Analysis of the Residential Building Stock Assessment

Research Into Action

Hadley Engineering

August 8, 2013

Structure of Report

- Section 1: Memo on methods
- Section 2: Analysis

Section 1: Memo on Method

research into action

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Memorandum

To: Carrie Cobb, Project Manager, Bonneville Power Administration

From: Jun Suzuki, Research Into Action, Inc.

Date: August 7, 2013

Re: Methodologies for the analyses of the Residential Building Stock Assessment of Public Sample in BPA Territory using Single-Family and Manufactured Homes Databases

1.1. Summary

The Residential Building Stock Assessment (RBSA) was completed by Ecotope under contract by Northwest Energy Efficiency Alliance (NEEA). This study included single-family, manufactured, and multifamily housing stock for the entire Pacific Northwest (PNW) region. In late 2012, Bonneville Power Administration (BPA) contracted Research Into Action, Inc. to conduct analyses of RBSA within public power samples in BPA service territory. The multifamily home sample was excluded from these analyses.

This memo outlines the methodologies that governed the analyses. The main report is in a separate Microsoft PowerPoint document. In addition, analyses tables that include all point estimates and sample sizes were produced in a standard output format using Microsoft Excel, which BPA can provide upon request.

1.2. Introduction

1.2.1. Background

In 2010, NEEA commissioned the RBSA, which was conducted by Ecotope with the support of Ecova. The primary objective of the RBSA is to establish the baseline characteristics of the existing residential building stock in the PNW based on field data from a representative, random sample of existing homes. The findings will guide future planning efforts and provide a solid base for assessing energy savings from residential programs throughout the Northwest.

In 1992, a large-scale residential survey was conducted based on a self-reported assessment of insulation and appliance use; this established fundamental characteristics of the region's residential sector. Since then, small, focused studies have updated this knowledge, but no similar large-scale residential survey has been conducted for nearly 20 years.

In 2012, the RBSA research team conducted on-site visits at 1,859 single-family, manufactured, and multifamily homes. Two auditors performed each site visit. Audits lasted approximately two hours and covered all of the major components of the homes that can be linked to the household's overall energy use, including: building envelope, HVAC systems, lighting,

appliances, electronics, and water technologies. In addition, this audit data was combined with self-reported home characteristics and demographics data that were collected in the phone survey during the recruitment of on-site sample.

In September 2012, Ecotope produced a report summarizing the single-family database of the entire PNW region by state (Washington, Oregon, Idaho, and Montana). Subsequent reports summarized the results for manufactured and multifamily homes.[1]

1.2.2. Analysis Objectives

This research analyzes the single-family and manufactured home RBSA databases for the BPA territory and identifies program opportunities for BPA's future energy efficiency activities in the region.

We performed all analyses at the following levels: 1) total PNW, 2) BPA vs. non-BPA territory, 3) each of the five BPA sub-regions, and 4) urbanization level within BPA territory.

1.3. Methodology

In this section, we describe the methods we used to analyze the RBSA databases. Ecotope's report describes the detailed sampling and data collection methodologies used for the development of the RBSA databases.

1.3.1. Analysis Scope

1.3.1.1. Measure Types

In order to narrow our analysis scope and to better understand how BPA intends to use the information in the databases, the Research Into Action team conducted a group interview with BPA staff in November 2012. Based on this interview, we determined this research's scope to analyze the variables that relate to the measure types shown in Table 1. Appendix A - Summary Statistics lists summarized statistics for each measure type.

Some measure types, such as envelope measures and HVAC systems, depend on the house type (i.e., single-family or manufactured home). Other measure types, such as lighting, water technologies, appliances, and electronics, are sold and installed in all kinds of housing. We analyzed the former measure types within each of the databases, and we used stacked or merged databases for analyses of the latter measure types.

[1] These reports are available at: http://neea.org/resource-center/regional-data-resources/residential-building-stock-assessment

Table 1: Measures Types and Data Aggregation

	ANALYSES BY BUILDING TYPE	ANALYSES AGGREGATED
Building characteristics	X	
Envelope measures	X	
HVAC systems	X	
Lighting measures		X
Water technology measures		X
Appliance measures		X
Electronics measures		X

1.3.1.2. Utility Domains

The primary objective of this research is to characterize the residential stock across the BPA region and for sub-regions within BPA to identify potential program opportunities. We approached all investigations using the following consistent utility domains as cross-variables to detect significant differences:

- **BPA Status:** Utilities in the BPA service territory and those that are not in the BPA service territory.
- **BPA Utilities in Five Sub-regions:** Puget Sound, Western Washington, Western Oregon, Eastern Oregon and Eastern Washington, and Idaho and Montana.
- **Small Rural Residential (SRR) Status:** BPA utilities serving SRR, non-SRR Option 1, and Option 2 designations.

Appendix B - Utility Domains provides definitions of these domains for each BPA utility.

1.3.2. Sampling and Weighting

RBSA databases consist of 1,404 randomly sampled single-family homes and 321 randomly sampled manufactured homes in the PNW. Ecotope derived the sample from an extensive phone survey followed by recruitment of a statistically robust sample of on-site energy surveys conducted by the auditors. Ecotope designed the sample to meet the complex needs for detailed statistics regarding each of the Northwest sub-regions, and achieve a statistically significant representation of the population of single-family homes and manufactured homes for each state and the BPA region as a whole. In addition, the single-family database satisfies statistical significance within each of the five BPA sub-regions. Moreover, several utilities added an oversample of residences within their service territory to obtain statistically valid sample sizes within their territories. These considerations resulted in a complex stratified sampling design based on geographic location and utility type, which subsequently required the application of probability weights. Ecotope's report presents detailed sampling and weight calculations.

Each of the databases contains probability-weight variables based on the stratified design. We applied this weight to all analyses so that the characteristics we developed describe population summaries.

Figure 1 through Figure 3 show the geographic distribution of the single-family and manufactured home samples for the PNW region, within the BPA region, and within the non-BPA region. Colored areas represent utility boundaries. Locations of sampled homes are approximated by ZIP code.

Figure 1: RBSA Single-Family and Manufactured Homes Distribution of All Samples

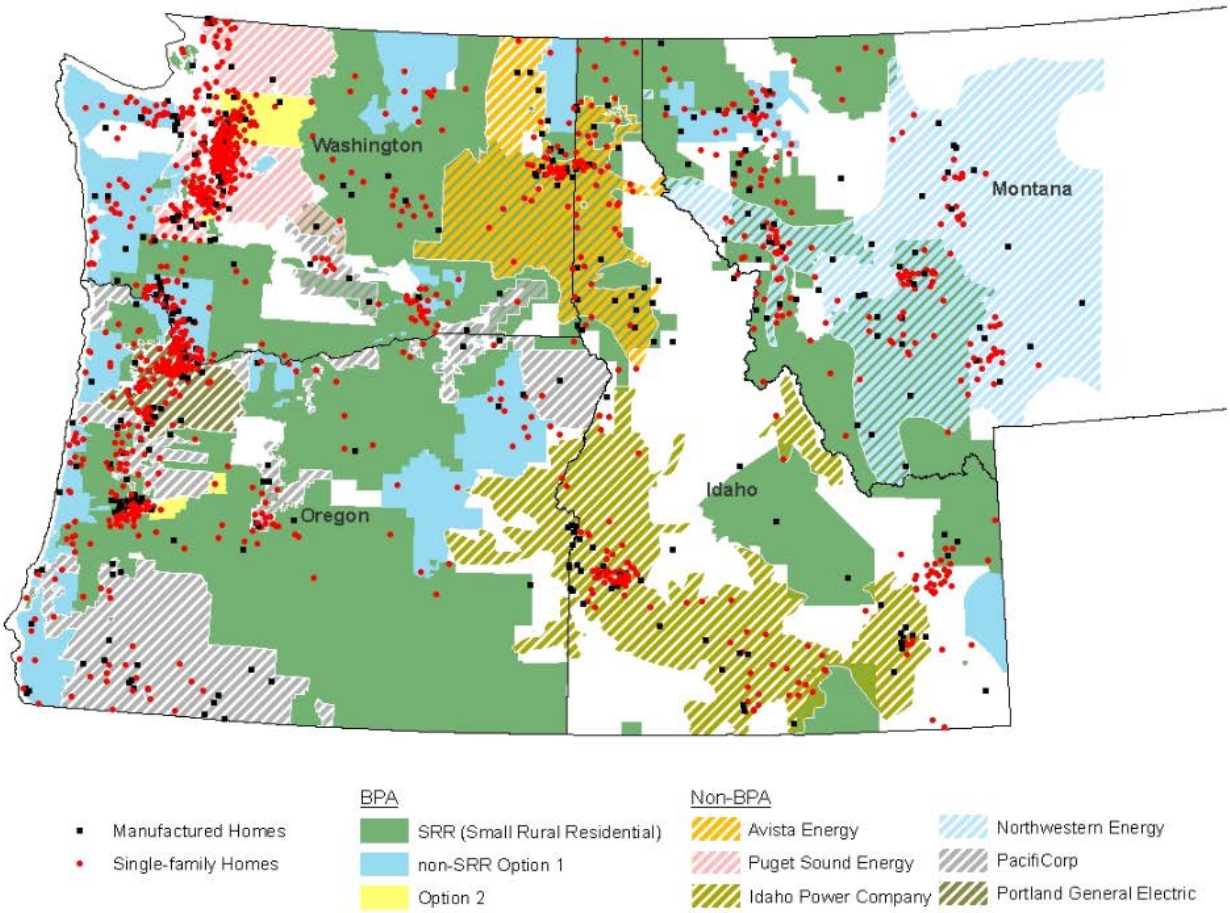


Figure 2: RBSA Single-Family and Manufactured Homes Samples Distribution within BPA Regions

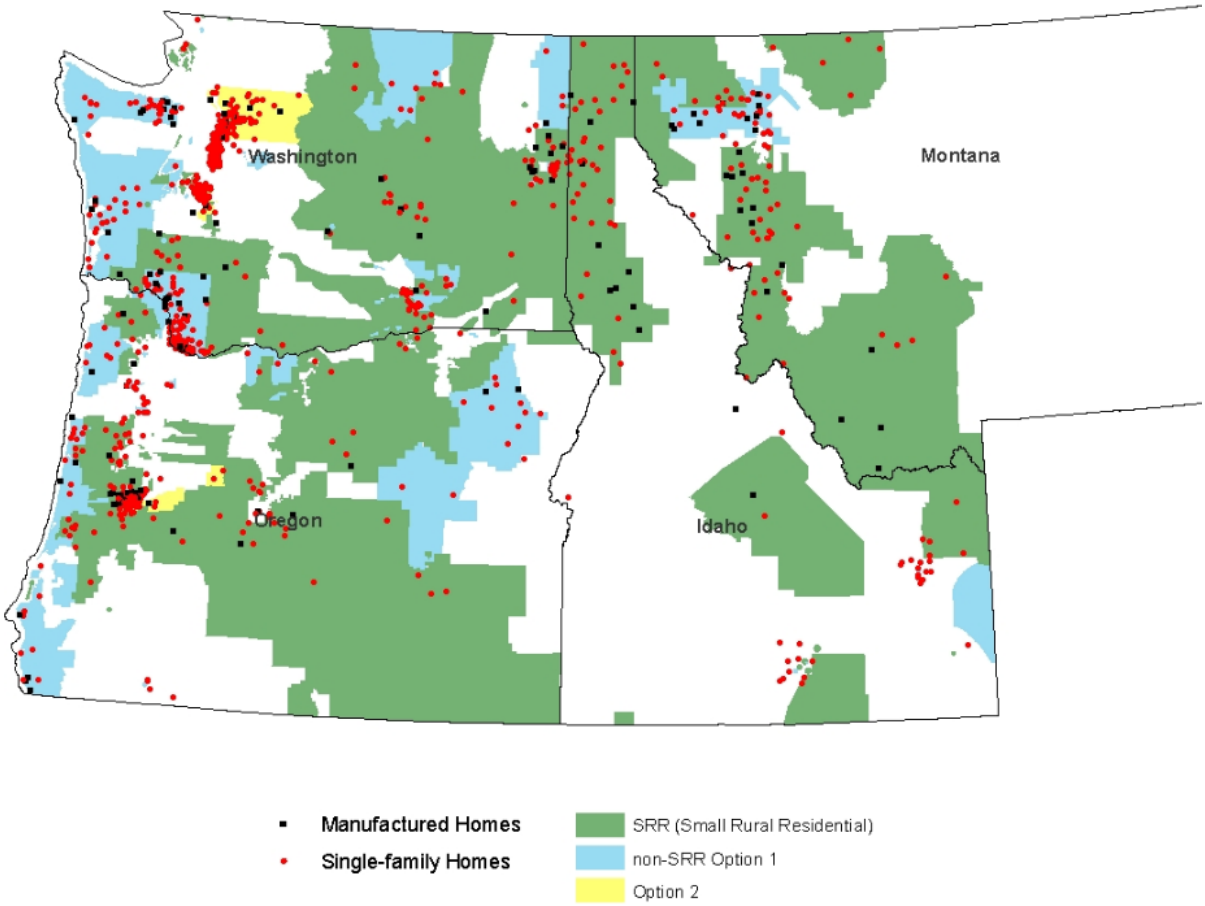
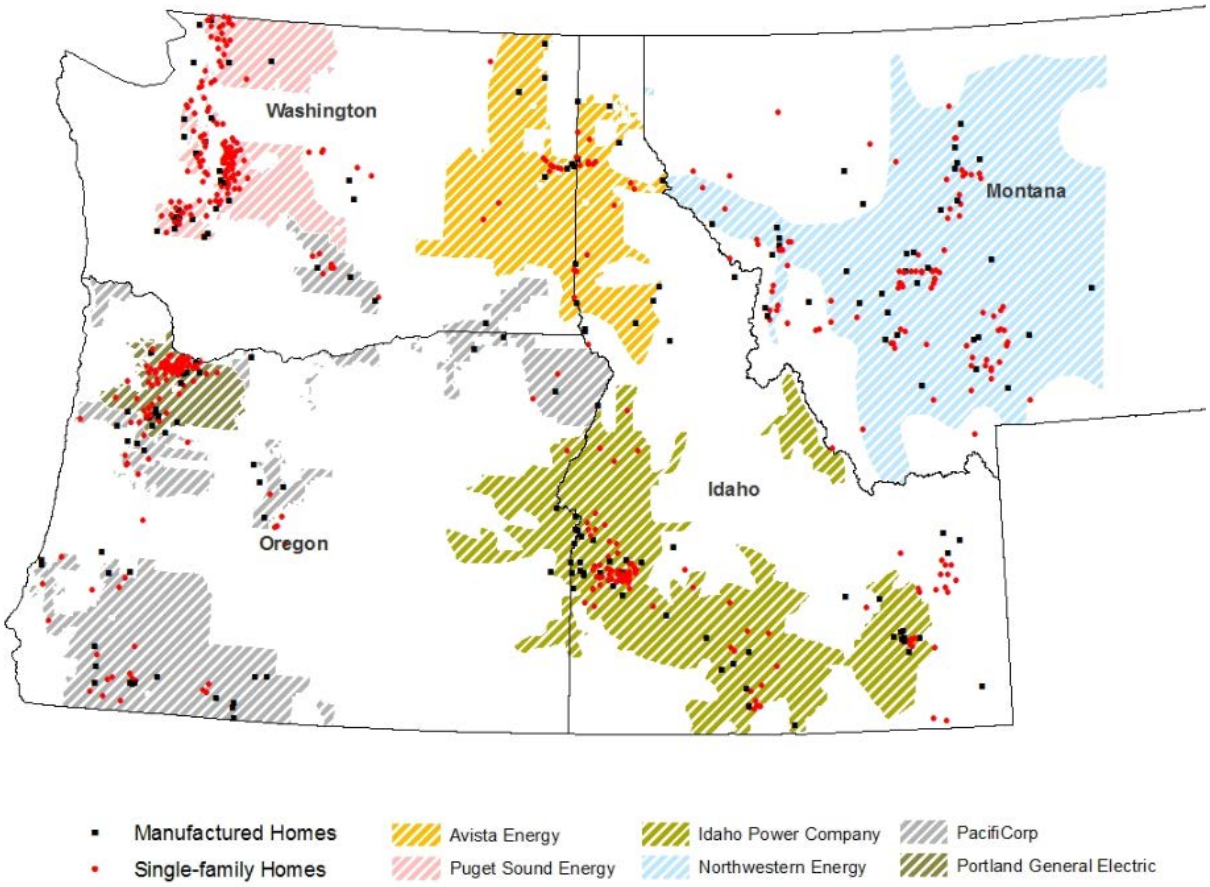


Figure 3: RBSA Single-Family and Manufactured Homes Samples Distribution within Non-BPA Regions



1.3.3. Data Analysis

1.3.3.1. Data Processing

The RBSA databases are large relational databases formatted in Microsoft Access that span more than 600 variables in more than 70 tables. To work with this complex database, we first set up the Microsoft SQL Server Management Studio application and uploaded RBSA Access files in this system. We designed all data queries in this environment to develop analyzable flat files. We then used IBM SPSS v21, a statistical analysis package, to conduct all statistical analyses with these flat files.

1.3.3.2. Iteration Variables

The unit of analysis for this study is an occupied housing unit or a house. RBSA databases are relational databases that store multiple tables, each of which includes related variables. All tables include a “siteid” (site ID) variable, which can be used to link variables in different tables to reconstruct a dataset that is based on a house as a unit and that contains target variables for a particular analysis.

In addition, most characteristic tables include iteration variables ("_it") that characterize multiple instances of a particular component or characteristic. For instance, if there are several refrigerators at a site, each refrigerator has a separate entry and is distinguished from the other refrigerators at the site by an "_it" variable numbered sequentially for each refrigerator observed. Using "siteid" and "_it" variables together, analysts can reconstruct the survey on any home. When multiple iterations occur, we used weighted proportions to account for the multiple components, or we selected a component that is the most meaningful for the summary. We dealt with these iteration issues on a case-by-case basis; Appendix A - Summary Statistics provides methodological details.

1.3.3.3. Missing Data

Many variables in the RBSA databases contain missing data. These indicate that no observation was made for particular cases for particular variables because of one of several reasons, including that a datum was not observable, was unreliable, or a combination of both.

We applied the listwise deletion method for all analyses. This method drops cases from an analysis when at least one of the specified variables contains a missing value; the analysis is run only on cases with a complete set of pertinent data. For example, when calculating "distribution of attic insulation level by building vintage," a given site is included in this analysis only if neither the attic insulation level nor the building vintage variable is missing. When performing calculations such as averages, denominators are the number of sites with non-missing observations. Methodological details in Appendix A - Summary Statistics describe how we treated missing data for appropriate summary statistics.

1.3.3.4. Statistical Validity

We performed additional analyses to determine if sample sizes of any given analysis were sufficiently statistically sound to provide accurate characterizations. For all summary outputs, we used either the sample proportion or the population estimate of the mean, properly applying the weights.

For all proportion estimates, we aimed for 90% confidence and 10% precision within a given subset, which requires a minimum of 68 observations within a subset. To determine the mean estimate of population, we required a minimum sample size of 30 for the denominators to ensure statistical validity. Statisticians use the convention of choosing a sample size greater than 30 for means, to ensure that the t-test will be reasonably well calibrated (i.e., achieving the correct Type I error rate).[2] In our deliverables, we indicated all of the data points that violated statistical validity under these guidelines.

As discussed in Section 1.3.1.2 (Utility Domains), we performed all analyses on measures using consistent utility regions as cross-variables to make meaningful regional comparisons. Also, as

[2] In order to calculate an exact level of confidence and precision for a given mean estimate of a population, we need to know the standard deviation and margin of error of the target measure which varies depending on the measure.

discussed in Section 1.3.2 (Sampling and Weighting), the RBSA sample provides appropriate statistical significance in representing the population of single-family homes and manufactured homes for each PNW state and the BPA region as a whole, as well as within each of the BPA sub-regions in the single-family database. Table 2 displays the sample sizes for each subset. This table shows that many of the manufactured homes analysis subsets (BPA sub-region and SRR status) are not of sufficient size to satisfy statistical validity.

Table 2: Sample Size by Utility Domain Subset

		Single-Family Homes	Manufactured Homes	Total
PNW Total		1,404	322	1,726
BPA Status	Non-BPA	491	176	667
	BPA	913	146	1,059
BPA Sub-region	Eastern Oregon and Washington	138	22	160
	Idaho and Montana	141	36	177
	Puget Sound	335	12	347
	Western Oregon	148	43	191
	Western Washington	151	33	184
SRR Status	SRR	225	53	278
	Non-SRR and Option 1	314	54	368
	Option 2	374	36	410

Section 2: Report Slides

August 7, 2013

RBSA

Residential Building Stock Assessment

Analysis of public power sample in BPA territory using single-family and manufactured homes databases

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Introduction

About the RBSA

Assessment of residential buildings which audited the major energy-related components of homes from a representative sample of more than 1,850 single-family, manufactured, and multifamily homes in the Pacific Northwest. The data provides regional organizations and program administrators with baseline characteristics for conservation planning, program design, and evaluation.

Objective of This Analysis

This analysis of single-family and manufactured home RBSA data characterizes BPA's territory and identifies program opportunities for future energy efficiency activities.

