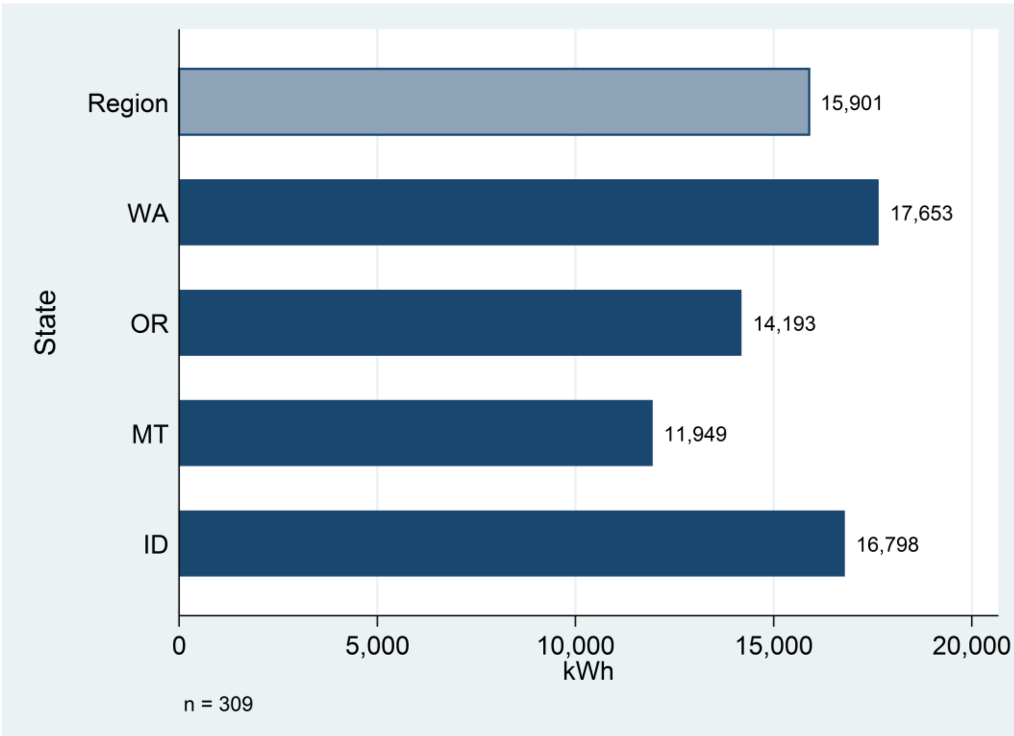


Table 127 summarizes the electricity use normalized by home size. This calculation uses the same conditioned floor area used to calculate LPD and normalize heat-loss rates. In Table 127, the results are separated into two categories. If the survey identified a home with primary electric heat, the total kWh consumption is in the "Electric Heat" column; if not, then the consumption is summarized in the "Other Heat" column. This separation is based on the onsite survey results, not the VBDD regression fits. The "All Homes" column combines the two groups to provide an EUI for each state and the region.

Table 127: Average Electric EUI per Home by Heating Fuel Type and State

State		Electric EUI per Home (kWh/sq.ft.)			
		Other Heat	Electric Heat	All Homes	n
ID	**Mean**	11.1	15.2	13.6	62
	EB	2.1	1.7	1.4	
MT	**Mean**	10.1	14.3	10.8	57
	EB	1.5	3.5	1.4	
OR	**Mean**	7.5	13.8	12.4	92
	EB	1.1	1.2	1.1	
WA	**Mean**	11.5	16.5	15.4	92
	EB	3.1	2.3	1.9	
Region	**Mean**	10.2	15.3	13.8	303
	EB	1.2	1.2	0.9	

Table 128 shows the results of the electric 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 some of 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 128: Average Estimated Annual Electric Space Heat per Home by State

State	Space Heat per Home (kWh)		
	Mean	EB	n
ID	9,953	1,938	38
MT	8,277	2,347	10
OR	5,972	593	75
WA	10,641	1,835	73
Region	8,848	971	196

11.3. Gas Energy Use Indices

Table 129 shows the average total gas use at homes with metered gas service. In this summary, the gas use has been annualized only. As Table 129 shows, the Montana homes use significantly more gas than the other states. This result could be partly explained by the colder climates.