Content

- Introduction
- Methodologies
- Primary Program Opportunities and Recommendations
- Data Analysis
  - *Building Characteristics*
  - *Envelope*
  - *HVAC*
  - *Lighting*
  - *Water Technologies*
  - *Appliances*
  - *Electronics*

Methodology

Study Scope

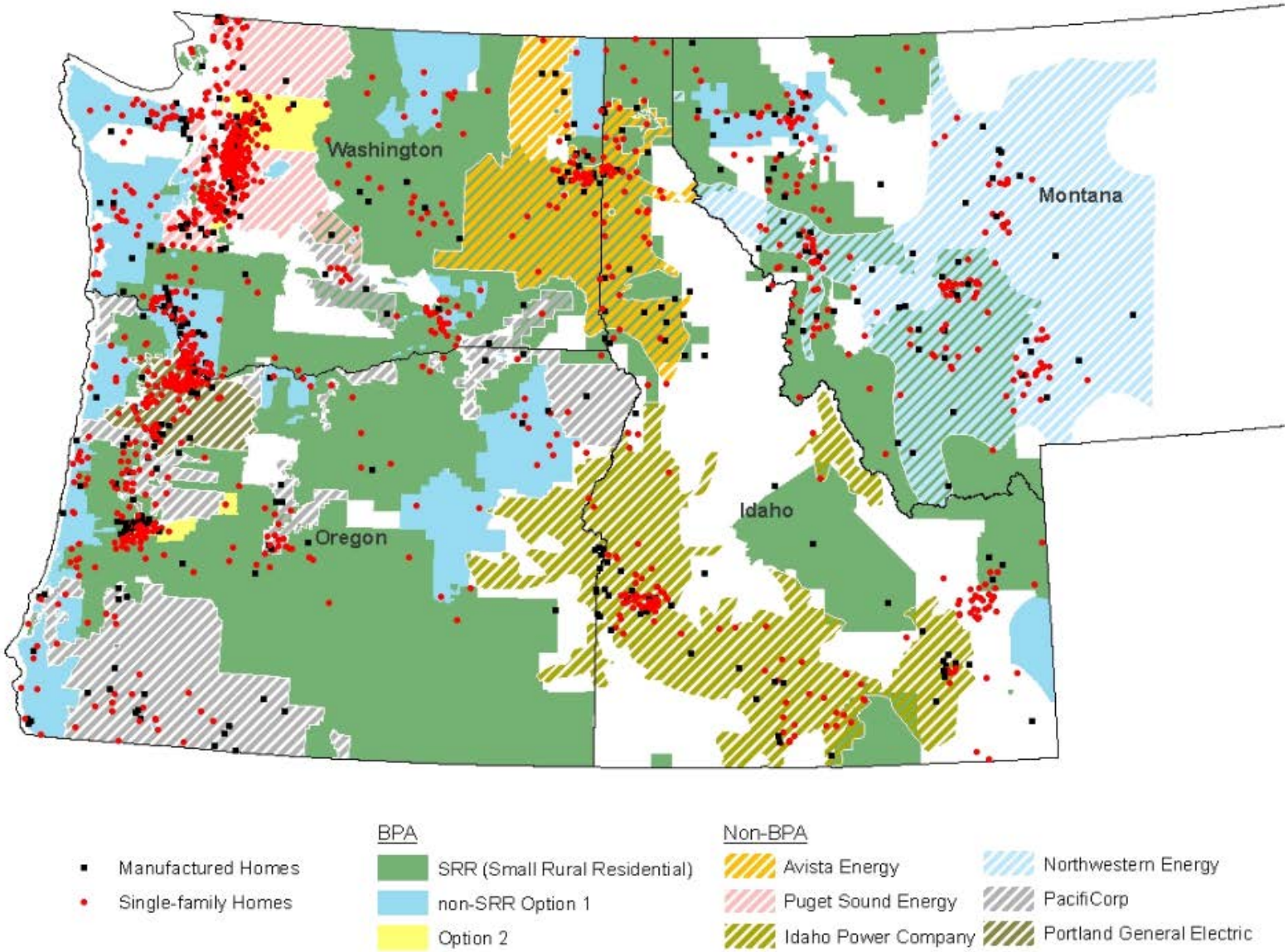
- A group interview with BPA residential programs staff in November 2012 guided study's scope.

Measure Types	Analyses by building type	Analyses aggregated
Building characteristics	✓	
Envelope measures	✓	
HVAC systems	✓	
Lighting measures		✓
Water technology measures		✓
Appliance measures		✓
Electronics measures		✓

Utility Domains for Analyses

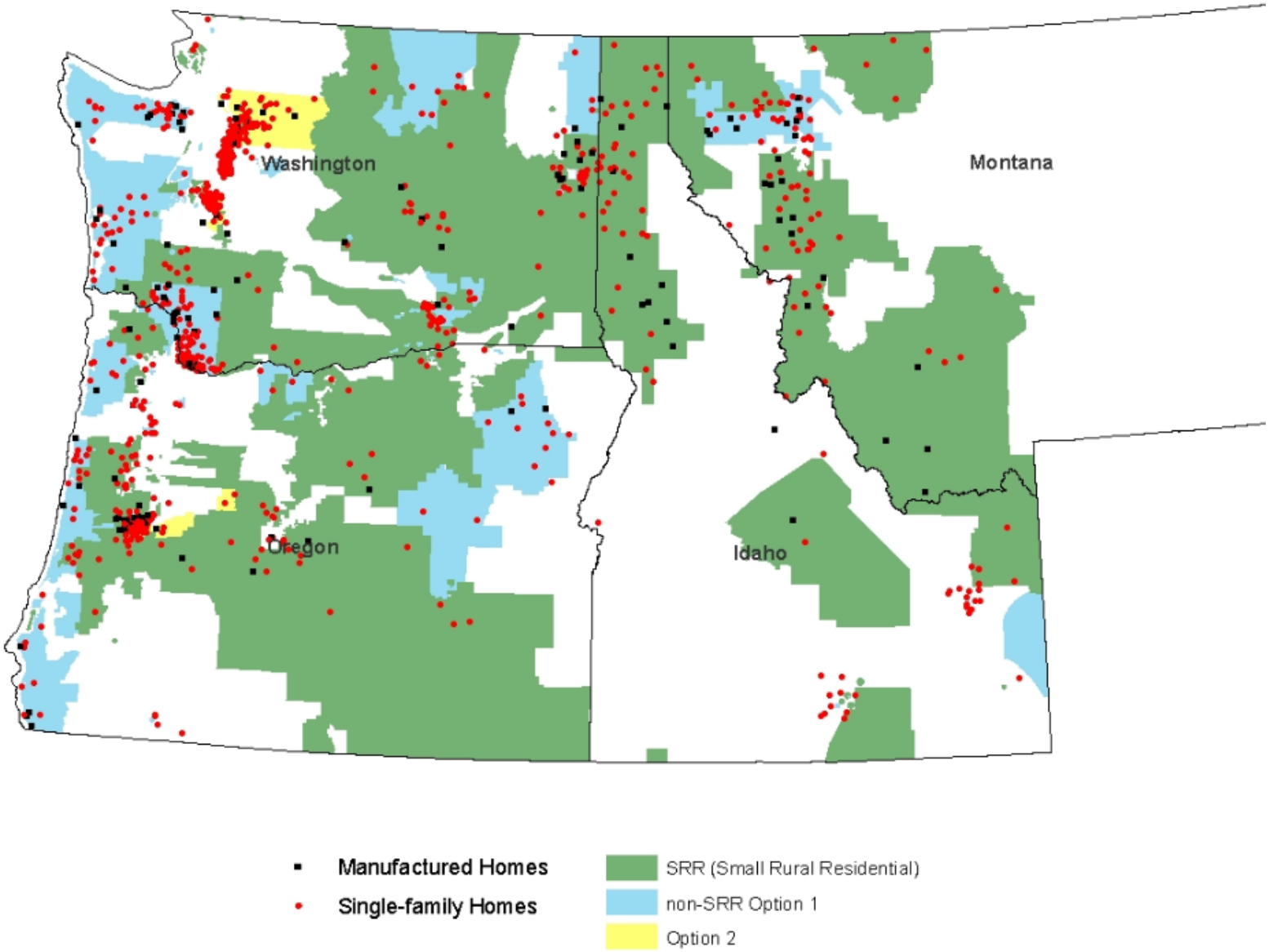
- BPA status: Utilities in BPA service territory vs. non-BPA territory
- BPA sub-region: BPA utilities in Puget Sound, Western Washington, Western Oregon, Eastern Oregon and Washington, and Idaho and Montana
- SRR status: BPA utilities serving SRR (rural), non-SRR Option 1 (suburban), and Option 2 (urban)

Final Sample Distribution – Entire Pacific Northwest



Note: Colored areas represent utility boundaries. Locations of sampled homes are approximated by ZIP code.

Final Sample Distribution – Within BPA Regions



Note: Colored areas represent utility boundaries. Locations of sampled homes are approximated by ZIP code.

Methodology

Unit of Analysis

- The unit of analysis for this study is an occupied housing unit or a house.
- For analyses that involves multiple instances of a particular component, we used either a selected component as a unit or a weighted proportion by site.
  - ✓ *Example 1: Many homes have multiple refrigerators, so the denominator of "% of ES refrigerator" is the sum of refrigerators in the region, not the sum of sites.*
  - ✓ *Example 2: If a site uses two heating systems with an equal frequency of use, we used weighted proportion (counted as 0.5 for each heating system).*

Missing Data

- Included only the sites with a complete set of data for the specific analysis.
- When performing calculations such as averages, denominators are the number of sites without missing observations.

Statistical Validity

- For proportion estimates, we used 68 minimum sample within a subset (90%+/-10% confidence and precision).
- For mean estimate of population, we used 30 minimum sample (standard practice at which t-test is well calibrated).

Primary Program Opportunities

Envelope measures

- Electrically heated single-family and manufactured homes in the BPA region have significant remaining potential for attic insulation. Floor insulation also has some remaining opportunities for single-family homes. Programs should target older vintages and homes in urban regions.
- The primary windows in more than one-fourth of single-family homes (27%) and more than half of the manufactured homes (52%) in the BPA region had a “poor” U-value (0.70 or higher).
- 37% of single-family homes and 41% of manufactured homes in the BPA region have “poor” ACH50 (above 10.0). 7.0 ACH50 is a typical goal for air sealing. There may be significant weatherization opportunities remaining, especially among older vintages.

HVAC measures

- E. Oregon and Washington have a high saturation of electric-FAF, and W. Oregon and Washington as well as Puget Sound areas have high saturations of electric-zonal heating systems. These indicate areas to target for central heat pump or DHP measures.
- There is a high prevalence of electric-FAF among manufactured homes.

Primary Program Opportunities

Lighting

- 68% of the region's lamps are inefficient lamps (incandescent or halogen). 36% of the region's lamps are currently non-EISA-compliant, but the EISA standard is still being implemented. 26% of region's lamps are exempt from EISA, a majority of which are incandescent and halogen lamps. This suggests a possible efficiency target.

Water technologies

- The low-flow showerhead saturation in the BPA region is 26% overall, and showerheads in a majority of BPA region homes remain high-flow type (greater than 1.8 gpm in-situ).

Appliances

- Rural and suburban regions have higher concentrations of old refrigerators. More than a quarter of refrigerators in Idaho and Montana were made before 1990, suggesting opportunity for early retirement measures.

Other Areas

- The Puget Sound region has the highest proportion of non-owner-occupied homes. There may be opportunity to design programs to target these homes for weatherization or heating systems.
- Almost 40% of the manufactured homes in the BPA region were built before 1980. There may be potential for a manufactured home decommissioning program to remove from service old and inefficient homes.

Other Recommendations

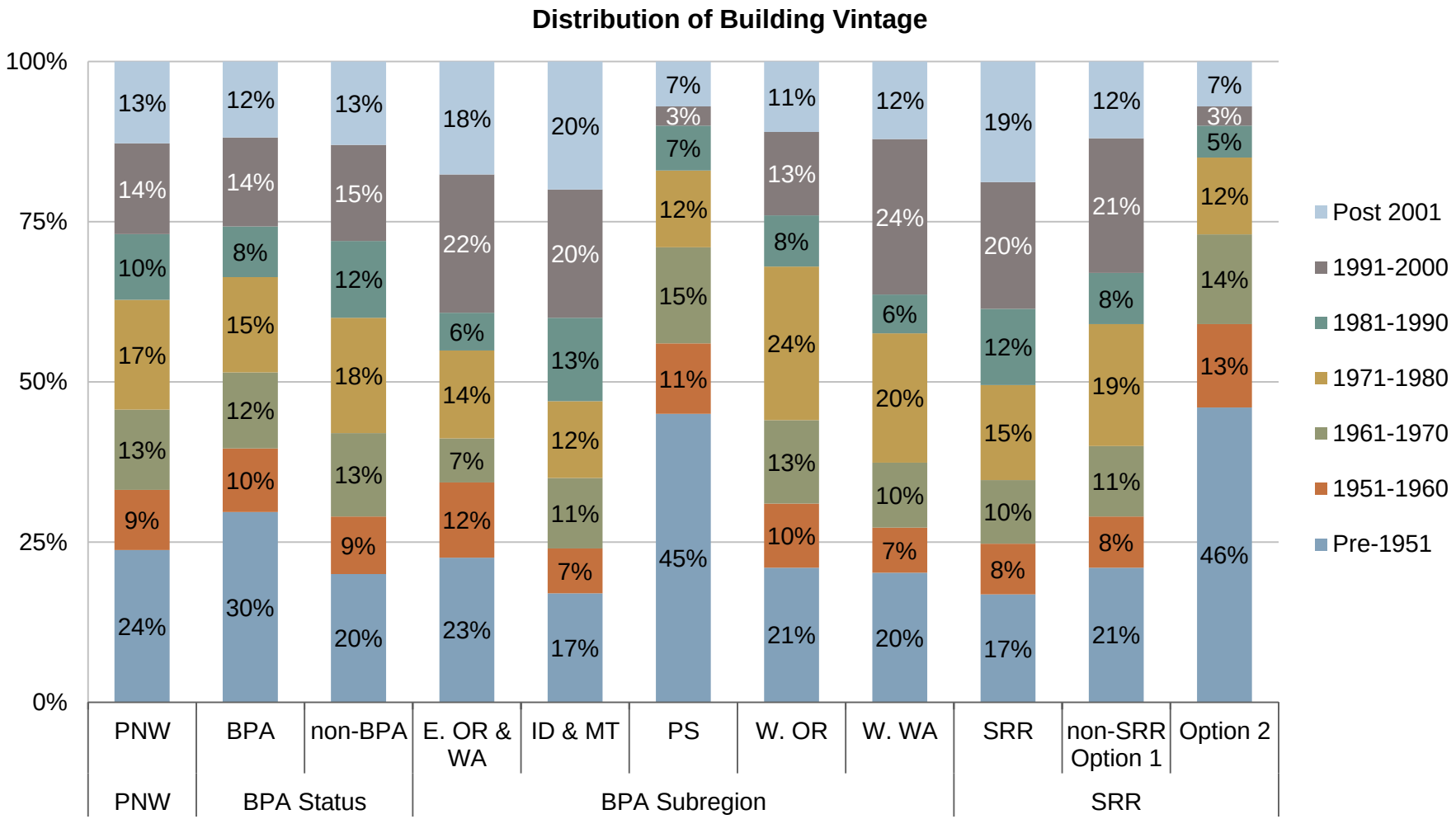
- Only 7% of refrigerators and freezers in the BPA region were identified as Energy Star models at the time of manufacture. BPA may want to identify the proportion of refrigerators and freezers manufactured since 2008 that meet Energy Star specifications (most recently updated in April 2008) to determine both saturation of currently qualifying units and the trend in annual saturation. Further, BPA might compare these statistics to national data.
- This report discusses similarities and differences among regions within BPA's territory, and thus discusses the proportions of the market described by the investigated stock characteristics. We recommend BPA consult the Excel workbook that accompanies this report to determine market size in terms of number of potential applications.

Building Characteristics (SF and MH separate)

Areas	Dependent variables	Database
Building vintage	Distribution of building vintage	
Building type	Distribution of building type	
Square footage	Distribution of square footage of conditioned space by building type	
Square footage	Average square footage of conditioned space by building type	
Square footage	Average square footage of conditioned space by building vintage	
Cubic volume	Distribution of cubic volume of conditioned space by building type	
Cubic volume	Average cubic volume of conditioned space by building type	
Cubic volume	Average cubic volume of conditioned space by building vintage	
Ceiling type	Distribution of ceiling type (location of ceiling insulation)	SF only
Foundation	Distribution of foundation	SF only
Natural gas use	% of homes with verified use of natural gas by building type	
Building tenure	% of owner-occupied homes by building type	
Number of floor	Distribution of the number of floors	SF only
Window area fraction	Average % of window area	
Number of residents	Average number of residents	

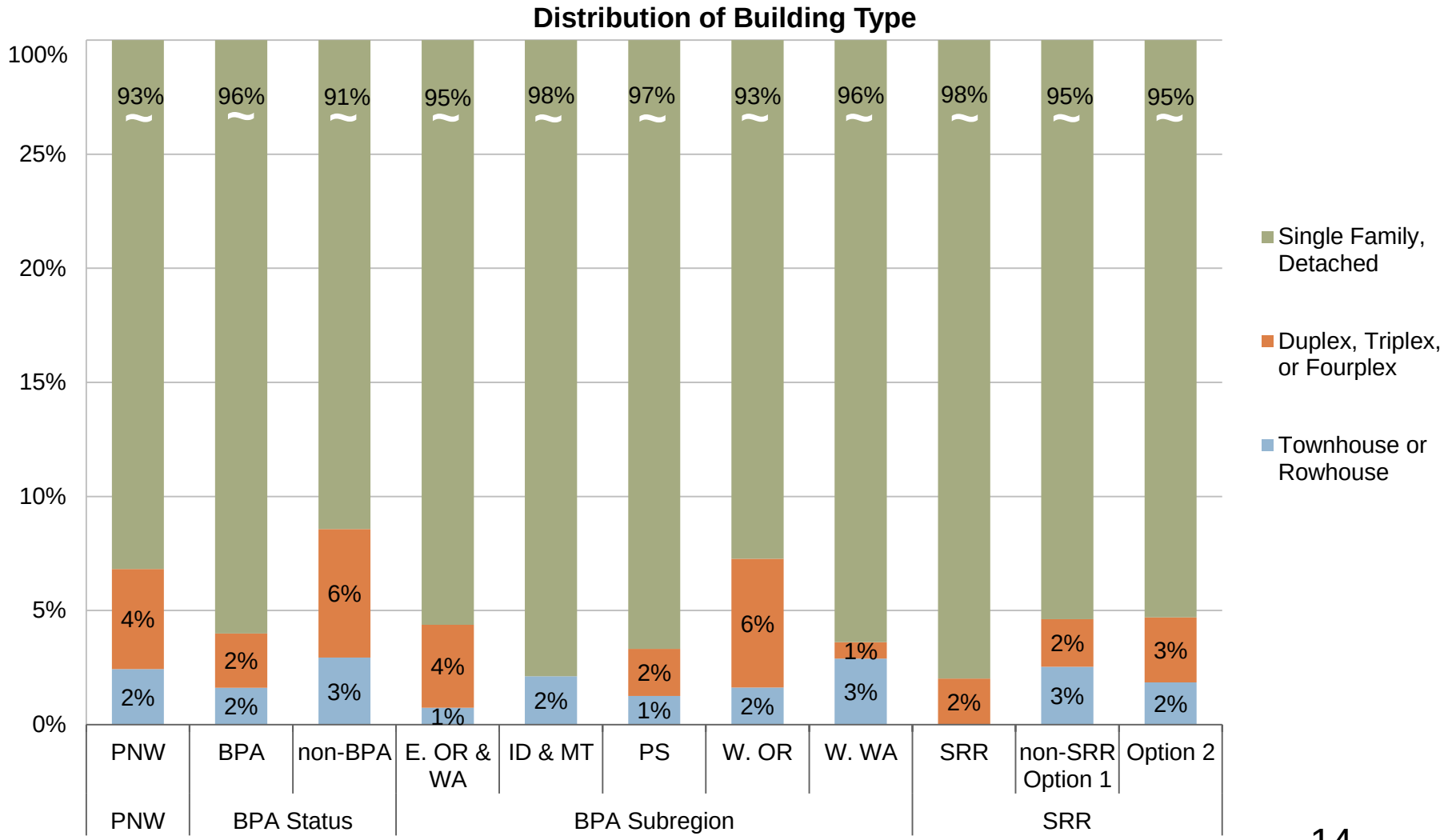
1. Overall, the BPA region has a higher distribution of older housing stock than non-BPA regions.
2. Puget Sound and urban regions have the highest concentration of older homes, with more than 70% of building stock in these areas built before 1970. The proportion of homes built after 2000 is only 7% in these regions.
3. Nearly 40% of homes in E. Oregon and E./W. Washington, Idaho and Montana, or rural area were built after 1990.

SF – Building Vintage

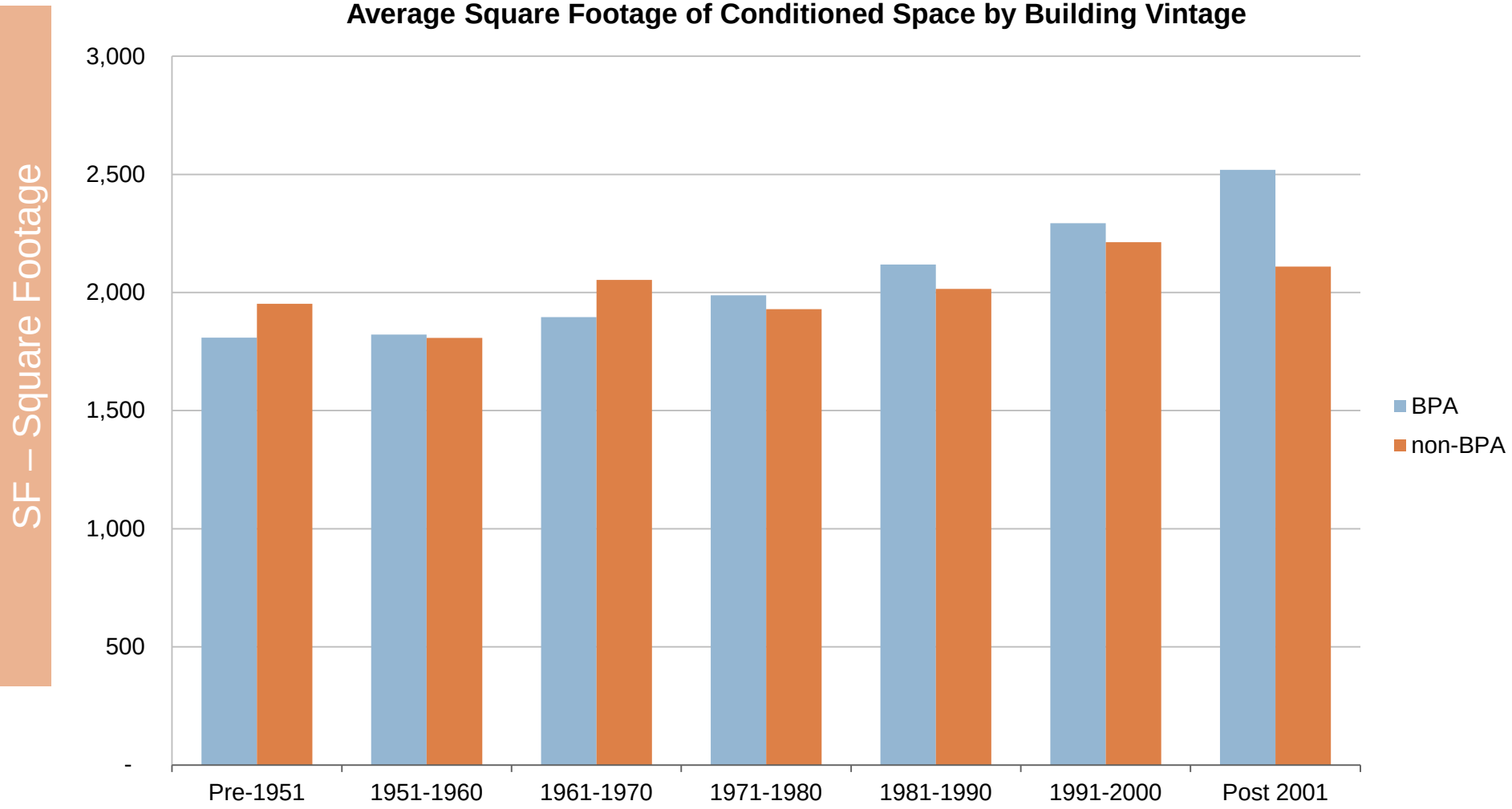


1. The BPA region has a higher distribution of single-family detached than non-BPA regions.
2. Within the BPA region, higher concentrations of duplexes, triplexes, and fourplexes are found in Oregon and E. Washington.
3. Townhouses, rowhouses, and multiplexes make up a small percentage of the overall single-family housing stock.

SF – Building Type

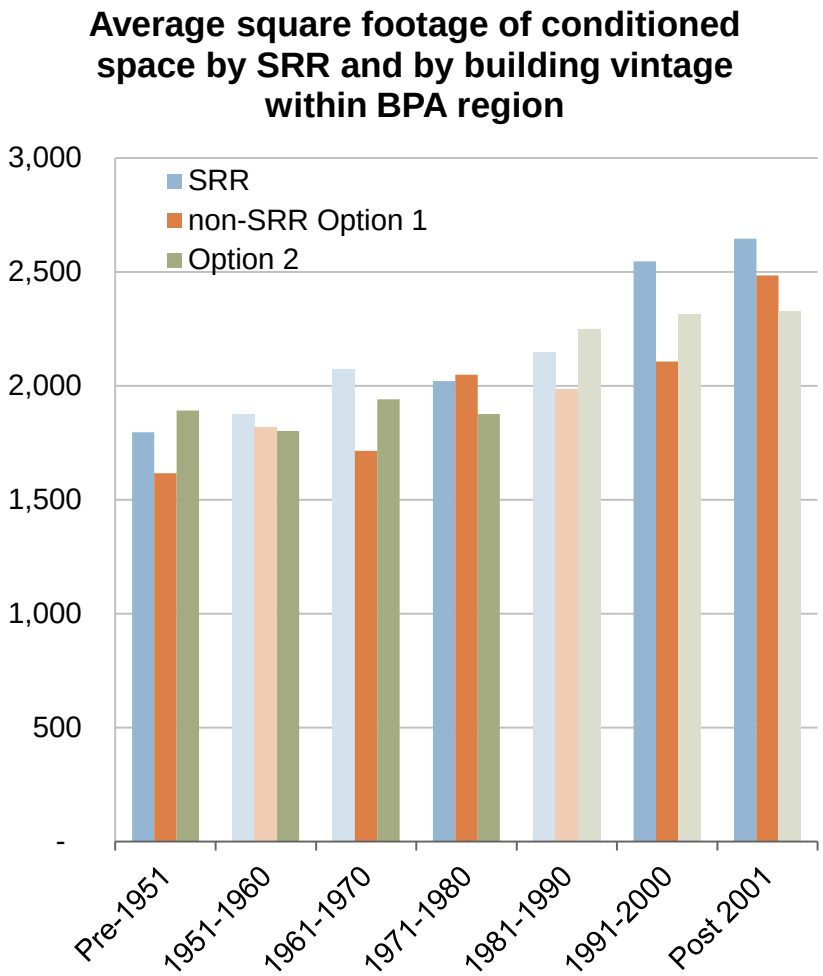


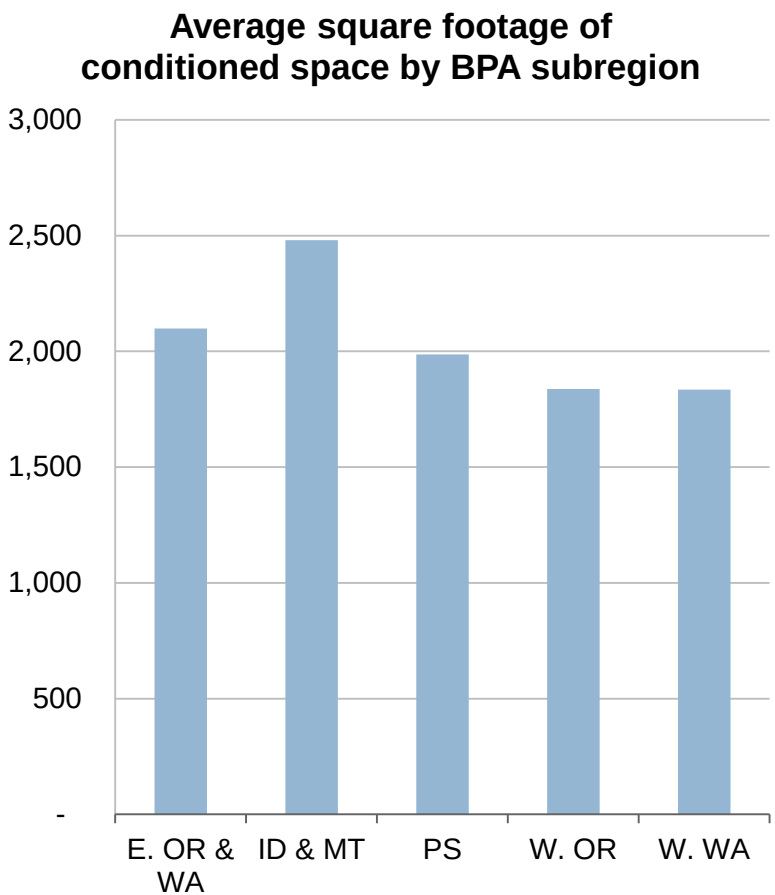
1. Newer homes in the BPA region are increasingly larger in size while the size of newer homes in non-BPA region are staying relatively constant. Homes built after 2000 exceed 2,500 square feet on average.



1. While home sizes are increasing in all BPA areas, this is particularly prominent in rural and suburban areas. The average size of homes built after 2001 in these regions are nearly 1,000 SQFT larger than homes built before 1951.
2. Homes in Idaho and Montana are the largest.

SF – Square Footage

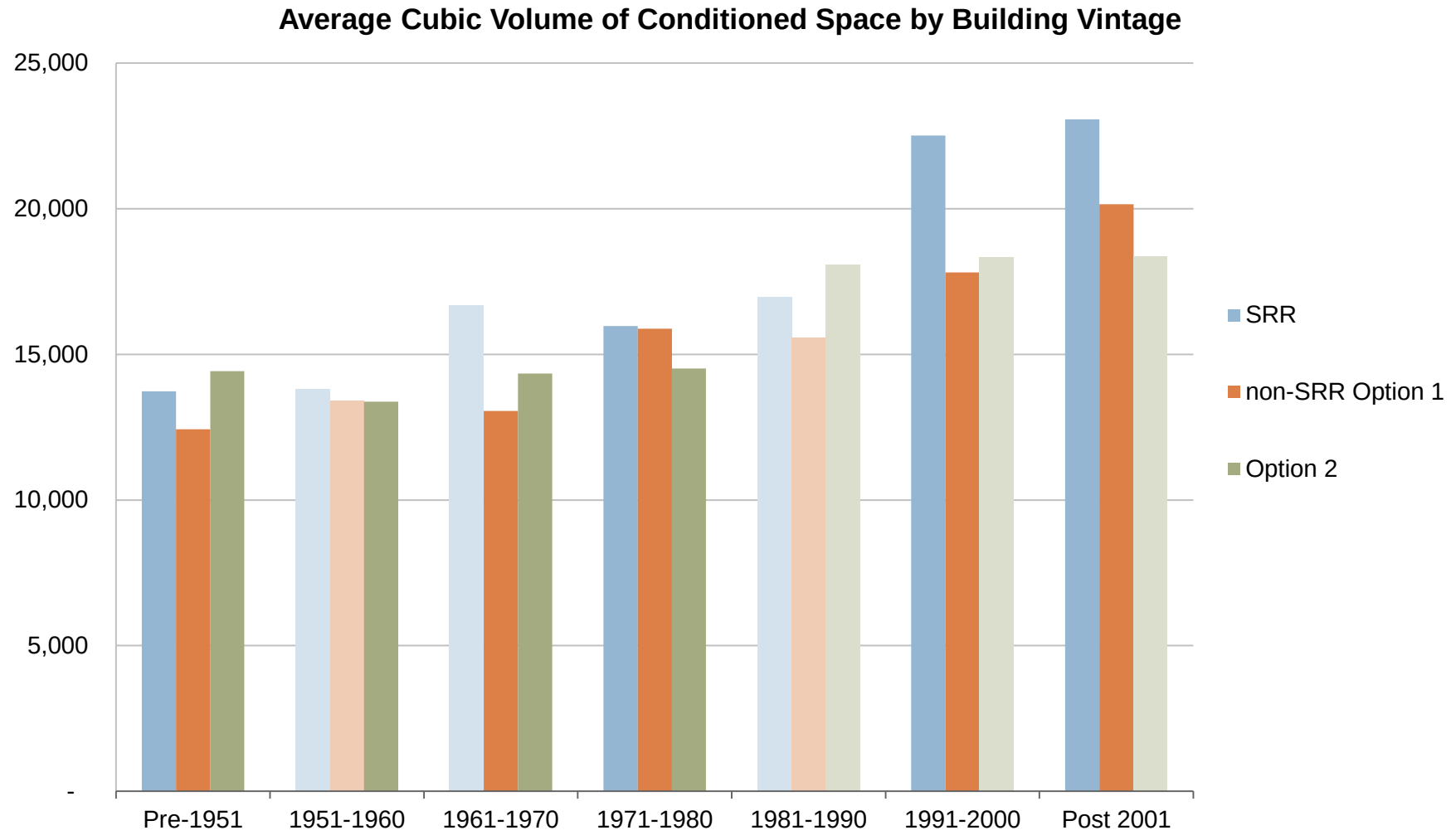




Note: Shaded color bars indicate small samples (< 30).

1. Increases in cubic volume of conditioned space as the building vintage becomes newer is even more apparent. In rural areas where this phenomena is more prominent, the increase in cubic volume between homes built pre-1951 and post 2001 is over 40%.

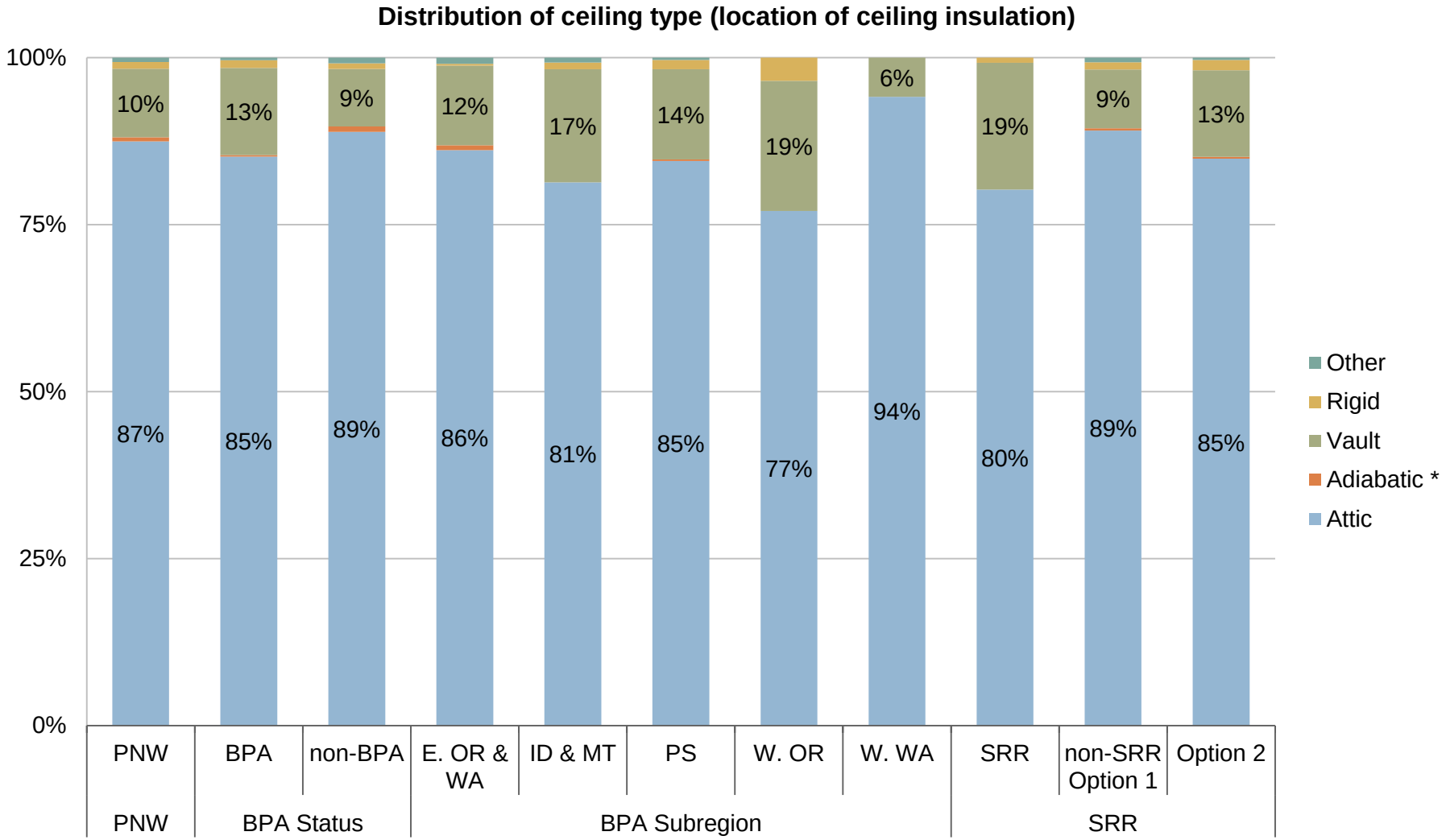
SF – Cubic Volume



Note: Shaded color bars indicate small samples (< 30).

SF – Ceiling Type

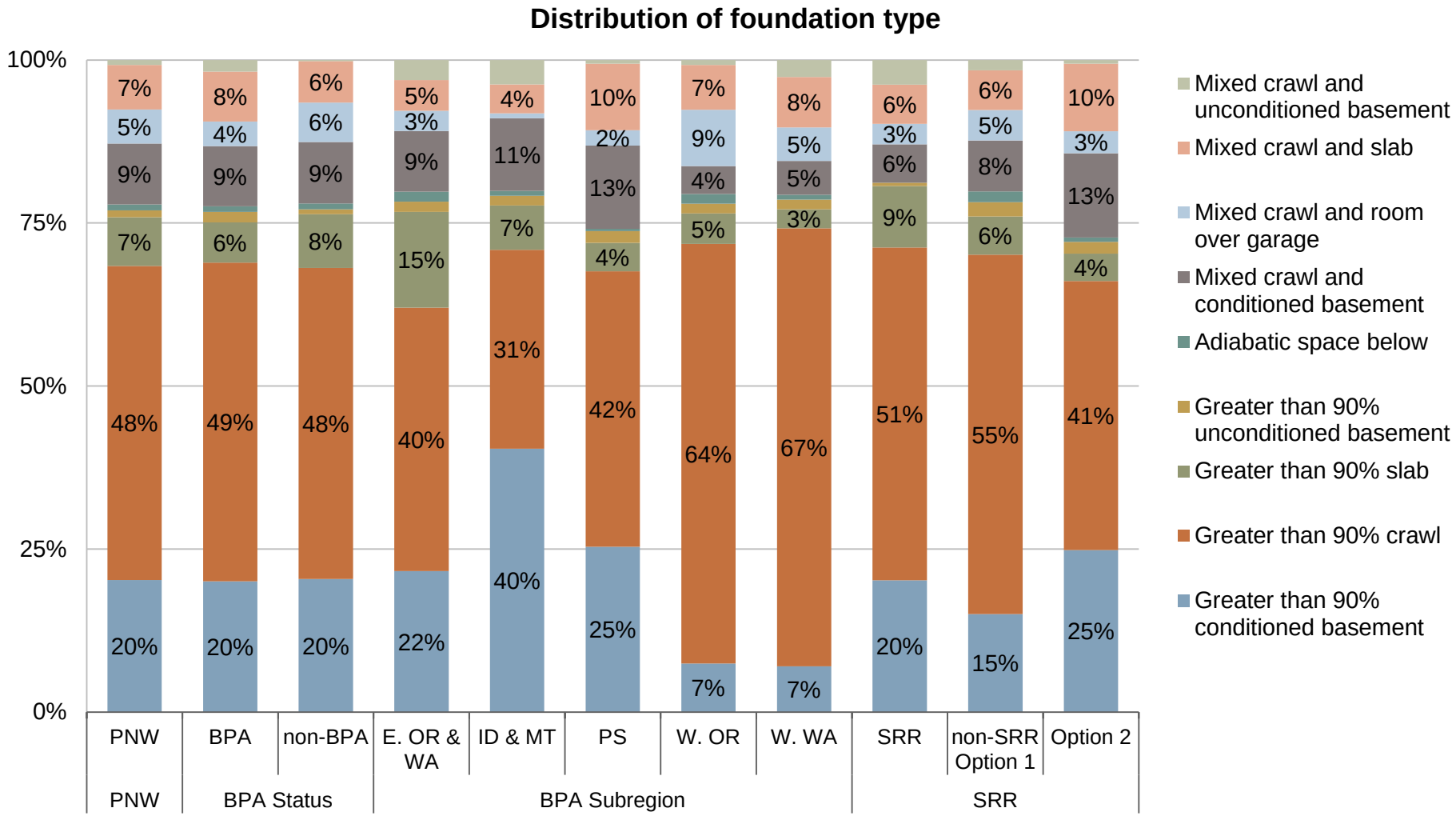
1. Prevalence of ceiling types differ by region. Homes in W. Oregon, Idaho, and Montana have the highest concentration of vaulted ceilings.



(*) Adiabatic ceilings have conditioned space above them. Because the SF sample included homes of up to 4 units but only one unit was visited, some single-family homes have adiabatic ceilings.