Table 129: Average Annual Gas Use per Home by State

State	Therms per Home		
	Mean	EB	n
ID	517	165	10
MT	746	98	25
OR	569	132	7
WA*	362	265	2
Region	608	71	44

* Does not include Puget Sound stratum because there were no gas homes

Table 130 shows the results of weather normalizing the gas consumption. The overall impact of weather normalization was less than 4%.

Table 130: Average Weather Normalized Gas Use per Home by State

State	Therms per Home		
	Mean	EB	n
ID	751	329	10
MT	673	96	28
OR	543	124	7
WA	347	254	2
Region	628	95	47

Table 131 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 “Gas Heat” column; if not, then the consumption is summarized in the “Other Heat” column. The “All Homes” column combines the two groups to provide a gas EUI for each state and the region. Table 132 shows the heating estimate for gas consumption.

Table 131: Average Gas EUI per Home by Heating Fuel and State

State		Gas EUI per Home (therms/sq.ft.)			
		Other Heat	Gas Heat	All Homes	n
ID	Mean	0.205	0.568	0.495	10
	EB	0.2	0.1	0.1	
MT	Mean	—	0.680	0.680	25
	EB	—	0.1	0.1	
OR	Mean	0.282	0.449	0.417	7
	EB	—	0.1	0.1	
WA*	Mean	0.238	0.705	0.471	2
	EB	—	—	0.4	
Region	Mean	0.240	0.608	0.554	44
	EB	0.1	0.1	0.1	

* Does not include Puget Sound stratum because there were no gas homes

Table 132: Average Estimated Gas Space Heat by State

State	Space Heat per Home (therms)		
	Mean	EB	n
ID	906	500	8
MT	636	88	25
OR	496	83	6
WA*	480	—	1
Region	657	124	40

* Does not include Puget Sound stratum because there were no gas homes

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 133 shows the total metered energy use. This total is expressed in thousands of 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 133: Average Annual Electricity and Gas Use per Home by State

State	kBtu per Home		
	Mean	EB	n
ID	67,915	5,220	62
MT	73,527	9,133	56
OR	54,500	3,861	92
WA	62,898	5,101	92
Region	62,020	2,819	302

Ecotope calculated EUIs from the total annual energy per home. The EUI is expressed as kBtu per square foot of conditioned floor area. Table 134, Table 135, and Figure 18 show the EUI results by state. Table 134 uses annualized values only, and Table 135 uses weather-normalized results divided by conditioned floor area.

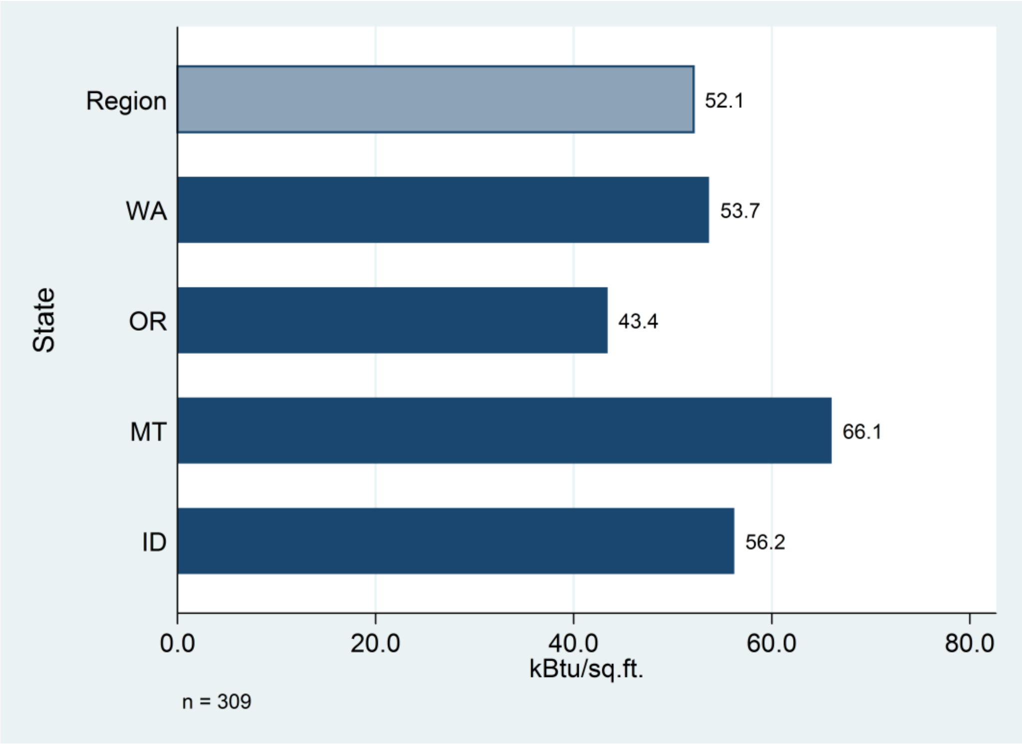
Table 134: Average Electricity and Gas EUI by State

State	EUI per Home (kBtu/sq.ft.)		
	Mean	EB	n
ID	54.4	5.3	62
MT	66.5	9 .3	56
OR	45.4	3.8	92
WA	54.8	6.5	92
Region	52.9	3.3	302

Table 135: Average Weather-Normalized Electricity and Gas EUI by State

State	EUI per Home (kBtu/sq.ft.)		
	Mean	EB	n
ID	56.2	7.8	64
MT	66.1	8.8	59
OR	43.4	3.7	92
WA	53.7	6.1	94
Region	52.1	3.3	309

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 136 summarizes these values based on the approximations made by the occupant. Table 137 summarizes the EUI for the non-metered fuels. These values were averaged over all the sites in each state and the region. There was no attempt to normalize these results. The values can be compared in aggregate to the values in Table 133 and Table 134, the annualized metered energy use.

Table 136: Average Annual Other Fuel Use per Home by State

State	kBtu per Home		
	Mean	EB	n
ID	19,248	6,106	66
MT	22,685	7,168	61
OR	12,453	3,838	97
WA	12,334	3,634	97
Region	14,396	2,306	321

Table 137 expresses the supplemental fuel use as EUI. This index was calculated as the average for the entire sample. The high level of fuel use presented in Table 137 is a further implication of the importance of supplemental fuels across the region.

Table 137: Average EUI, Other Fuel Use

State	EUI per Home (kBtu/sq.ft.)		
	Mean	EB	n
ID	14.8	4.7	66
MT	20.5	7.1	61
OR	10.3	3.6	97
WA	9.0	2.8	97
Region	11.4	1.9	321

The analysis of these non-metered fuels is compromised by the quality of self-reported data and the approximations 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 manufactured homes by about 23% above and beyond the metered fuel use. Although the variance of these estimates prevents any statistical inferences on these differences, they are large and reflect the extensive use of supplemental heat, especially in Idaho and Montana.

12. Conclusions and Comparisons

The goal of the RBSA was to collect as many physical characteristics as possible in the residential sector. The manufactured home sector was separately sampled but the field survey was conducted in conjunction with the single-family survey. The sample design for the manufactured home sector was less complex than the single-family sample. In general, the design was meant to characterize each state and the region. Added sample strata for two oversample utilities increased the complexity of the sample modestly. The size of the manufactured home 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 principal characterizations shown in this report (area, heat loss, lighting power, etc.), the confidence interval meets the 90/10 criteria set as a goal for this sample when summarized by state. For subcategories, including vintages and other subdivisions of the population, the sample size does not always meet 90/10 criteria. Nevertheless, the overall characterization of this sector appears robust and quite easily compared to the rest of the residential sector.

12.1. Findings and Comparisons to Previous Studies

The region has not embarked on a survey of the manufactured home sector that is directly comparable to this survey. There were about five surveys conducted over the last 25 years that individually focused on particular contemporary homes sited in a one or two-year period. A total of about 550 homes were audited in these studies together across the entire region. The result of these studies is a complete picture of manufactured home construction and program status over this period. The RBSA sample, on the other hand, spans the full range of manufactured home vintages beginning in the 1960s and continuing until the present. In this sense, the RBSA sample provides a more complete baseline for this sector than any study fielded in the region to date.