SF – Foundation

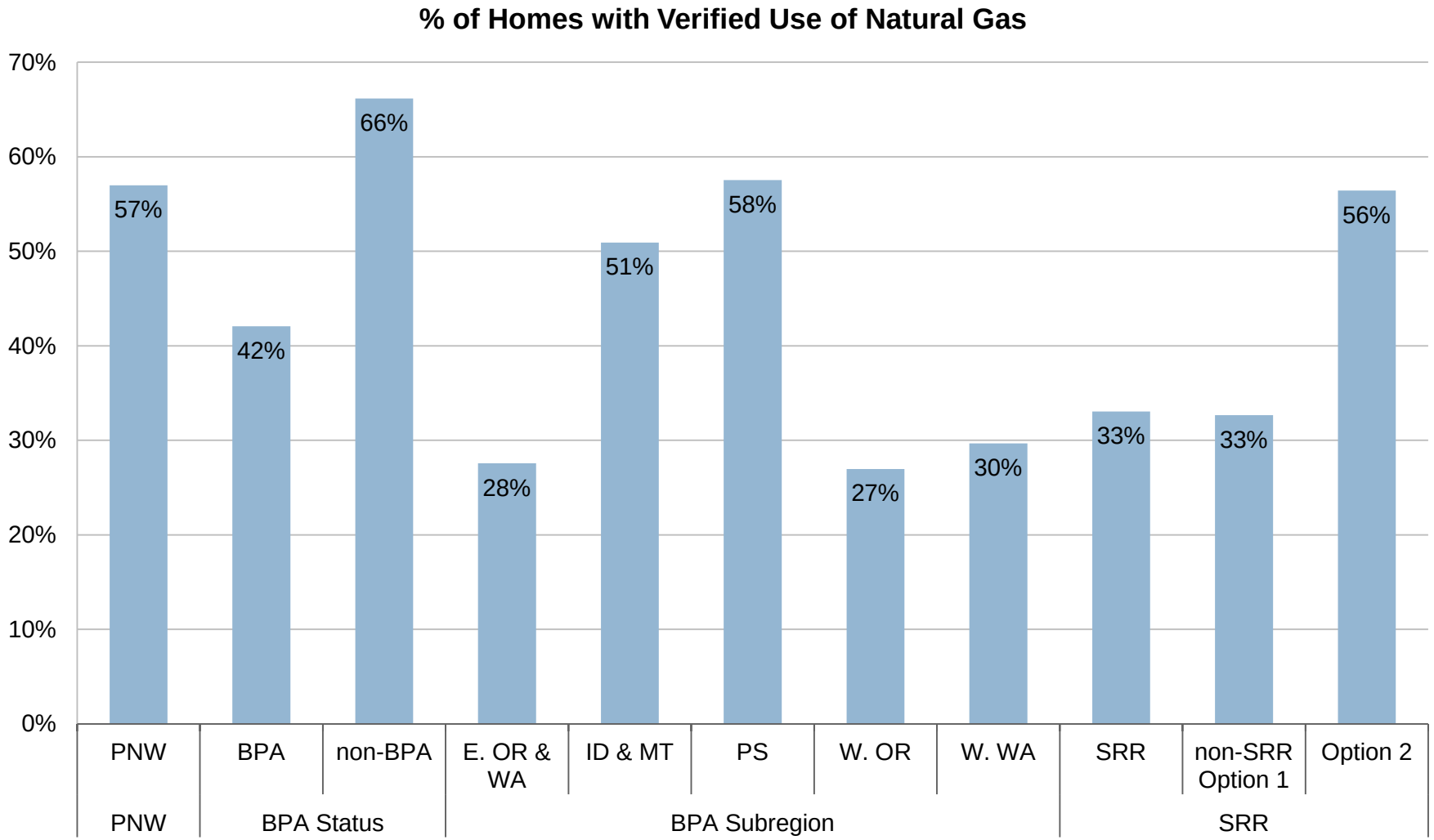
1. The majority of homes in the BPA region have unconditioned crawl space as the foundation.
2. Less than 30% of single-family homes in the BPA region have conditioned basements. The presence of a conditioned basement widely varies by region; conditioned basements are present in more than half of homes in Idaho and Montana, but only in 11-12% of homes in W. Oregon and W. Washington areas.



Note: A conditioned basement is “Greater than 90% conditioned basement” or “Mixed crawl and conditioned basement”.

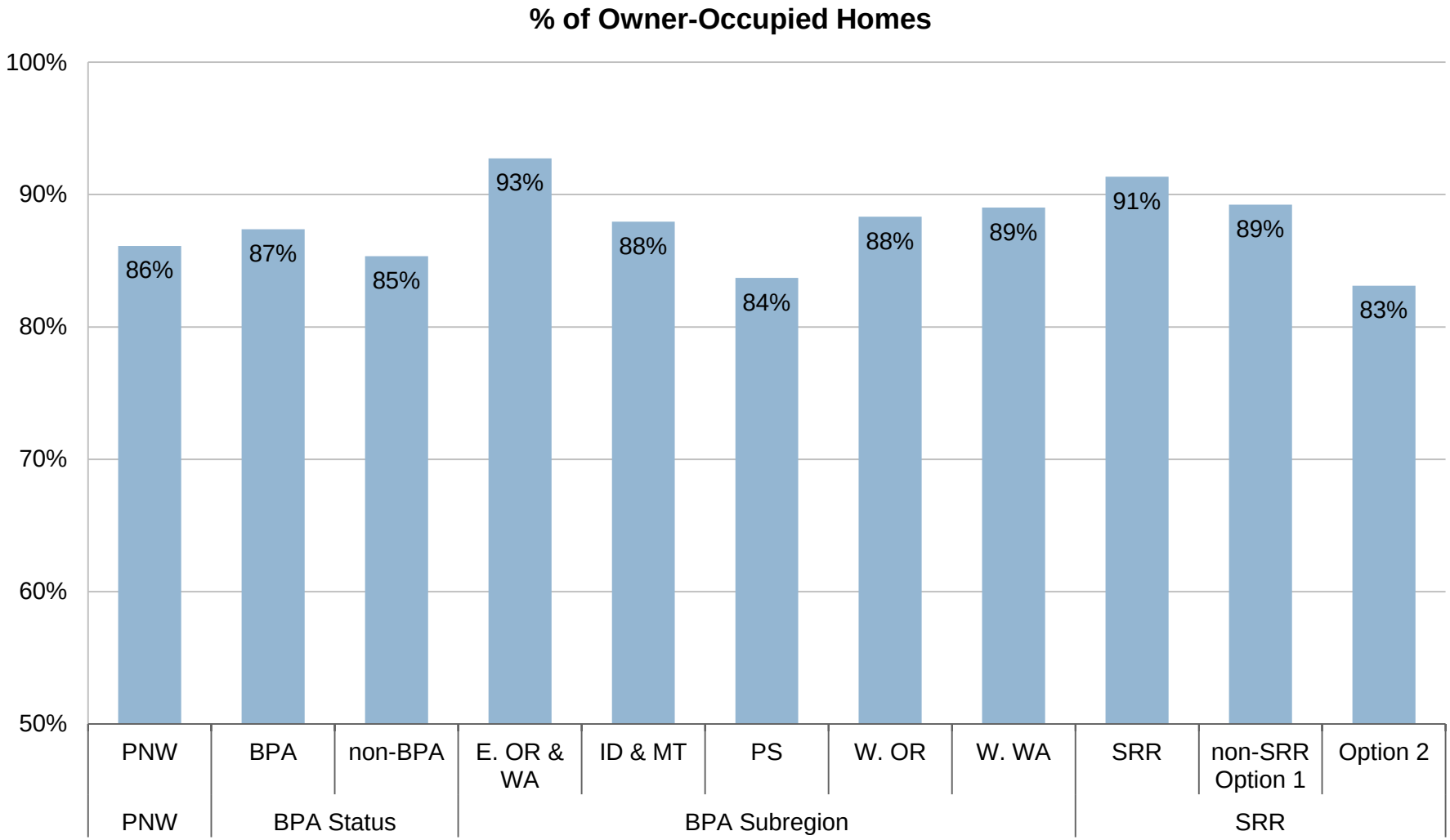
SF – Natural Gas Availability

1. The BPA region has a smaller proportion of homes using natural gas (42%) than in the non-BPA region (66%).
2. The proportion of homes that use natural gas is larger in urban areas (56%) than in rural areas (33%).



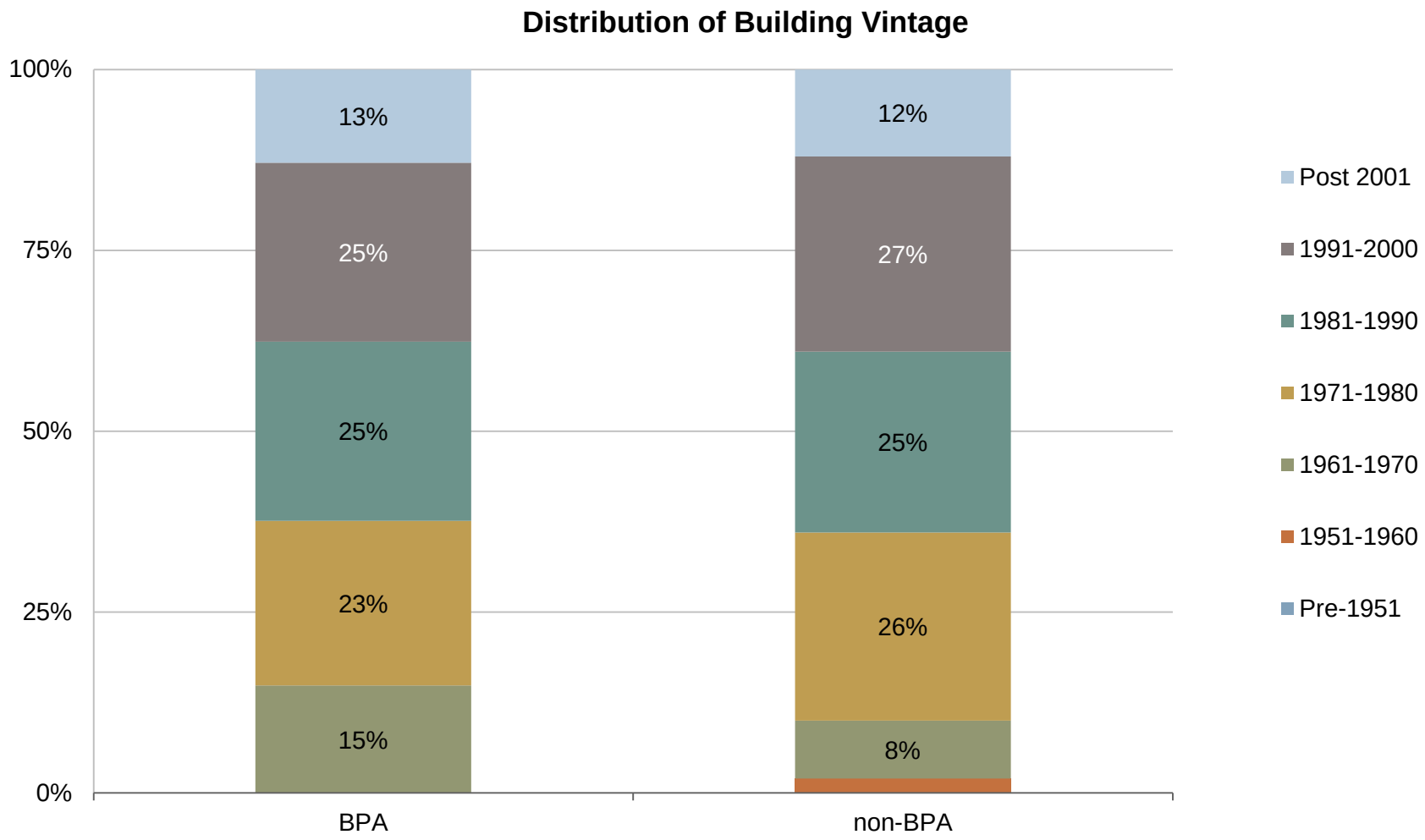
SF – Building Tenure

1. The Puget Sound region within the BPA's service territory has a larger percentage (16%) of non-owner-occupied single-family homes than other regions in the BPA's service territory.



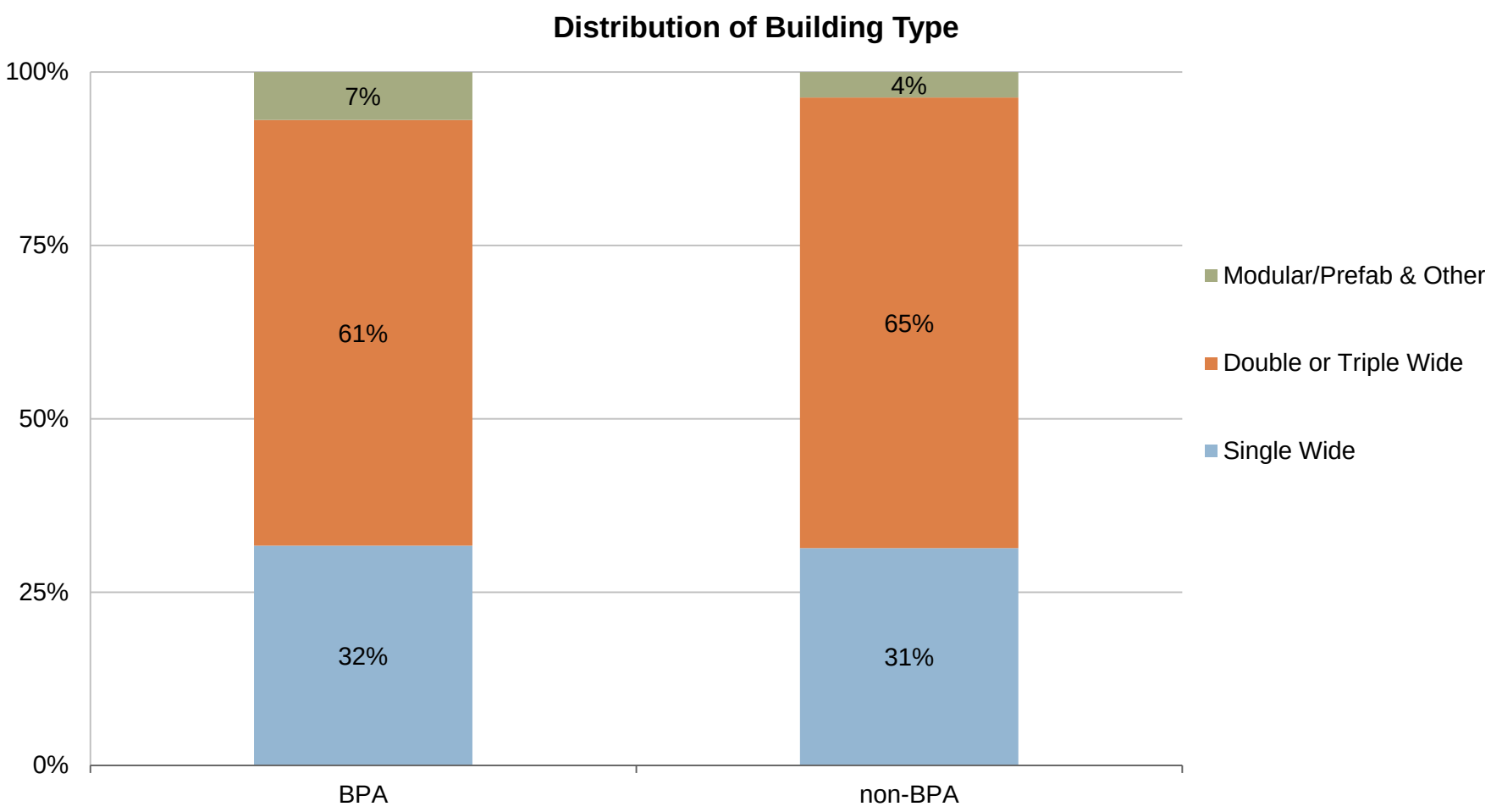
1. Building vintage of manufactured homes in the BPA territory is similar to non-BPA territory.
2. The majority (63%) of manufactured homes in the BPA territory were built after 1980, but only 13% were built post-2001.

MH – Building Vintage



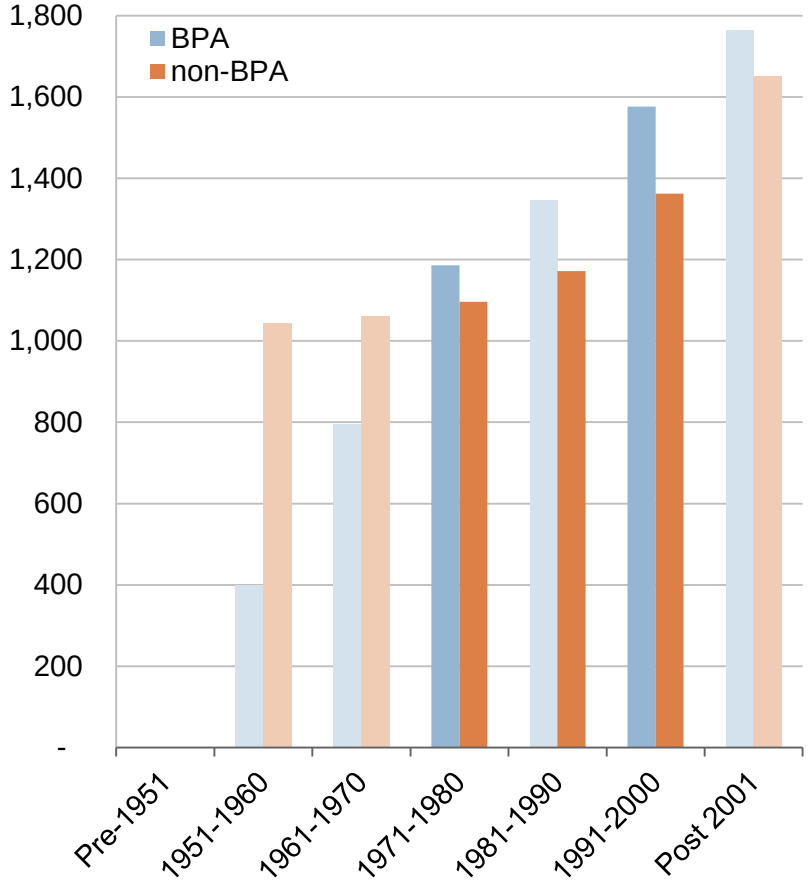
1. Distribution of manufactured building type in the BPA region is similar to non-BPA region.
2. In the BPA region the majority of manufactured homes are double- or triple-wide (61%). Only 7% are modular or prefab homes.

MH – Building Type

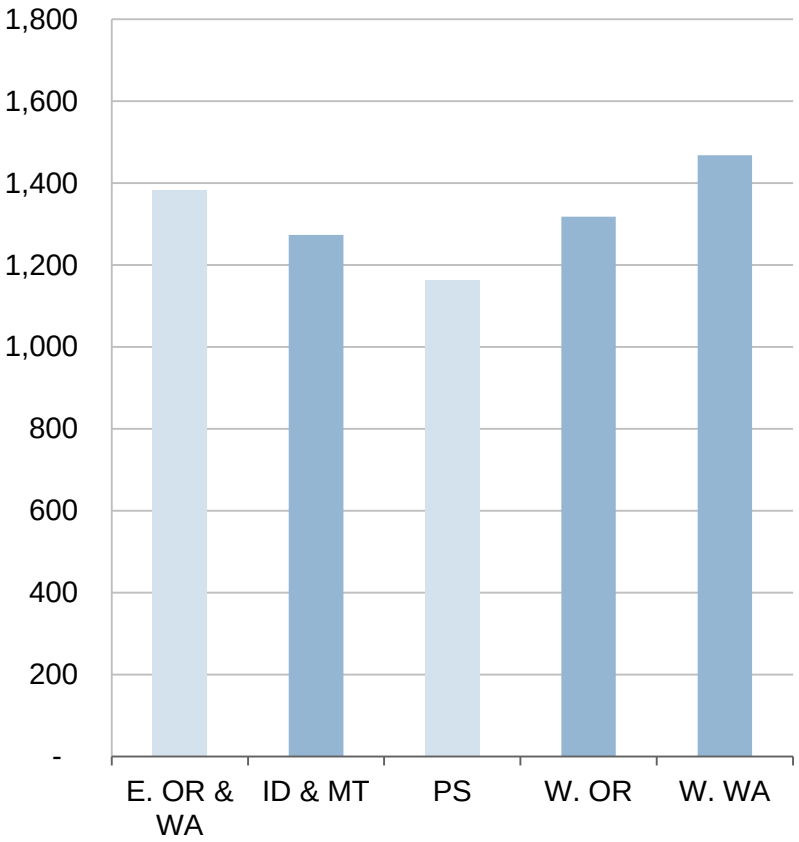


1. Average size of manufactured homes in the BPA region (1,334 SQFT) is larger than non-BPA regions (1,249 SQFT). There is a strong positive correlation between average home size and building vintage. In the BPA territory, average size built after 2001 is more than double 1960's sizes, indicating most of the manufactured homes built after 1981 are double- or triple-wide homes.
2. On average manufactured homes in W. Washington are the largest in size, and smallest in the Puget Sound area.