For purposes of this comparison the five studies[23] will be referred to using the program abbreviations that applied at the time and the year of manufacture and siting that applied to these studies. Each study developed a final report which is included in the references (Section 13):

1. RCDP 1988-1989, (Baylon et al., 1991)
2. MAP 1992-1993, (Baylon et al., 1995)
3. SGC 1997-1998, (Davis et al., 2000)
4. NEEM1 2000-2001, (Davis et al., 2004)
5. NEEM2 2006, (Baylon et al., 2008)

[23] See Section 1.2 for a more background on these studies.

The RBSA manufactured home sample greatly expands the age coverage of previous regional studies. About 60% of this sample was manufactured and sited prior to any of the previous regional studies referenced in this report. The remaining 40% can be compared to this sample although the RBSA has a much smaller sample in these vintages.

12.2. Building Size and Age

The overall average home size in the RBSA is 1280 sq.ft., which is much smaller than the average of these studies. However when the vintages are reviewed there is a strong agreement with these surveys. The RCDP sample had an average house size of 1,550 sq. ft. and the MAP survey had an average house size of 1,490 sq. ft. In this vintage (1991-2000) the average house size in this sample is about 1,440 sq.ft., well within the error bounds of the samples. Post-2000 homes studied as part of the two NEEM studies have an average house size of about 1,750 sq. ft. This compares to 1,720 sq. ft. in the RBSA post-2000 vintage.

When compared to the RBSA single-family results there is a marked contrast as single-family site-built homes average 2,006 sq. ft., while manufactured homes average less than 1,300 sq. ft. (64% of the size of the single-family homes).

One area where there is good agreement however, is occupancy. The manufactured homes have an average occupancy of 2.5 people, while the single-family occupancy is only slightly larger at 2.7 occupants per household. This difference is not statistically significant.

12.3. Building Envelope

The impact of insulation and window upgrades over the life of these manufactured homes appears to be substantial. There is evidence of insulation retrofits in about 12% of the overall sample and about 20% of the pre-1990 homes. Window replacements on the other hand have affected about 40% of the overall sample and about 60% of the pre-1990 homes.

The overall average heat loss rates (Uo) for the RBSA manufactured home sample is about 0.115, which is dominated by the 78% of the sample that is built to the minimum HUD standard (both before and after 1995). The manufactured homes in this sample built under the utility programs since 1991 have an average Uo of about 0.06.

Air tightness test are remarkably consistent with the blower door testing done in the previous studies. The SGC studies from the 1990s (Palmiter et al., 1992) showed an average of about 5.5 ACH50 across the three studies. This finding compares with the 7.9 ACH50 in this study. Given the emphasis on air sealing in the utility specifications, this result is as expected. Moreover, the small control group tested in the early 1990s showed an air leakage rate of 8.7 ACH50. In the post-2000 period the previous study of NEEM buildings documented a leakage rate of 4.1 ACH50. The results of this survey showed air tightness of 4.9 ACH50 for the same vintage buildings.

Across the manufactured home sector sample there is very little difference in the heat loss and air tightness results by state.

12.4. Lighting

The number of lamps per home in the manufactured home sector is 34.5. This compares with about 62 lamps observed in the RBSA single-family homes. The size of the manufactured homes is about 63% of the size of the single-family homes. Given this size difference the amount of lamps is about 13% lower.

The use of high efficacy lamps in this sector is slightly higher than the RBSA single-family homes. About 28% of the lamps observed were CFL types and over 10% were linear florescent lamps. Taken as a whole, the fraction of high efficacy lamps in manufactured homes is over 38% compared to 35% for single-family homes.

The LPD for manufactured homes is about 1.27 after adjustment for under reports of exterior lighting. This compares with an LPD of about 1.42 in single-family homes and, overall, this reduced lamp count translates into an 11% reduction in the overall house LPD. This finding seems fairly consistent with the reduced lamp count in this sector.

12.5. HVAC

The heating systems used in manufactured homes are based on factory installed forced air furnaces. Seventy-nine percent of the primary heating systems are forced air systems. This compares with 68% forced air heating systems in single-family homes.

The distribution of fuel choices in primary heating systems is dominated by electricity. The saturation of primary gas heat is about 11%, including propane the saturation of gas is only about 12% of the manufactured homes. When compared with the site-built housing the saturation of gas heating fuel is over 50%. In contrast the saturation of primary electric heat is over 70% compared to 34% in single-family homes. In the only previous manufactured homes study that addressed multiple fuels (Baylon et al., 2008), gas heating had 11% saturation.

Included in the electric heat saturation are air source heat pumps. These systems represent about 25% of the electric systems. Overall, 14% of the manufactured homes used air source heat pumps as their primary heating system. This saturation is comparable to the 13% saturation observed in single-family homes. Generally, the heat pumps observed in the manufactured homes had performance ratings that were slightly lower (not statistically significant) than the single-family homes.

About 54% of the RBSA manufactured homes reported cooling equipment. This finding compares with about 42% in single-family homes. This difference is statistically significant and probably results from the increased saturation of forced air distribution systems in manufactured homes.

12.6. Domestic Hot Water

In the RBSA single-family homes, the fuel type for water heat is 55% electric and 43% gas, with the balance as propane or other fuel. In the manufactured homes, the electric water heat saturation is 89% with the balance being gas and propane.

12.7. Appliances

On average the saturation of refrigerators in manufactured homes is about 1.2 refrigerators per home. This compares to 1.3 refrigerators per home in the single-family sector. Freezers in manufactured homes have a saturation of 43% and in single-family homes the saturation is 52%. The distribution of age and size of both refrigerators and freezers is comparable between the two sectors.

About 34% of the clothes washers surveyed in the RBSA single-family sample were reported as horizontal axis washers. In the manufactured home sample only about 20% of clothes washers were the higher efficiency horizontal axis technologies. In the manufactured home sample 59% of all clothes washers surveyed were manufactured in 2000 or later. In the RBSA single-family sample, 69% of all washers were in this vintage range.

Both the RBSA single-family survey and the manufactured home survey recorded the saturation of appliances. Across all appliances the saturations were comparable except in dishwashers. In the manufactured home sample the saturation of dishwashers was 77%; in the single-family sample the saturation of dishwashers was about 89%.

12.8. Electronics

The comparison of the saturations of electronic equipment in the RBSA single-family and manufactured homes is instructive. In general, the saturation of consumer electronics (including TVs) is lower in manufactured homes. Generally, these differences are statistically significant.

The average number of televisions per home is 2.3 in single-family homes and 2.0 in manufactured homes. While both surveys reported 1.5 set-top boxes per home, the saturation of DVR set-top boxes and gaming systems is about a third less in manufactured homes. In single-family homes, more than 90% of homes have a computer and the average number of computers is 1.67 per home. In manufactured homes, 74% of all homes have at least one computer with an average of 1.16 computers per home across the region.

12.9. Energy Use

Useable electricity and gas bills were collected for about 95% of the homes for both the RBSA single-family and manufactured home samples. The energy use compiled from the utility bills in the manufactured home sample is about 53 kBtu/sq.ft. with an electric load of about 13 kilowatt hours per square foot (kWh/sq.ft). across the entire sample (about 84% electric use for all utility bills). In contrast, in the RBSA single-family sample, the average home uses about 44 kBtu/sq.ft., including 10.8 kWh/sq.ft. of electric load. The source of these differences appears to be lower insulation levels and higher infiltration rates in the older portions of the manufactured home sector.

In addition, the saturation of electric heat is much higher in the manufactured homes. Finally, across the entire manufactured home sample the use of supplemental fuels (non-metered fuels such as propane and wood) represents about a 23% increase in overall energy use per square foot above the metered fuel use. This increase in overall energy use is comparable to the impact of supplemental fuels in the single-family sample.

13. References

Baylon, D., B. Davis, I. Brown, M. Kennedy, M. Lubliner, and S. Onisko. 1991. Manufactured Homes Thermal Analysis and Cost Effectiveness Report. Prepared for the Bonneville Power Administration, Portland, OR.

Baylon, D., B. Davis, L. Palmiter. 1995. Manufactured Home Acquisition Program: Analysis of Program Impacts. Prepared for the Bonneville Power Administration, Portland, OR.