Average square footage of conditioned space by vintage by BPA status

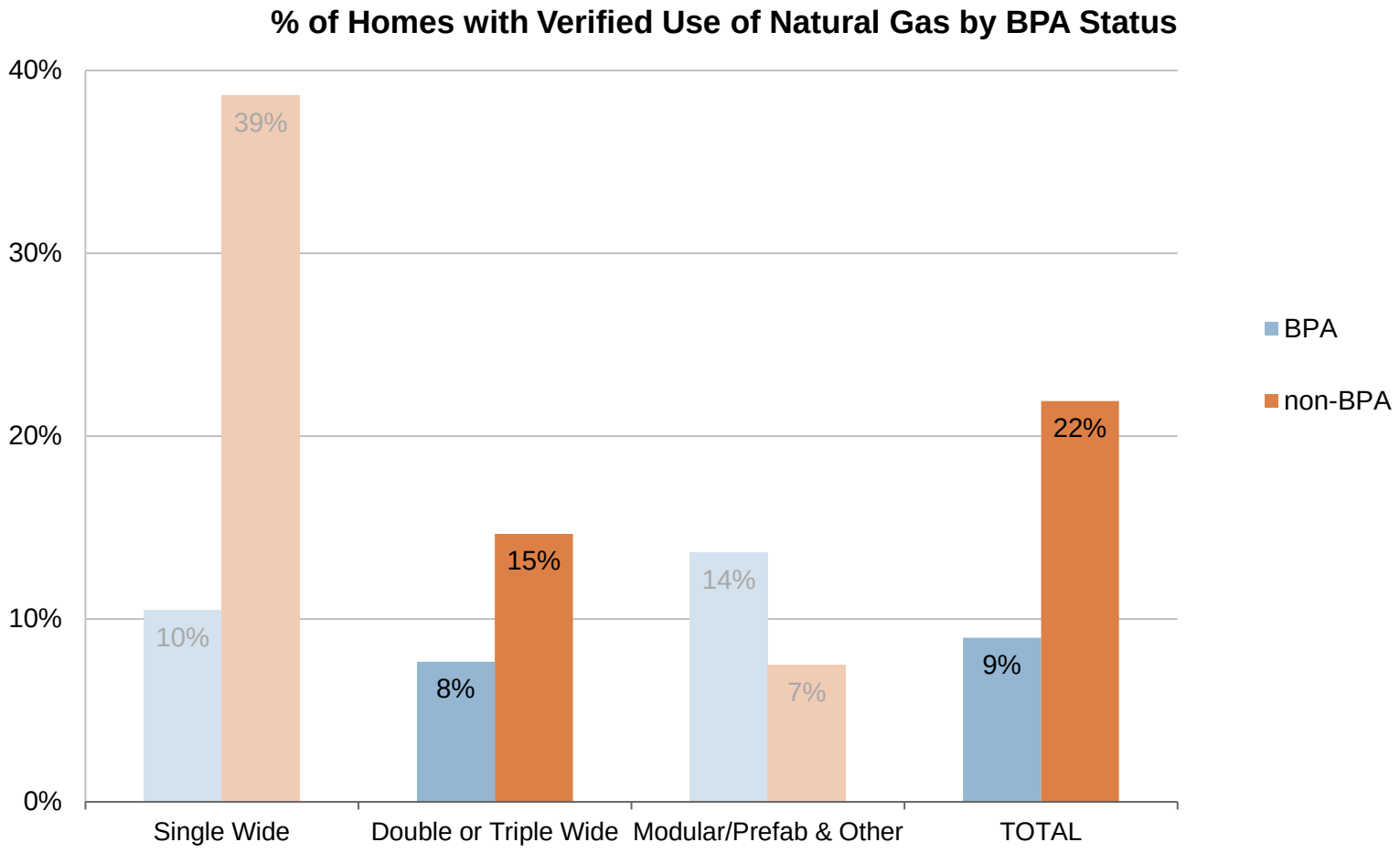


Average square footage of conditioned space by BPA subregion



Note: Shaded color bars indicate small samples (< 30).

1. Manufactured homes are more prevalent in areas where gas is not available (42% of single-family homes in the BPA region use natural gas service). As a whole, natural gas is used only among 9% of the manufactured homes in the BPA region.



Note: Shaded color bars indicate small samples (< 68).

Summary – building characteristics

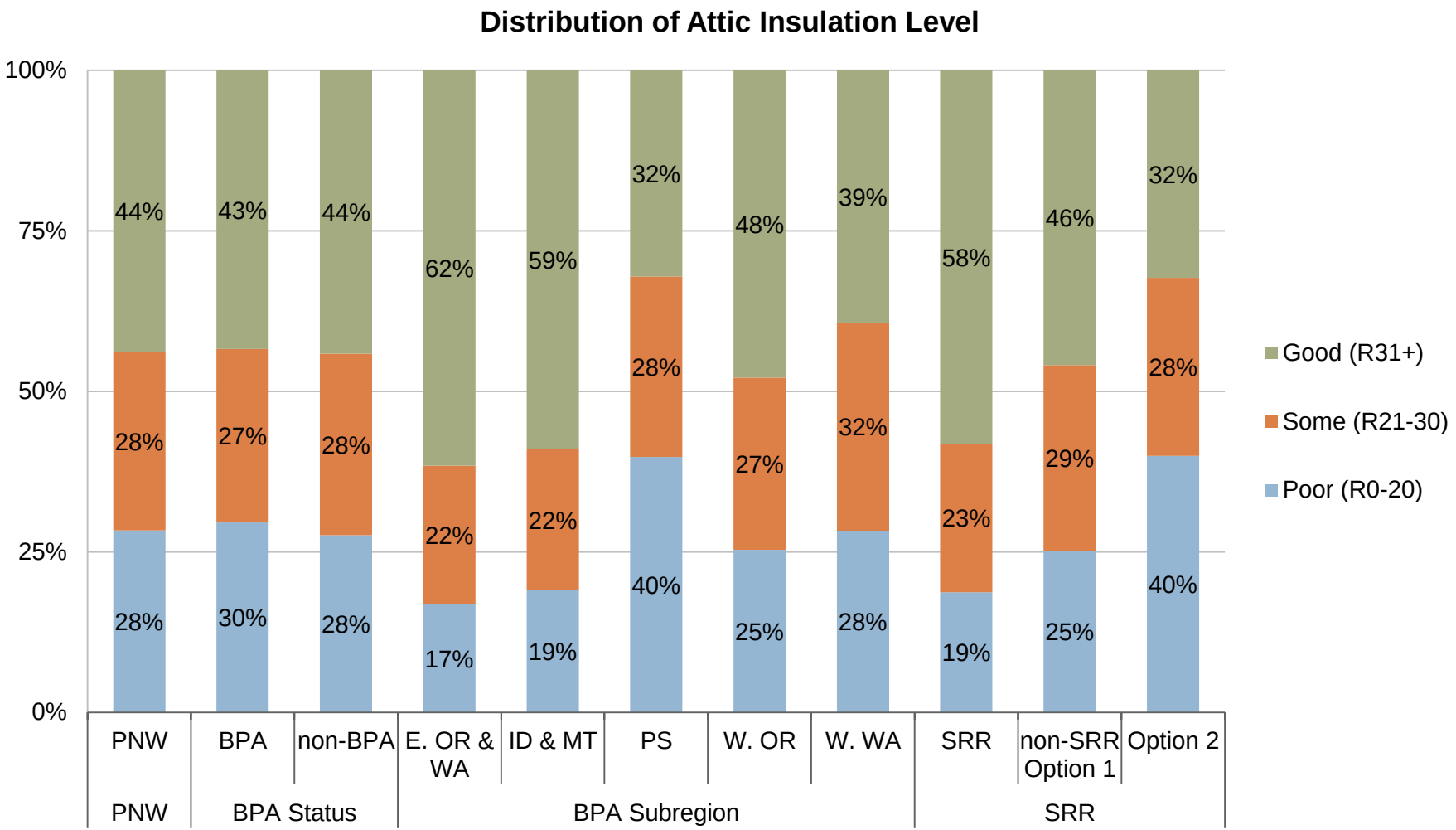
- BPA region as a whole has a higher distribution of older single-family housing stock than in non-BPA regions. In the Puget Sound, 70% of single-family homes were built before 1970 and only 7% after 2000. Nearly 40% of homes in E. Oregon and E./W. Washington, Idaho and Montana were built after 1990.
- Almost 40% of the manufactured homes in the BPA region were built before 1980. This distribution indicates potential for a manufactured home decommissioning program to remove old and inefficient homes from service.
- Among single-family homes, single-family detached is by far the most prevalent. Among manufactured homes, double- or triple-wide are the dominant building type especially among newer vintage homes.
- For both single-family and manufactured homes, newer homes in the BPA region are increasingly larger in size. Comparing homes built before 1951, homes built after 2001 are nearly 1,000 SQFT larger. This is particularly prominent in rural and suburban areas. In contrast, non-BPA region's single-family home sizes are staying relatively constant.
- A majority of single-family homes in the BPA region have attic ceiling type (85%). Vault ceiling is also common in W. Oregon, Idaho and Montana.
- The majority of BPA region homes' foundations are unconditioned crawl space. Less than 30% of single-family homes in the BPA region have conditioned basement. Prevalence of conditioned basement is higher in Idaho and Montana, E. Oregon and Washington, and Puget Sound regions.
- The proportion of natural gas using homes is lower in the BPA region than non-BPA region. Homes in urban regions are more likely to use natural gas. Manufactured homes are more prevalent in areas where gas is not available.
- The Puget Sound region within the BPA territory has the highest rate of non-owner-occupied homes. There may be opportunity to design programs to target these homes for weatherization or heating systems.

Envelope (SF and MH separate)

Areas	Dependent variables	Database
Attic insulation	Distribution of attic insulation level	
Attic insulation	Distribution of attic insulation level by building vintage	
Floor insulation	Distribution of insulation level of floors above crawl spaces among sites without crawl space wall insulation	
Floor insulation	Distribution of insulation level of floors above crawl spaces by building vintage among sites without crawl space wall insulation	
Wall insulation	Distribution of framed wall insulation level	
Wall insulation	Distribution of framed wall insulation level by building vintage	
Window U-value	Distribution of window U-value of wood, vinyl, fiberglass, single pane window	
Window U-value	Distribution of window U-value of wood, vinyl, fiberglass, double pane window	Aggregated U-value in MH
Window U-value	Distribution of window U-value of wood, vinyl, fiberglass, triple pane window	Aggregated U-value in MH
Window U-value	Distribution of window U-value of metal single pane window	Aggregated U-value in MH
Window U-value	Distribution of window U-value of metal double pane window	Aggregated U-value in MH
Window U-value	Distribution of window U-value of metal triple pane window	Aggregated U-value in MH
Window U-value	Distribution of U-value of primary window type	
Blow door test	Distribution of ACH50 (air changes calculated at 50 Pa pressure)	
Blow door test	Average ACH50 by building vintage	

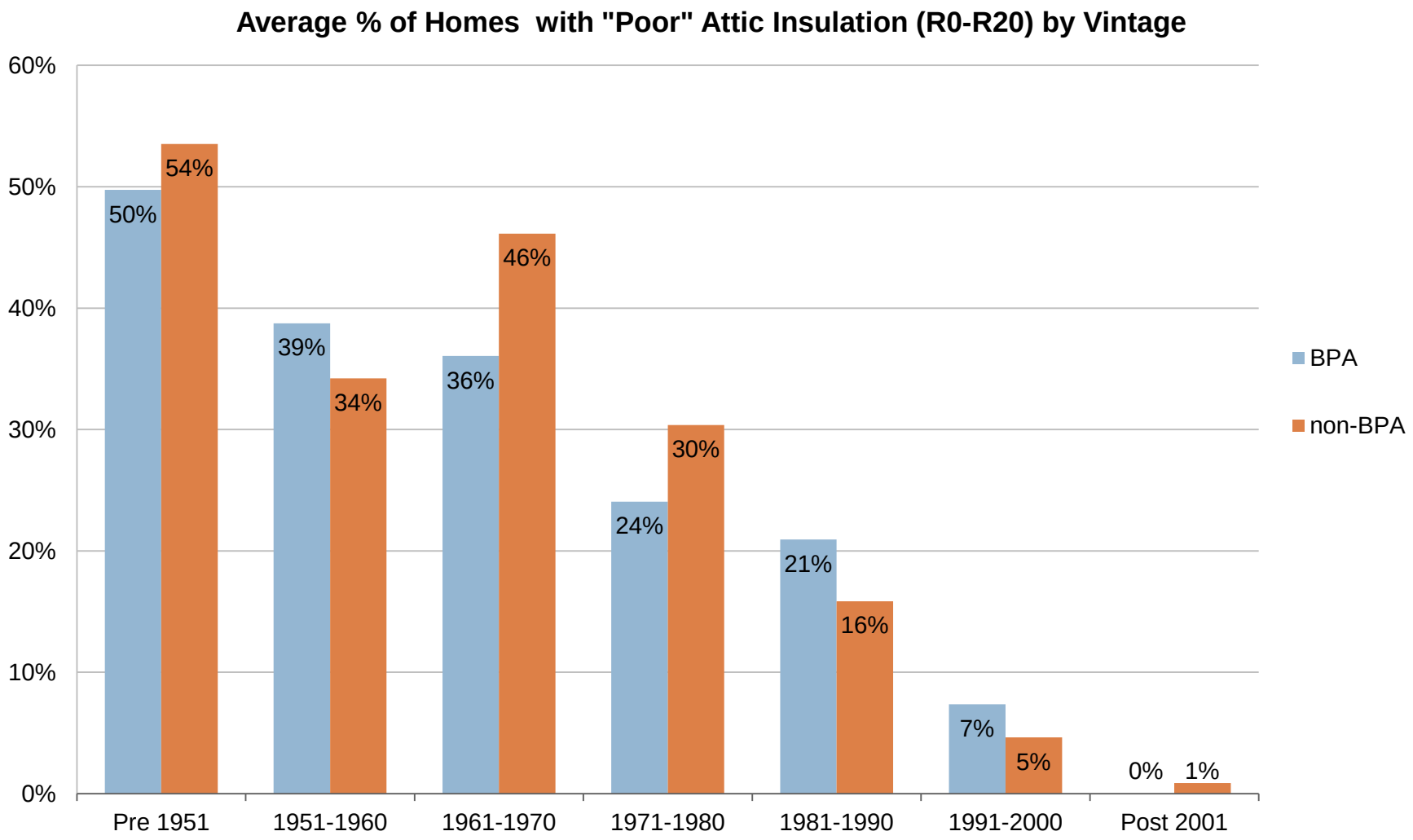
SF – Attic Insulation

1. The proportion of single-family homes that have “poor” attic insulation (R0-R20) is slightly higher in the BPA region (30%) than non-BPA region (28%). Homes in cold climate are more likely to have better attic insulation than milder climate. The Puget Sound region has the highest proportion of homes with “poorly” insulated attics (40%).
2. “Poor” attic insulation is more prevalent in urban areas than rural areas.



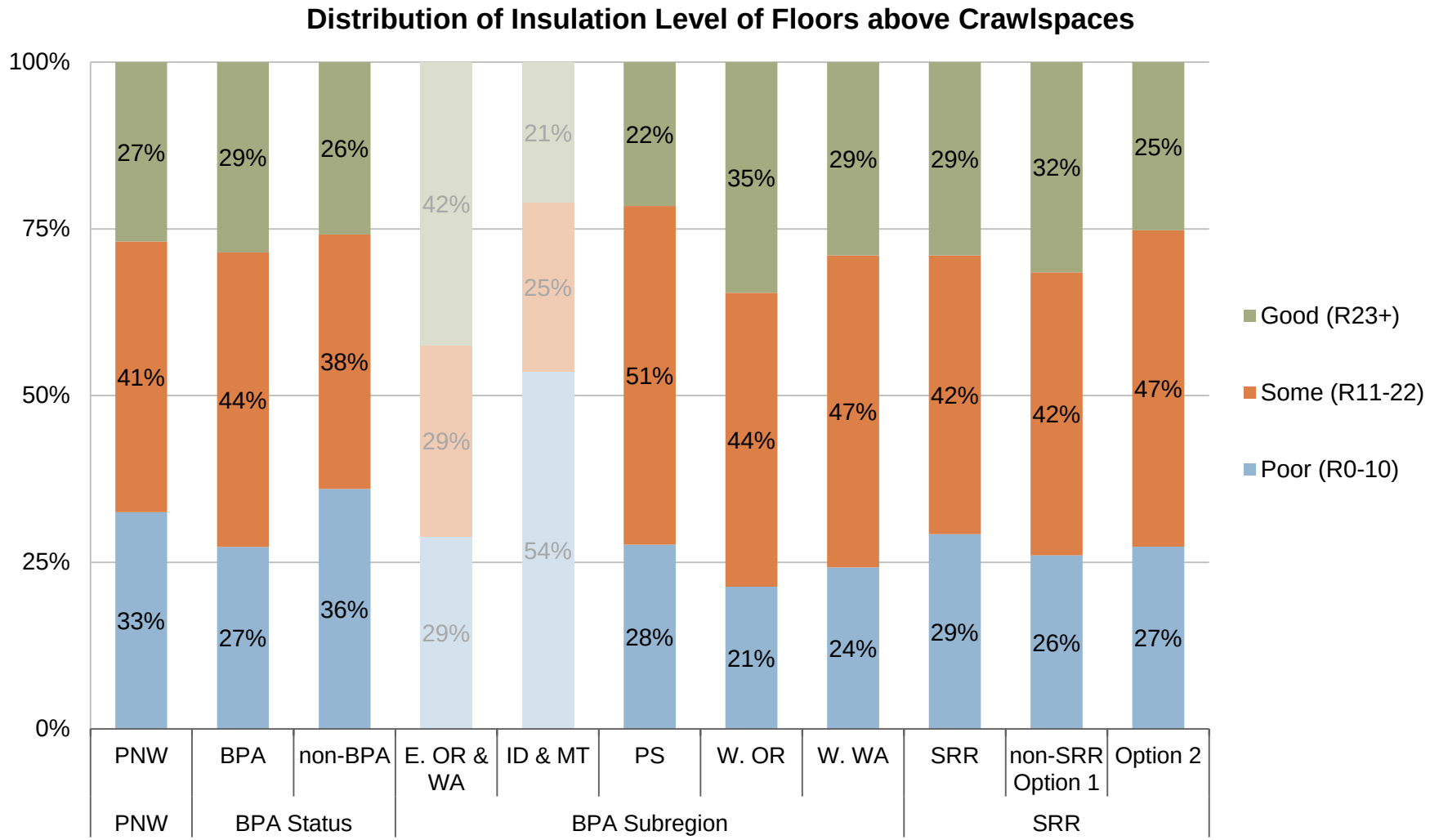
SF – Attic Insulation

1. "Poor" insulation in attics is strongly correlated with building vintage. Half of homes built before 1951 have "poor" attic insulation. Homes built after 1990 are less likely to have "poor" attic insulation.



SF – Floor Insulation

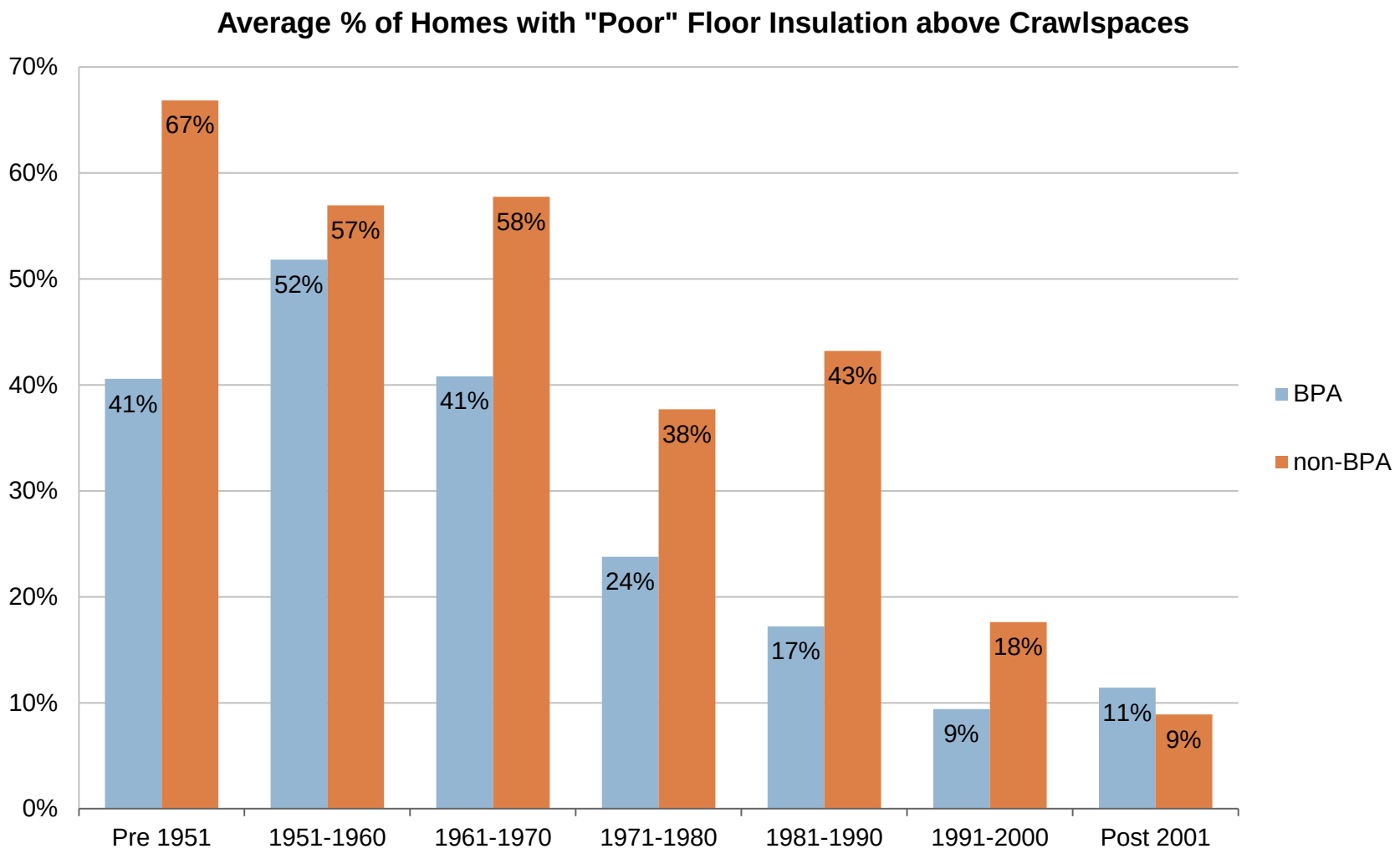
1. 27% of homes in the BPA region have “poor” floor insulation, slightly better than non-BPA regions. There appears to be some remaining potential in the BPA territory for floor insulation.