Baylon, D. B. Davis, K. Geraghty, and T. Hewes. 2009. Summary of 2006 NEEM Manufactured Homes: Field Data and Billing Analysis. Prepared for Northwest Energy Efficient Manufactured Housing Program (NEEM) and Oregon Department of Energy. Salem, OR.

Baylon, D., P. Storm, K. Geraghty, and B. Davis. 2012. Residential Building Stock Assessment: Single-Family Home Characteristics and Energy Use. Prepared for Northwest Energy Efficiency Alliance. Portland, OR.

Bonneville Power Administration. 1993. The 1992 Pacific Northwest Residential Energy Survey. DOE/BP-25174. United States Department of Energy, Bonneville Power Administration. Portland, OR.

Davis, B and D. Baylon. 1996. Energy Efficient Manufactured Homes, Technical Reference. Prepared for the Bonneville Power Administration, Portland, OR.

Davis, B and D. Baylon. 2004. Summary of SGC Manufactured Home Field Data (2000-2001), Prepared for the Northwest Energy Efficient Manufactured Homes Program, Salem, OR.

Davis, B, A. Roberts, D. Baylon. 2000. Summary of SGC Manufactured Home Field Data (1997-98 Sitings in Idaho and Washington). Prepared for Idaho Department of Water Resources- Energy Division.

Energy Independence and Security Act of 2007. Pub. L. No. 110-140, (2007). http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf

Fels, M. 1986. PRISM: An Introduction. Energy and Buildings, Volume 9 (1986), pp. 5-18.

Geraghty, K. and D. Baylon. 2009. Residential Ductless Mini-Split Heat Pump Retrofit Monitoring. Prepared for the Bonneville Power Administration, Portland, OR.

Harkreader, S.A., D. Lee and M.P. Sherman. 1987. Pacific Northwest Manufactured Home Energy Conservation Construction Practices and Upgrade Possibilities. Prepared for the Bonneville Power Administration, Portland, OR.

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

Northwest Power and Conservation Council (Council). 2010. Sixth Northwest Conservation and Electric Power Plan. NPCC-2010-09. Portland, OR. http://www.nwcouncil.org/energy/powerplan/6/final/SixthPowerPlan.pdf

Palmiter, L., and I.A. Brown. 1989. "Northwest residential infiltration survey: Analysis and results." Prepared for the Bonneville Power Administration, Portland, OR.

Palmiter, L., T. Bond, I. Brown, and D. Baylon. 1992. Measured Infiltration and Ventilation in Manufactured Homes. Prepared for the Bonneville Power Administration, Portland, OR.

RLW Analytics. 2007. Single-Family Residential Existing Construction Stock Assessment. Northwest Energy Efficiency Alliance. Portland, OR. http://neea.org/docs/reports/Single-FamilyResidentialExistingConstructionStockAssessment.pdf?sfvrsn=4

U.S. Census Bureau. 2002a. Census 2000 Summary File 3. Idaho, Montana, Oregon and Washington. http://www.census.gov/prod/cen2000/doc/sf3.pdf.

U.S. Census Bureau. 2002b. Census 2000 Summary File 3. Technical Documentation. http://www.census.gov/prod/cen2000/doc/sf3.pdf.

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RESIDENTIAL BUILDING STOCK ASSESSMENT: MANUFACTURED HOMES CHARACTERISTICS AND ENERGY USE

Appendix A: Manufactured Home Onsite Data Collection Protocol

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Appendix A: Manufactured Homes 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 manufactured 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
Type of building		
Single Wide		
Double Wide		
Triple Wide		
Modular/Prefab		
Other		
na		
unk		
Is there a site built conditioned addition?		
Yes		
No		
Are there any outbuildings >100 sqft that are conditioned?		
Yes		
No		
	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 incandescents stored (standard A lamp)		
Number of CFLs stored		
Number of other types of light bulbs stored		
Notes - Walkaround		
Survey Start Time		
Survey Complete Time		

2. Shell

Tier 1	Tier 2	Tier 3
Age & Construction Standard		
1975 and older, HUD		
1976-1994, HUD		
1990-1994, SGC or Natural Choice		
1995 to current, HUD		
1995 to current, NEEM		
2000 to current, Energy Star		
na		
unk		
Is there evidence of increased Ceiling insulation?		
Yes		
No		
	Ceiling insulation level	
	R14	
	R19	
	R22	
	R30	
	R38	
	R49	
	na	
	unk	
Ceiling Area (sqft)		
Is there evidence of increased Wall insulation?		
Yes		
No		
	Wall Insulation Level	
	R14	
	R19	
	R19+foam	
	na	
	unk	
Average ceiling height		
Wall area (sqft)		
Is there evidence of increased Floor insulation?		
Yes		
No		
	Floor insulation level	
	R11	
	R14	
	R19	
	R22	
	R30	
	R33	
	na	
	unk	

Tier 1	Tier 2	Tier 3
	Floor Insulation Condition	
	100% in place	
	90 % in place	
	75 % in place	
	50 % in place	
	25% in place	
	0 % in place	
	na	
	unk	
Floor Area (sqft)		
Windows upgraded		
Yes		
No		
	Replacement type	
	Double Metal	
	Double Vinyl/Wood	
	Modern	
	na	
	unk	
	Replacement window area	
% Windows South Facing		
Ducts - Evidence of mastic (sealing)?		
Yes		
No		
Duct material		
Metal		
Ductboard		
na		
unk		
Duct crossover present		
Yes		
No		
	Crossover Condition	
	Connected	
	Partially Connected	
	Disconnected	
	na	
	unk	
Notes - Shell		

3. Customer Interview

3.1. 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		

3.2. 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		

3.3. 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		

3.4. 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	

3.5. 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		

4. 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		

5. 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		

6. 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		

7. 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		

8. 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		

9. 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		

10. 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	

10.1. 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	

10.2. 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	

11. Appliances

11.1. 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		

11.2. Showerheads

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

11.3. 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		

11.4. Clothes Dryer

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

11.5. 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		

11.6. 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		

11.7. Dishwasher

Tier 1	Tier 2	Tier 3
Year of manufacture		
Notes		

11.8. 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	

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RESIDENTIAL BUILDING STOCK ASSESSMENT: MANUFACTURED HOMES 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
1961–1970	%	4.9%	—	10.8%	12.8%	10.8%	18
	EB	5.6%	—	6.7%	6.9%	4.2%	
1971–1980	%	19.5%	40.0%	31.0%	17.0%	22.8%	54
	EB	10.3%	25.7%	9.9%	7.4%	5.2%	
1981–1990	%	24.4%	10.0%	19.1%	34.0%	26.9%	47
	EB	11.1%	15.7%	8.5%	9.6%	5.8%	
1991–2000	%	39.0%	20.0%	33.7%	21.0%	27.8%	63
	EB	12.6%	21.0%	10.1%	8.2%	5.7%	
Post 2000	%	12.2%	30.0%	5.4%	15.2%	11.7%	23
	EB	8.5%	24.0%	4.8%	7.4%	4.2%	
Total		100.0%	100.0%	100.0%	100.0%	100.0%	205

Table B - 2: Average Conditioned Floor Area by State, Electrically Heated Homes

State	Conditioned Floor Area (sq.ft.)		
	Mean	EB	n
ID	1,395	104	39
MT	1,270	218	10
OR	1,257	84	76
WA	1,244	93	75
Region	1,269	57	200

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

Vintage		Conditioned Floor Area (sq.ft.)					
		ID	MT	OR	WA	Region	n
1961–1970	Mean	930	—	874	785	825	18
	EB	190	—	182	179	125	
1971–1980	Mean	1,083	1,076	1,159	1,171	1,152	52
	EB	223	313	119	158	87	
1981–1990	Mean	1,265	1,152	1,249	1,211	1,226	46
	EB	173		157	117	86	
1991–2000	Mean	1,640	1,129	1,402	1,280	1,398	61
	EB	127	240	130	163	90	
Post 2000	Mean	1,471	1,661	1,736	1,858	1,769	22
	EB	210	356	477	200	160	
All Vintages	Mean	1,395	1,270	1,257	1,244	1,269	199
	EB	104	218	84	93	57	