Note: Shaded color bars indicate small samples (< 68). This analysis is only among the sites without crawl space wall insulation.

SF – Floor Insulation

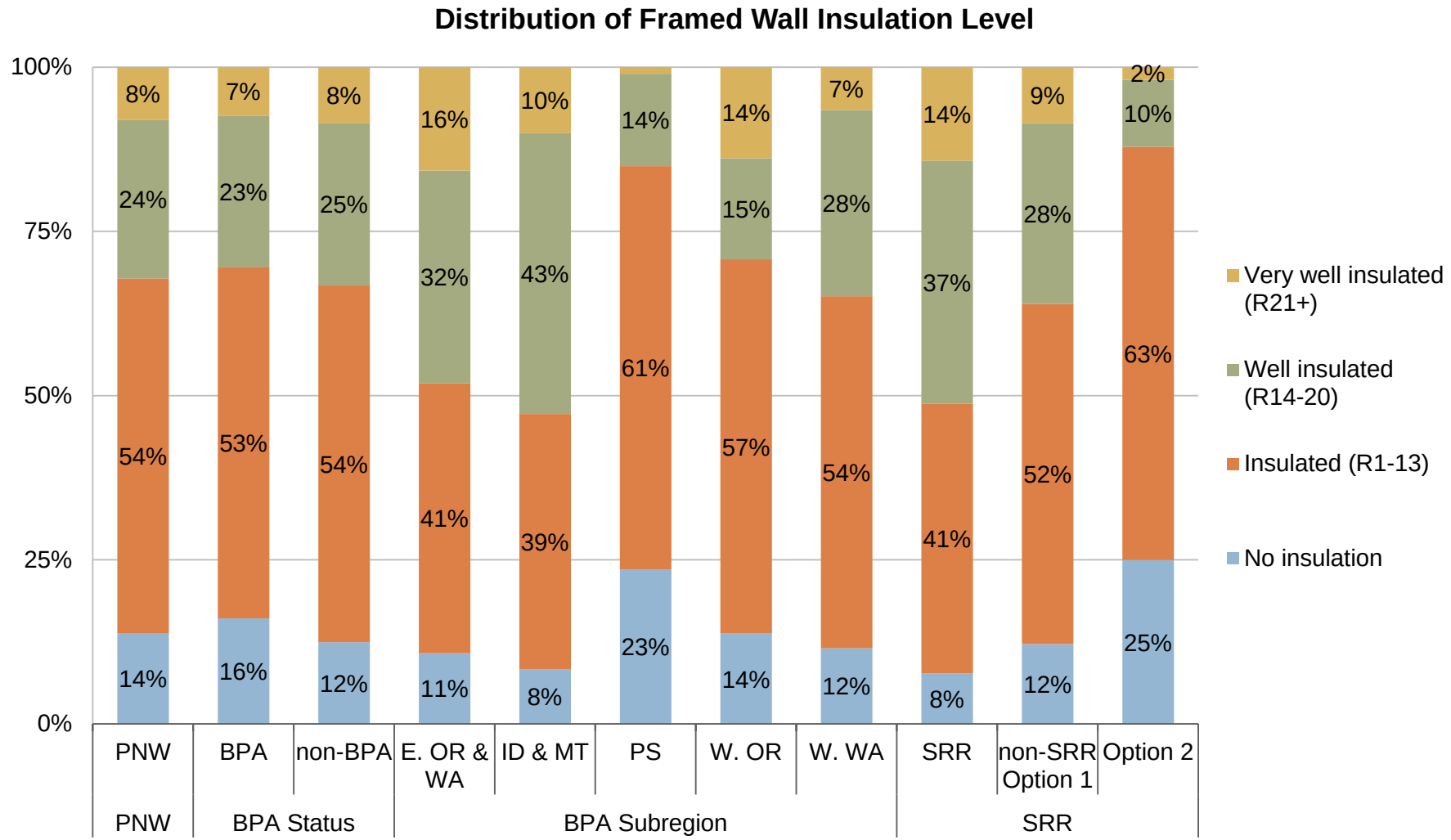
1. "Poor" floor insulation is strongly correlated with building vintage.
2. Homes built before 1980 still have significant remaining potential for floor insulation measures.



Note: This analysis is only among the sites without crawl space wall insulation.

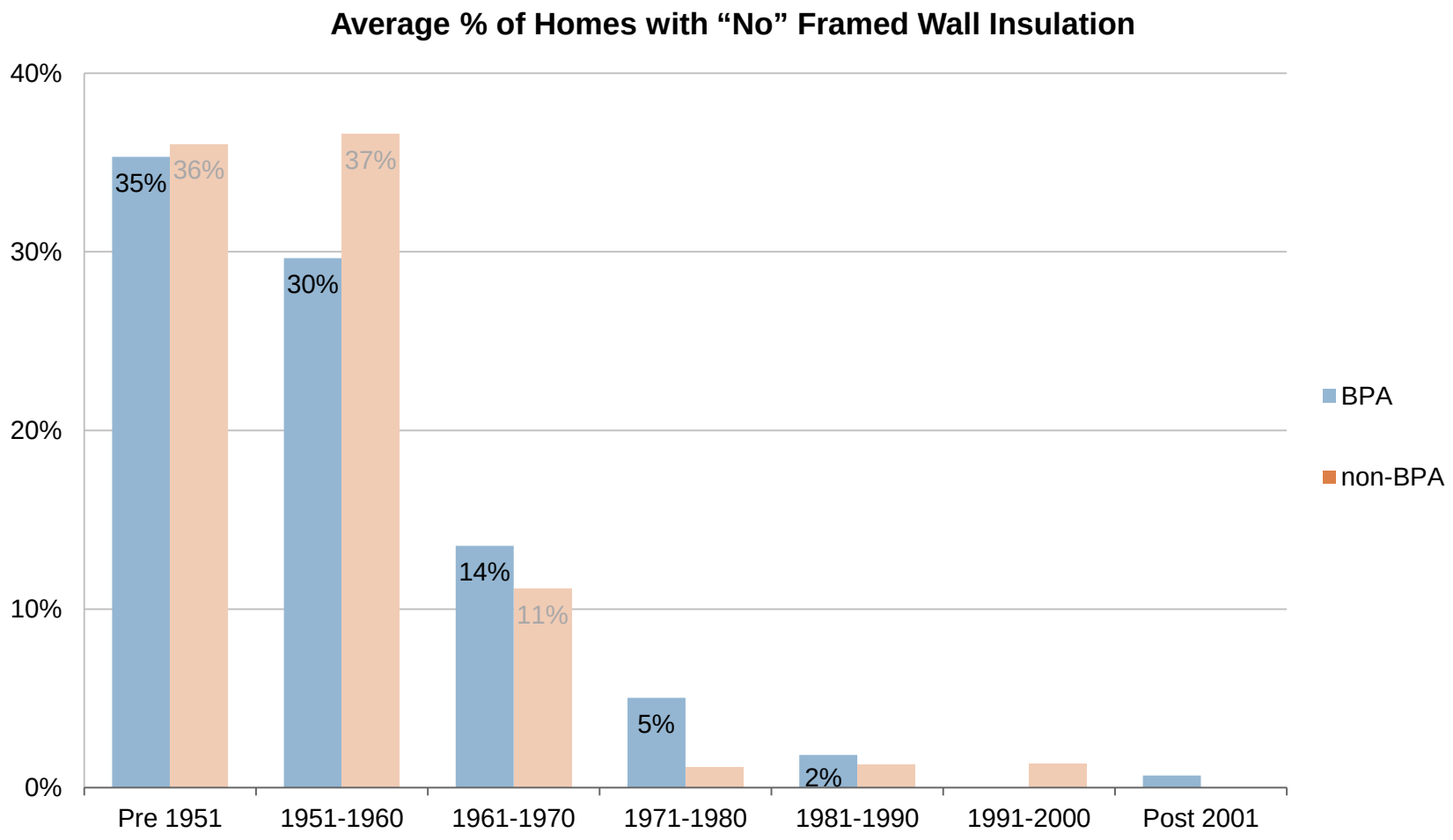
SF – Wall Insulation

1. 16% of single-family homes in the BPA region have walls with no insulation.
2. There is a limited remaining opportunities for wall insulation measures (the Council uses 85% as the achievable potential), except for within the Puget Sound region or urban areas.



SF – Wall Insulation

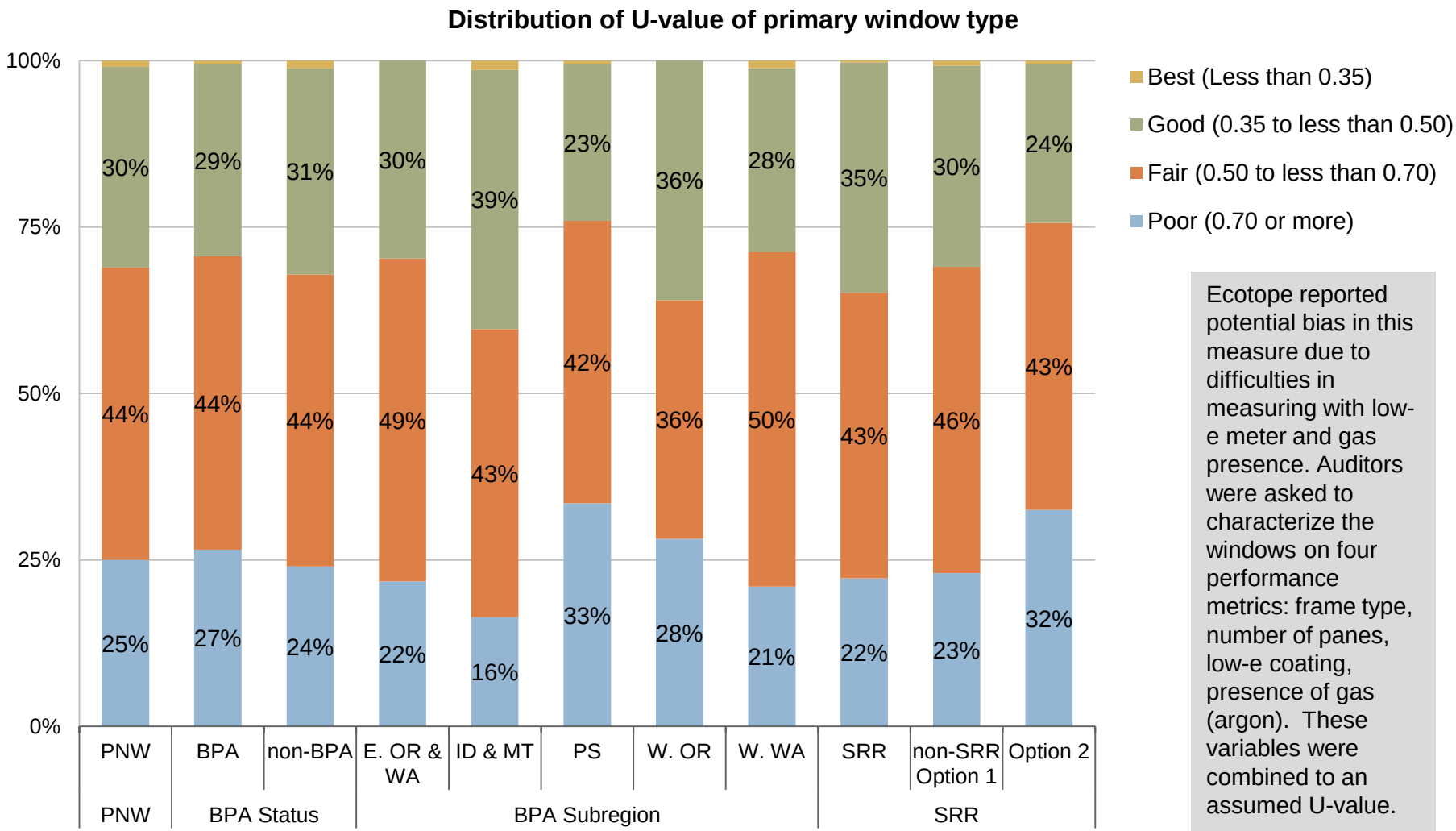
1. There is a strong correlation between building vintage and lack of wall insulation.



Note: Shaded color bars indicate small samples (< 68).

1. Primary windows of more than a quarter (27%) of single-family homes in the BPA region have “poor” U-value*.
2. Significant window replacement opportunities remain especially in Puget Sound or urban regions.

SF – Window U-value

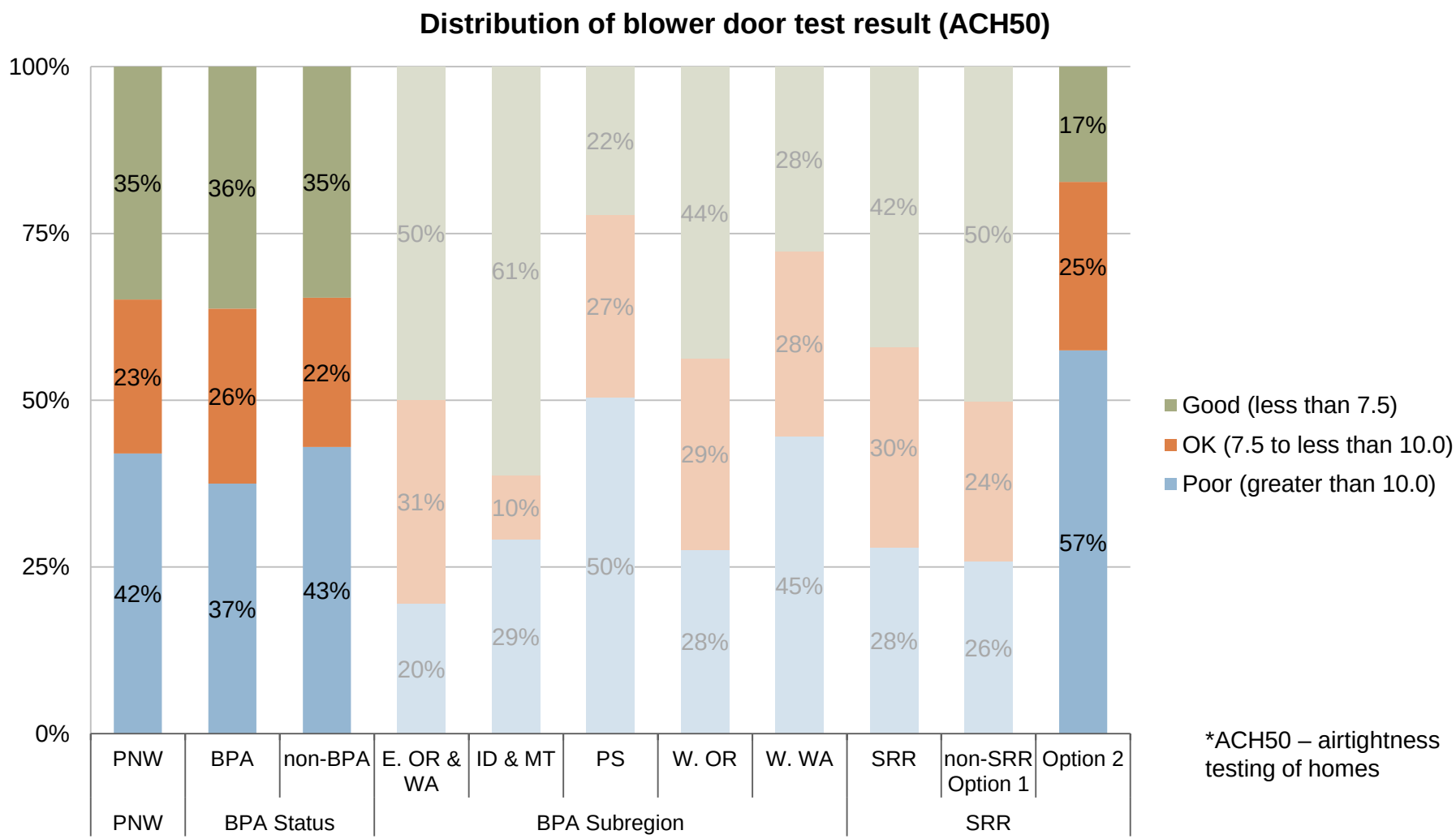


Ecotope reported potential bias in this measure due to difficulties in measuring with low-e meter and gas presence. Auditors were asked to characterize the windows on four performance metrics: frame type, number of panes, low-e coating, presence of gas (argon). These variables were combined to an assumed U-value.

(*) U-value is the measure of the amount of heat (in Btu) that moves through a square foot of window in an hour for every °F difference, typically ranging from 0.20 to 1.20. The lower the U-value, the higher the window’s performance is.

SF – Blow Door Test

1. In the BPA region, 37% of homes have "poor" blower door test result (ACH50* greater than 10.0).

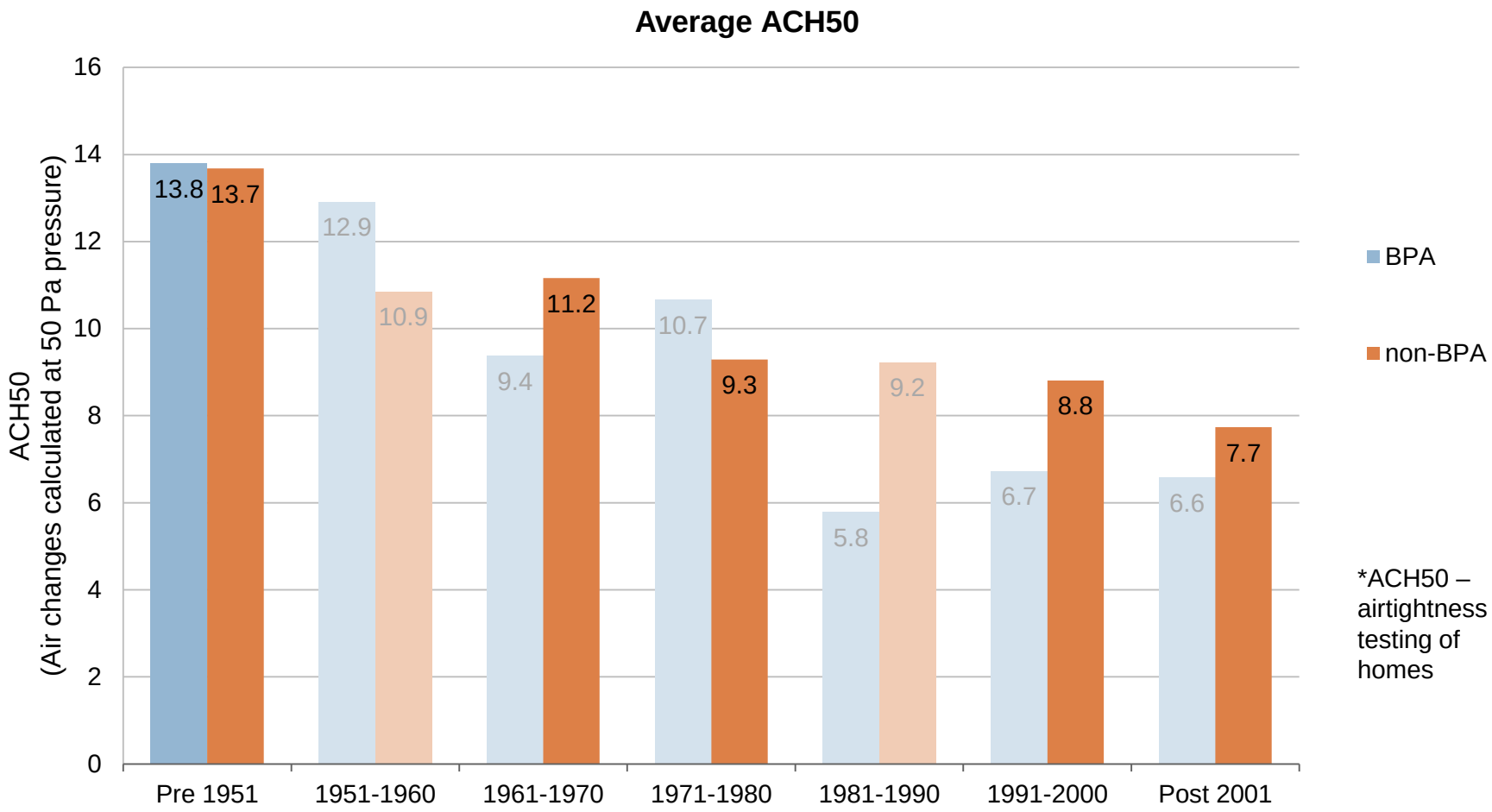


*ACH50 – airtightness testing of homes

Note: Shaded color bars indicate small samples (< 30).

SF – Blow Door Test

1. Average ACH50* is correlated with building vintage.
2. For context, Energy Star for New Homes 3.0 requires ACH50 4.0 or less, and retrofit programs typically target reduction to 7.0 ACH50 or less. There may be some air-tightening opportunities in older homes.