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

Age/Standard		Conditioned Floor Area (sq.ft.)					
		ID	MT	OR	WA	Region	n
1975 and Older, HUD	Mean	994	1,155	934	897	924	43
	EB	177	389	121	148	94	
1976–1994, HUD	Mean	1,331	996	1,266	1,240	1,259	89
	EB	156	183	102	100	65	
1990–1994, SGC or Natural Choice	Mean	1,513	1,333	1,530	1,467	1,496	22
	EB	135		168	163	94	
1995 to Current, HUD	Mean	1,730	924	1,579	1,443	1,510	23
	EB	297		298	303	197	
1995 to Current, NEEM	Mean	1,404	—	1,444	1,537	1,469	7
	EB		—	81	136	82	
2000 to Current, ENERGY STAR	Mean	1,552	1,661	1,266	1,888	1,693	16
	EB	229	356	148	431	254	
All Age/Standards	Mean	1,395	1,270	1,257	1,244	1,269	200
	EB	104	218	84	93	57	

Table B - 5: Average Normalized Heat Loss Rate by Vintage, Electrically Heated Homes

Vintage		Heat Loss Rate (UA/sq.ft.) per Home					
		ID	MT	OR	WA	Region	n
1961–1970	Mean	0.551	—	0.519	0.553	0.541	18
	EB	0.027	—	0.055	0.062	0.042	
1971–1980	Mean	0.410	0.466	0.394	0.441	0.417	52
	EB	0.050	0.068	0.040	0.056	0.029	
1981–1990	Mean	0.351	0.938	0.366	0.376	0.376	45
	EB	0.037	0.000	0.032	0.020	0.018	
1991–2000	Mean	0.277	0.259	0.268	0.299	0.281	63
	EB	0.049	0.084	0.029	0.048	0.024	
Post 2000	Mean	0.171	0.168	0.185	0.211	0.199	23
	EB	0.007	0.008	0.025	0.026	0.018	
All Vintages	Mean	0.323	0.382	0.346	0.373	0.358	201
	EB	0.033	0.122	0.026	0.028	0.017	

Table B - 6: Average Heat Loss Rate by Vintage, Electrically Heated Homes

Vintage		Heat Loss Rate (UA) per Home					
		ID	MT	OR	WA	Region	n
1961–1970	Mean	517	—	436	414	428	18
	EB	130	—	68	66	47	
1971–1980	Mean	463	493	433	489	461	52
	EB	81	129	37	54	30	
1981–1990	Mean	430	1,080	485	447	460	45
	EB	65		78	40	34	
1991–2000	Mean	441	278	369	388	388	63
	EB	66	32	48	79	38	
Post 2000	Mean	251	277	333	379	348	23
	EB	32	52	138	52	43	
All Vintages	Mean	428	444	414	426	423	201
	EB	39	135	29	27	18	

Table B - 7: Average Blower Door Air Tightness by State, Electrically Heated Homes

State	Blower Door Air Tightness (ACH50)		
	Mean	EB	n
ID	9.9	2.4	17
MT	10.0	3.7	4
OR	11.3	1.9	34
WA	11.8	3.9	47
Region	11.3	2.0	102

Table B - 8: Average Heating Thermostat Setpoint by State, Electrically Heated Homes

State	Heating Thermostat Setpoint (°F)		
	Mean	EB	n
ID	71.8	1.02	42
MT	69.7	0.88	10
OR	70.1	0.87	78
WA	68.2	0.94	77
Region	69.4	0.58	207

Table B - 9: Percentage of Electrically Heated Homes Reporting a Heating Setback by State

State	Homes Reporting Heating Setback		
	%	EB	n
ID	45.2%	12.7%	42
MT	80.0%	21.0%	10
OR	60.1%	10.4%	78
WA	64.7%	9.6%	77
Region	60.9%	6.3%	207

Table B - 10: Average Weather Normalized kWh per Home by State, Electrically Heated Homes

State	kWh per Home		
	Mean	EB	n
ID	20,172	1,523	38
MT	16,694	3,575	10
OR	16,018	1,118	75
WA	18,691	1,636	73
Region	17,890	925	196

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RESIDENTIAL BUILDING STOCK ASSESSMENT: MANUFACTURED HOMES 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 Pascals (Pa) with respect to (WRT) outside. Note that 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 dryers 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 Pa WRT outside.
3. Pressurize tested part of duct system to about 50 Pa 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 outside, 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

Setup: 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)______/______