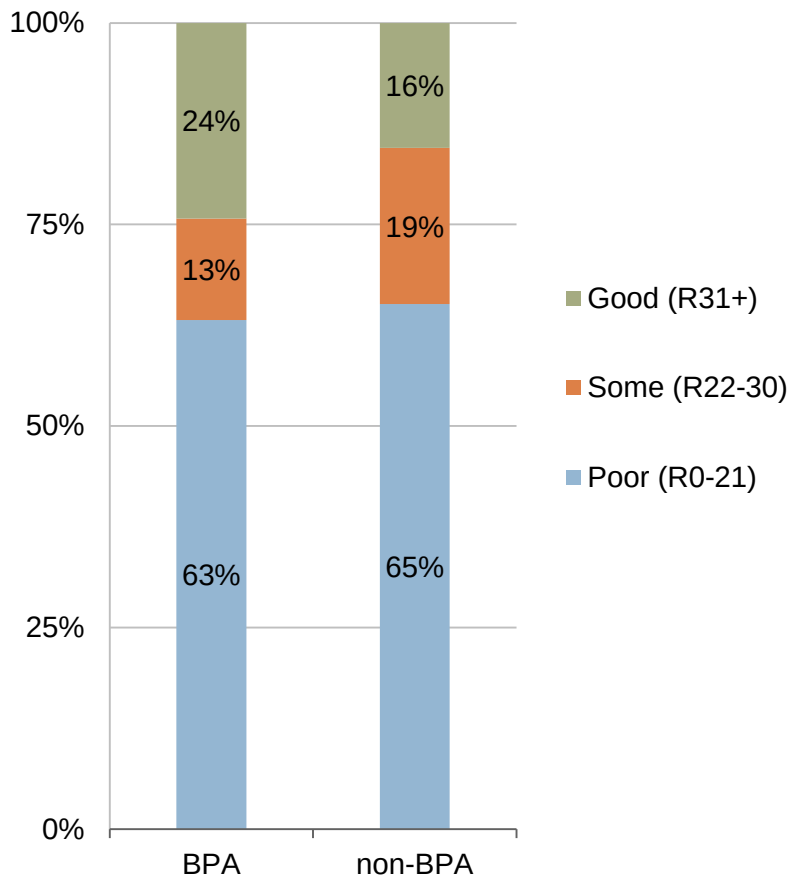


*ACH50 – airtightness testing of homes

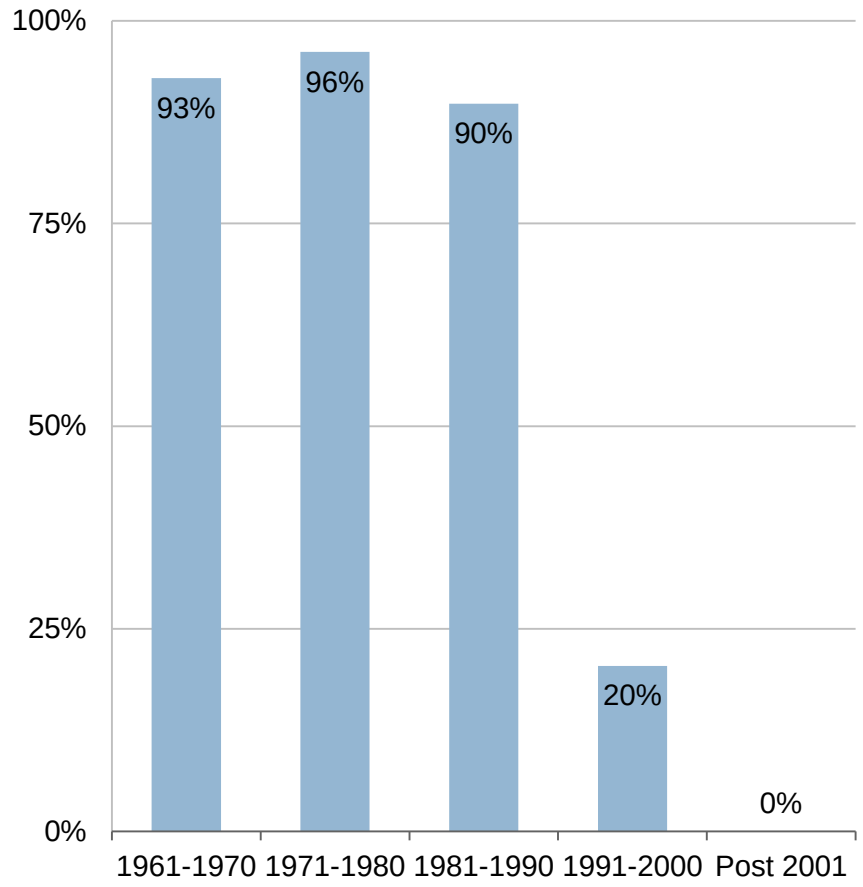
Note: Shaded color bars indicate small samples (< 30).

1. More than 60% of manufactured homes in the BPA region have “poor” attic insulation.
2. “Poor” attic insulation is highly prevalent in manufactured homes built before 1990. Improvements in homes built after 1990 indicate effects of such programs as the Manufactured Home Acquisition Program and Super Good Cents.

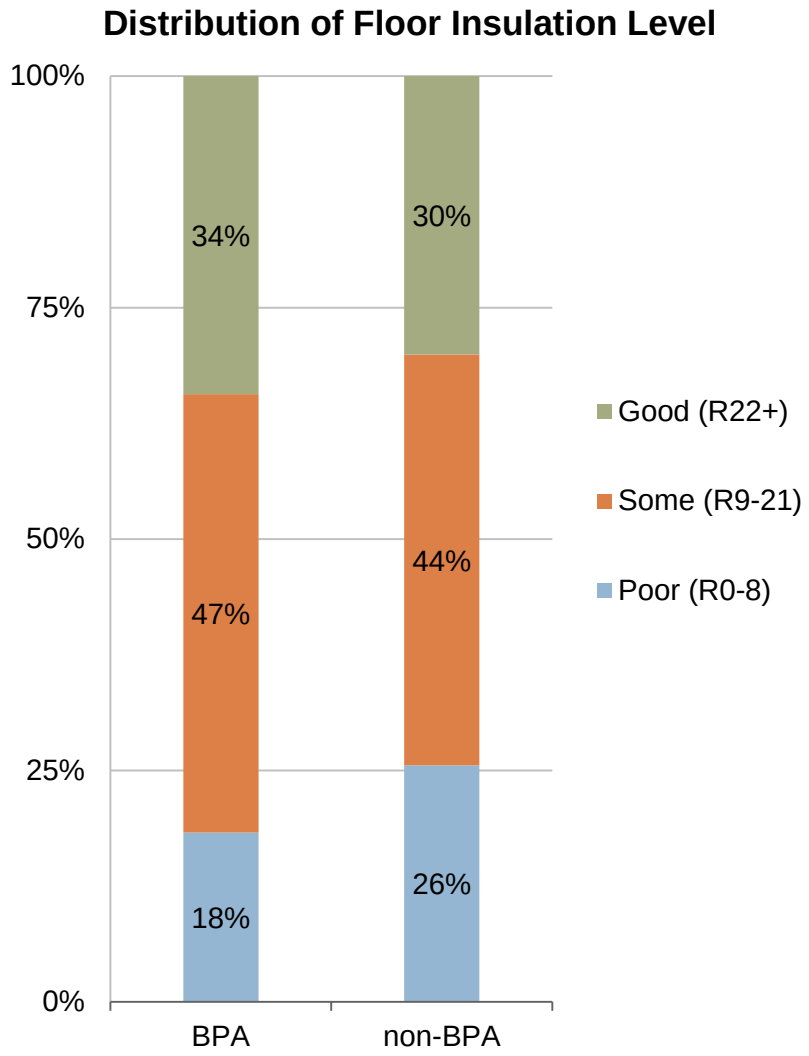
Distribution of Attic Insulation Level by BPA Status

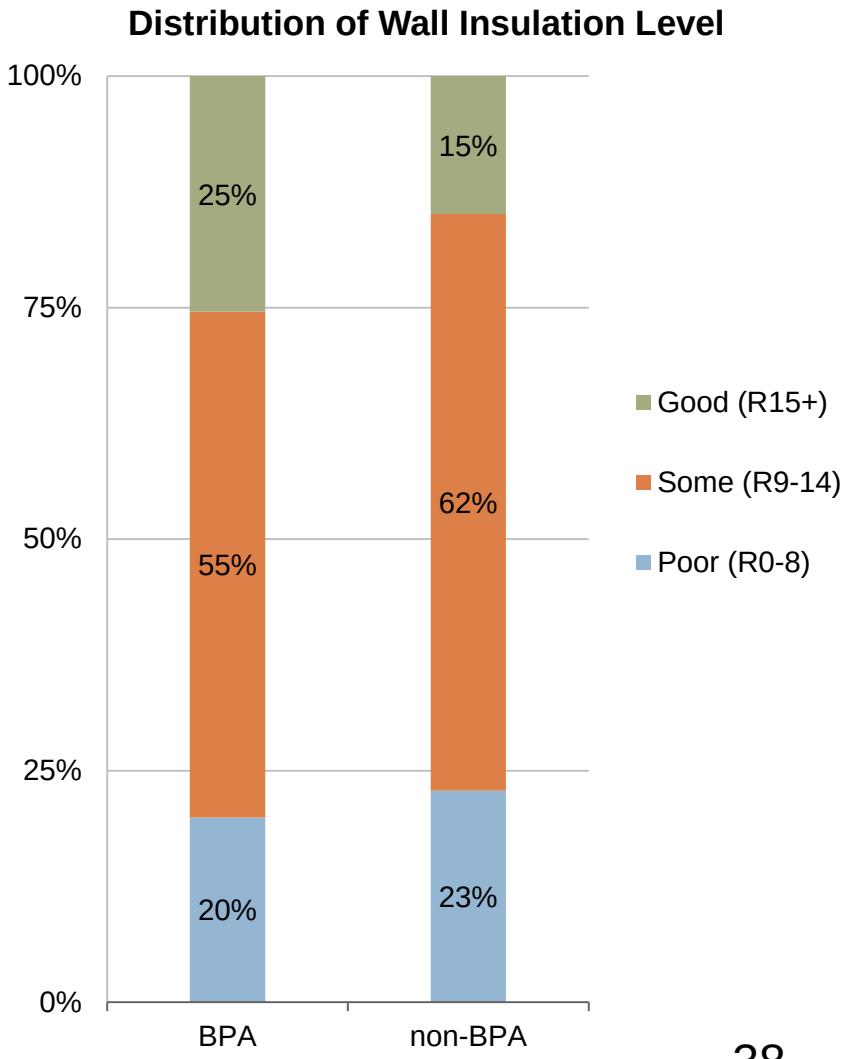


Average % of Homes with "Poor" Attic Insulation by Vintage in BPA Region

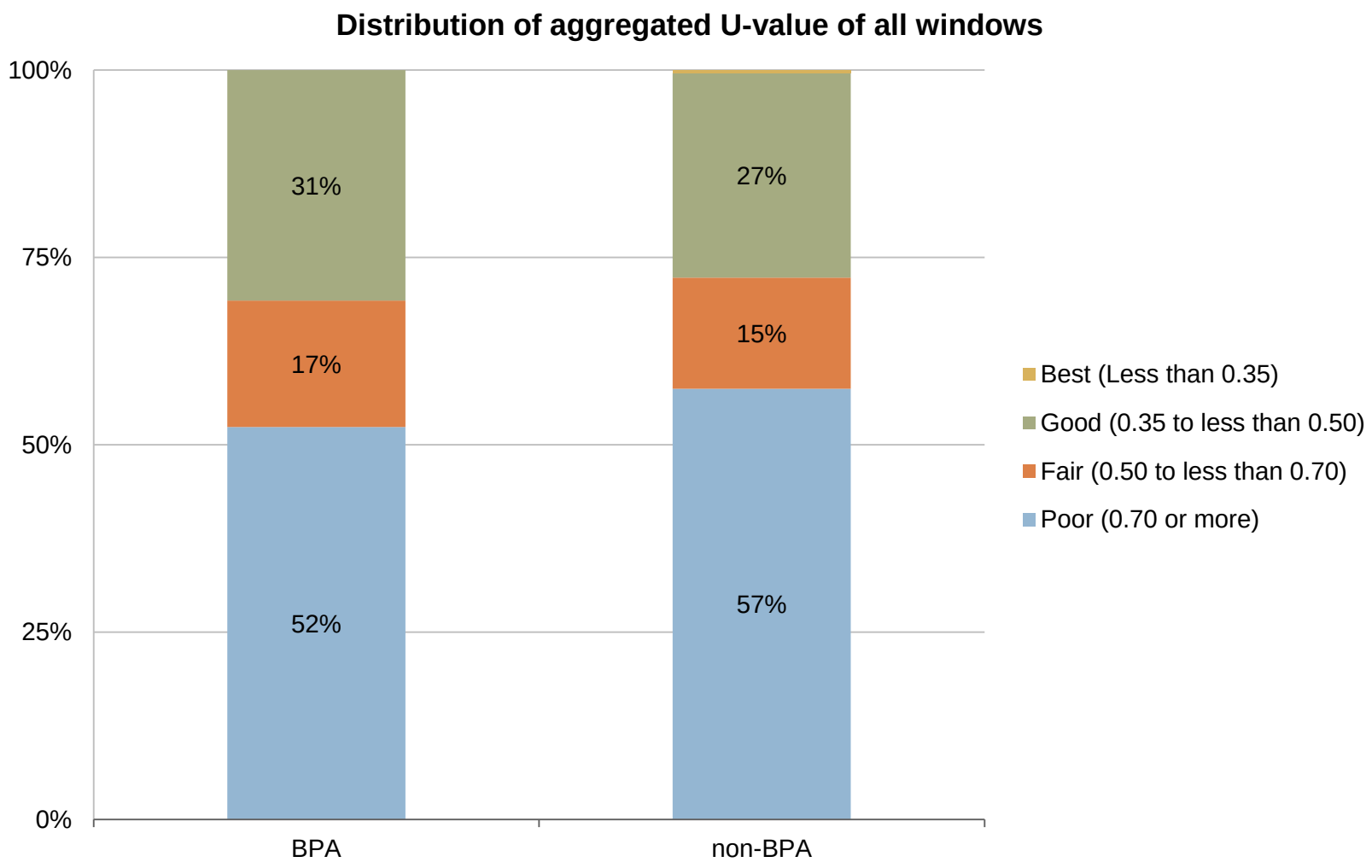


1. In the BPA region manufactured home floors and walls are fairly well insulated. Less than 20% of homes have "poor" floor or wall insulation.

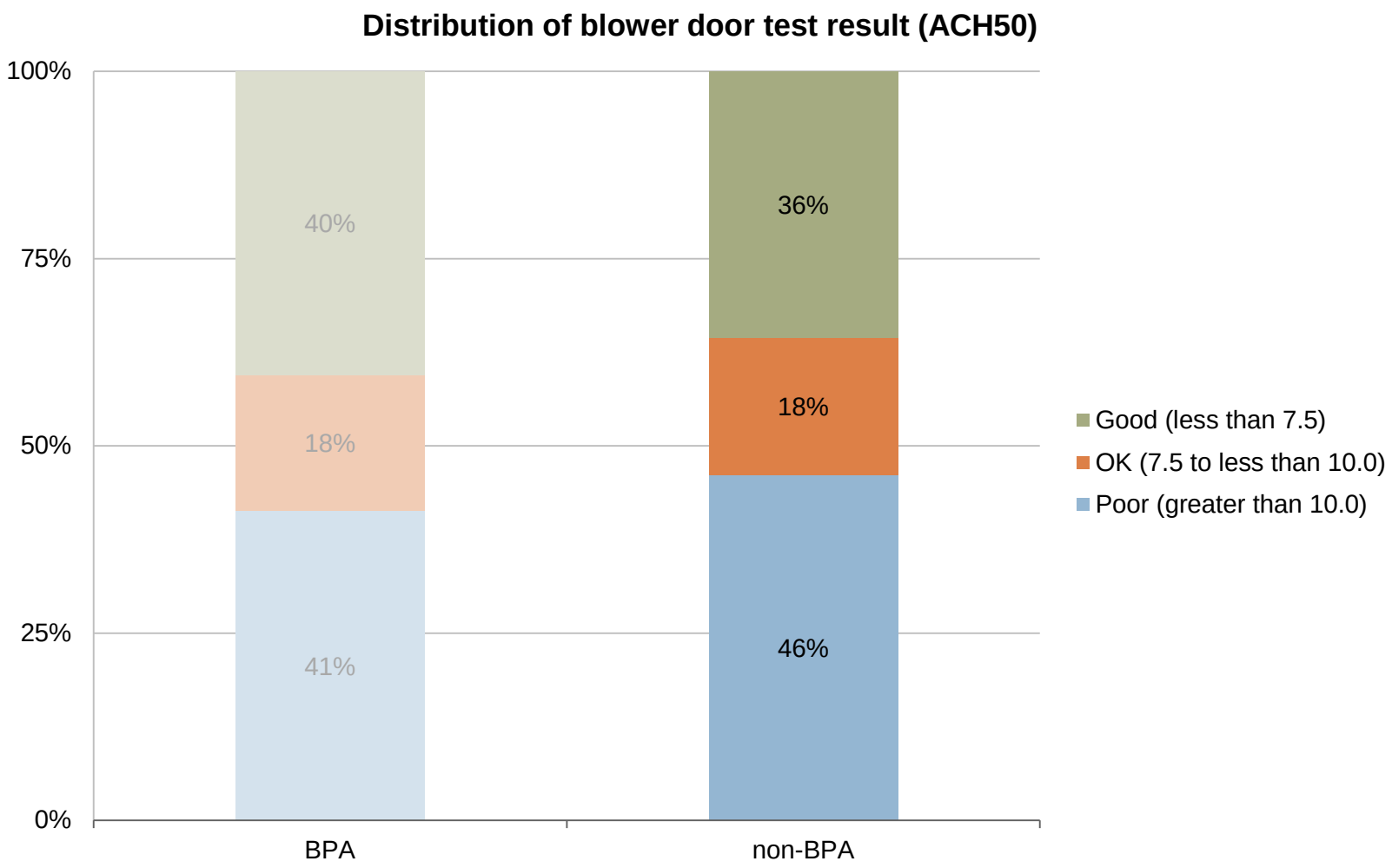




1. Average window u-value of more than half of manufactured homes in the BPA region was rated “poor”.

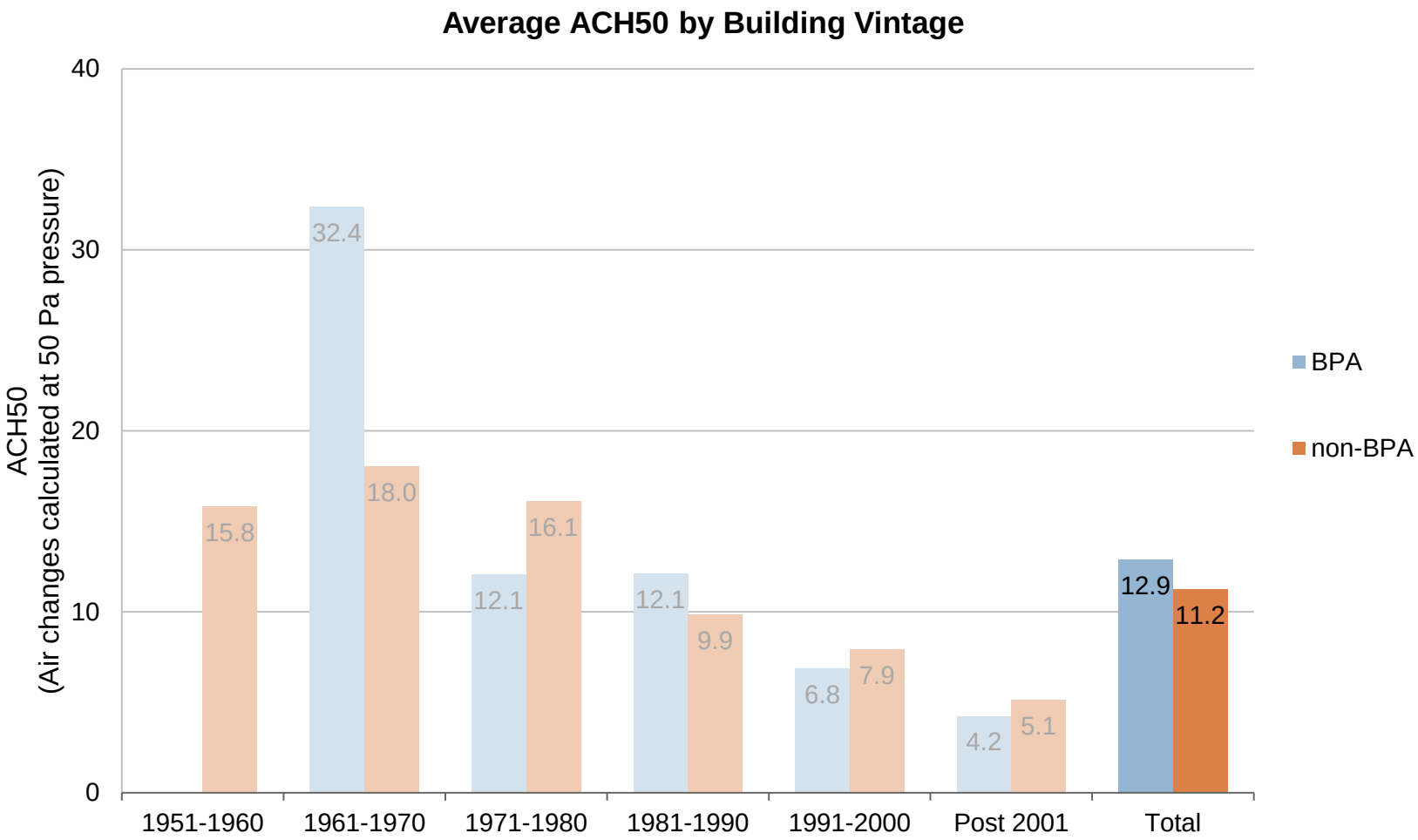


1. 41% of manufactured homes in the BPA region had a “poor” blower door test result (ACH50 greater than 10.0) This inference is limited due to small sample sizes in the BPA region.



Note: Shaded color bars indicate small samples (< 68).

1. Average ACH50 of manufactured homes in the BPA region is 12.9.
2. A fall-off of ACH50 of homes built after 1990 indicate a effect of Super Good Cents standards.
3. For context, Energy Star for New Homes 3.0 requires ACH50 4.0 or less, and retrofit programs typically target reduction to 7.0 ACH50 or less. There may be some air-tightening opportunities in older homes.



Note: Shaded color bars indicate small samples (< 30).

Summary – envelope

- 30% of single-family homes and over 60% of manufactured homes in the BPA region have “poor” attic insulation. There are significant remaining program opportunities for attic insulation measures, but priorities should be in older homes especially within urban areas and the Puget Sound region. Homes built after 1990 have a limited potential.
- 27% of single-family homes in the BPA region have “poor” floor insulation, with the highest concentrations in older vintage homes built before 1980. A vast majority of the remaining opportunities in floor insulation measures lie in homes built between 1961 and 1980. Manufactured homes’ floor insulation opportunity is limited.
- Wall insulation opportunity is limited. Remaining opportunities for wall insulation lie in homes built before 1961.
- Primary windows of more than a quarter of single-family homes (27%) and more than half of manufactured homes (52%) in the BPA region have a “poor” window U-value. Significant window upgrading opportunities remain.
- 37% of single-family homes and 41% of manufactured homes in the BPA region have “poor” ACH50 (above 10.0). 7.0 ACH50 is a typical goal for air sealing. There may be significant weatherization opportunities remaining especially among older vintages.

HVAC (SF and MH separate)

Areas	Dependent Variables	Database
Heating system and fuel	Distribution of primary heating equipment and fuel type	
Heating system and fuel	Distribution of secondary heating equipment and fuel type	
Heating system and fuel	Distribution of heating fuel	
Wood	Average annual reported wood consumption (kBtu)	
Wood	% of homes reporting wood consumption	
Efficiency	Average efficiency of primary heating equipment type/fuel	
Efficiency	Average efficiency of secondary heating equipment type/fuel	SF only
Resistance heat	Average plug-in heater count among sites with plug-in heater	
Resistance heat	% of homes with plug-in heater	
Resistance heat	Average baseboard count among sites with baseboard	SF only
Resistance heat	% of homes with baseboard	SF only
Cooling system and fuel	Distribution of primary cooling equipment type	
Cooling system and fuel	Average SEER of primary cooling equipment	
Cooling system and fuel	Average window AC unit count among sites with window AC	

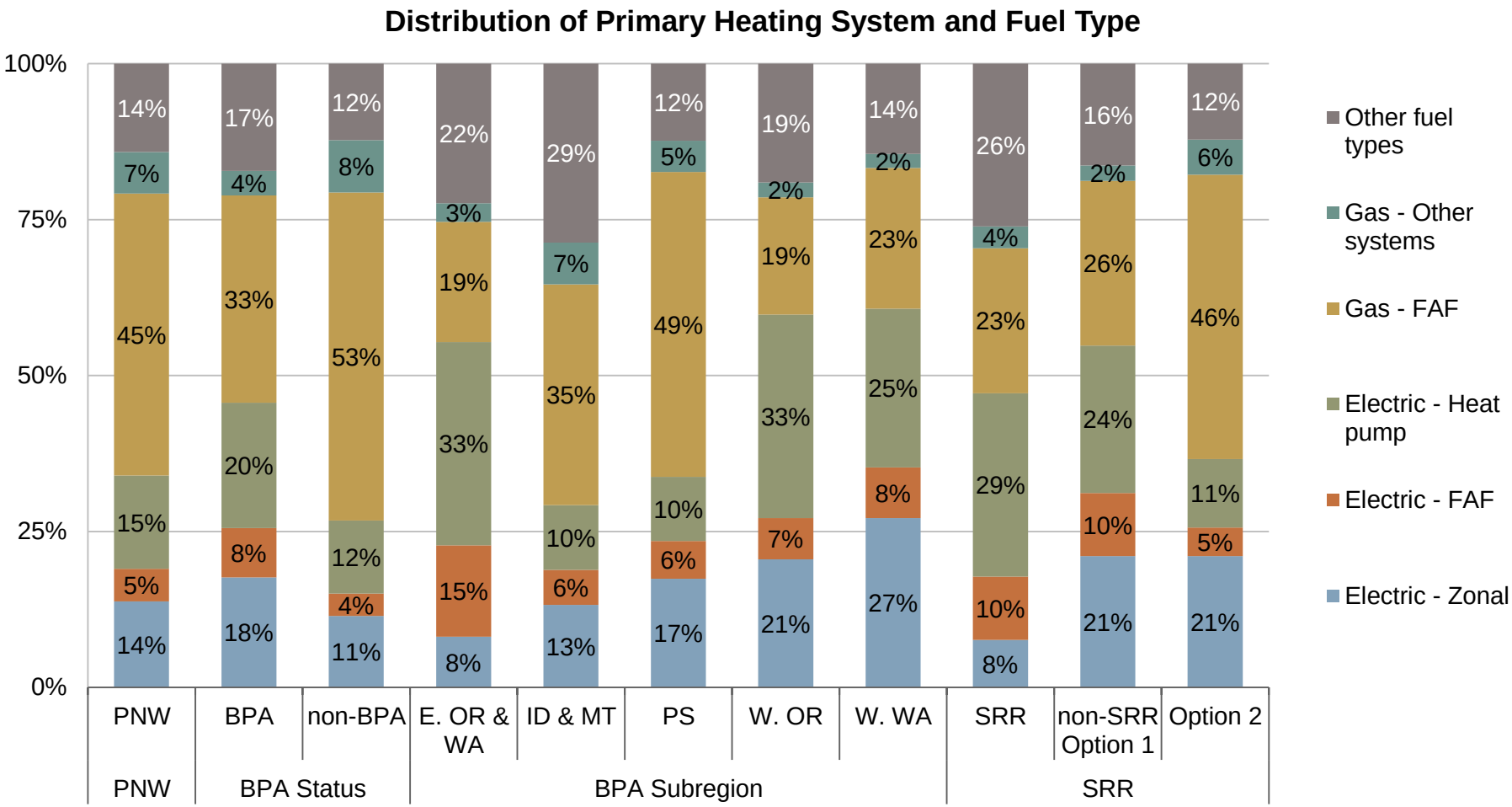
Continued…

HVAC (SF and MH separate)

Areas	Dependent Variables	Database
Ducts	Distribution of duct type by heating climate zone	
Ducts	% of homes with ducted systems with >50% or more supply ducts in accessible unconditioned space by climate zone	SF only
Ducts	% of homes with ducted systems with >50% of supply ducts in conditioned space by climate zone	SF only
Ducts	% of homes with ducted systems with >50% of return ducts in unconditioned space by climate zone	SF only
Ducts	Distribution of space where the majority of return ventilation ducts are located by heating climate zone	
Ducts	Distribution of space where the majority of supply ventilation ducts are located by heating climate zone	
Ducts	Average total unconditioned surface area of all return ducts by climate zone	SF only
Ducts	Average total unconditioned surface area of all supply ducts by climate zone	SF only
Ducts	Average duct leakage to outside, CFM50, by climate zone	
Ducts	Average tested duct leakage ratio at half plenum pressure divided by tested air handler flow rate by climate zone	SF only
Ducts	Average % of good duct condition by climate zone	SF only

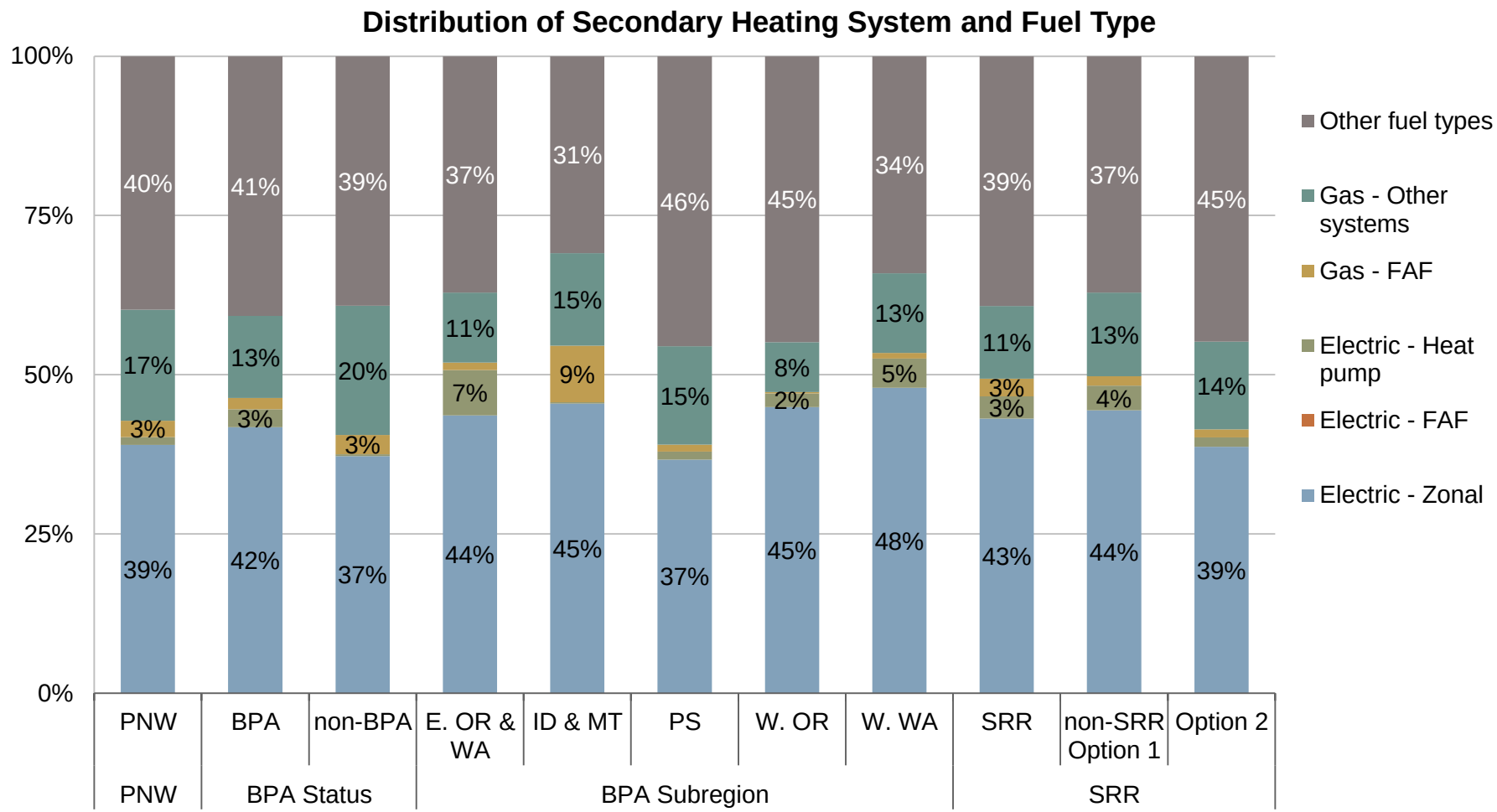
SF – Heating System and Fuel Type

1. Compared to the non-BPA region, the BPA region has more homes whose primary heating system is electric-zonal, electric heat pump, and systems that use fuels other than electricity or natural gas.
2. 46% of BPA region single-family homes use electricity for their primary heating system.
3. A large proportion of rural homes heat their homes primarily with "other" fuel types. In the BPA region, the majority of "other fuel type" systems uses a heating stove (not fire place).



Note: "Electric Zonal" includes baseboard, boiler, and plug-in heaters. "Heat Pump" includes DHP. "Gas – Other systems" includes boiler and stove heaters. "Other fuel types" includes oil-, propane-, pellets-, or wood-based systems.

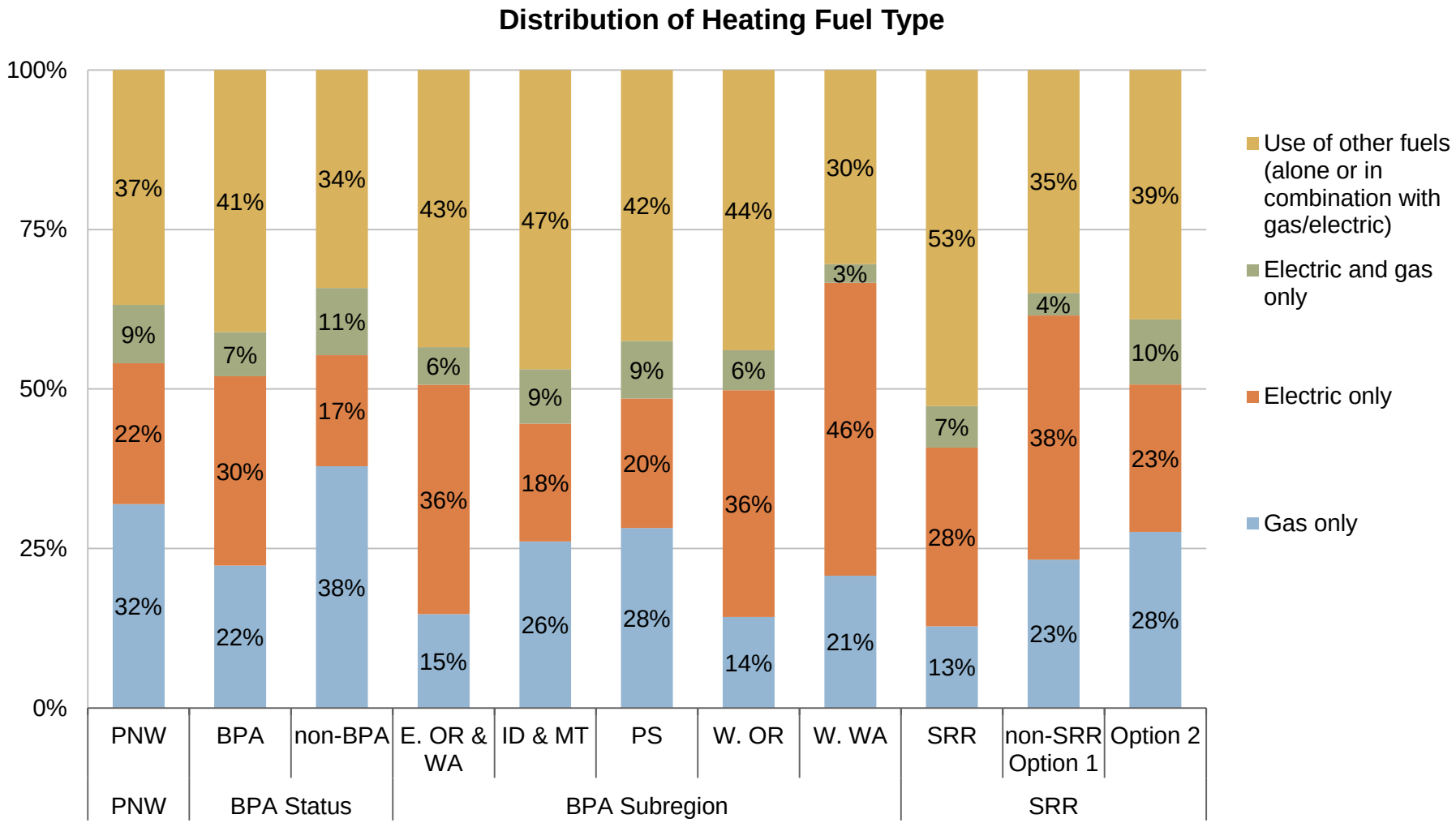
1. In the BPA region, 55% of homes reported at least one secondary heating system.
2. Electric-zonal systems and "Other fuel types" are equally common as secondary heating systems in single-family homes in the BPA region. 13% of BPA region homes use gas based boiler or stove heaters.
3. Presence of "other fuel types" as a secondary heating system is more common in urban areas than in suburban and rural areas. More than 90% of these systems in urban homes are wood stove heaters.



Note: "Electric Zonal" includes baseboard, boiler, and plug-in heaters. "Heat Pump" includes DHP. "Gas – Other systems" includes boiler and stove heaters. "Other fuel types" includes oil-, propane-, pellets-, or wood-based systems.

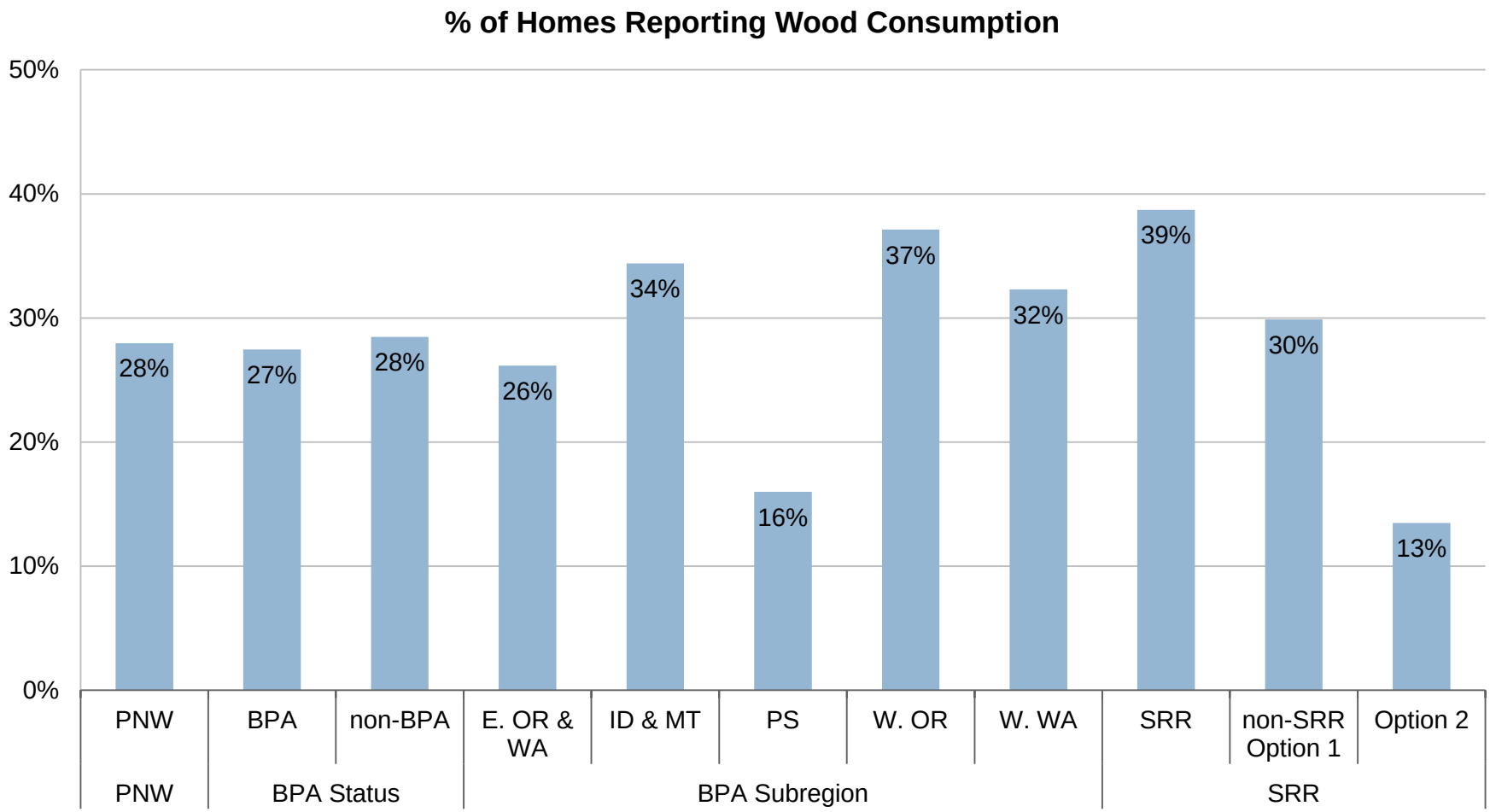
SF – Heating Fuel Type

1. The BPA region has a significantly higher percentage of electric-only heated homes and lower percentage of natural gas heated homes than non-BPA regions. Prevalence of "other" fuels to heat their home is also higher in the BPA region.
2. In BPA region, electric heat is more prevalent in suburban and rural areas than in urban areas. More than half of rural homes use "other" fuel types as primary and/or secondary heating systems.



Note: Categories are mutually exclusive. "Use of other fuels" includes other fuel alone and in combination with electric and or natural gas. This includes both primary and secondary systems.

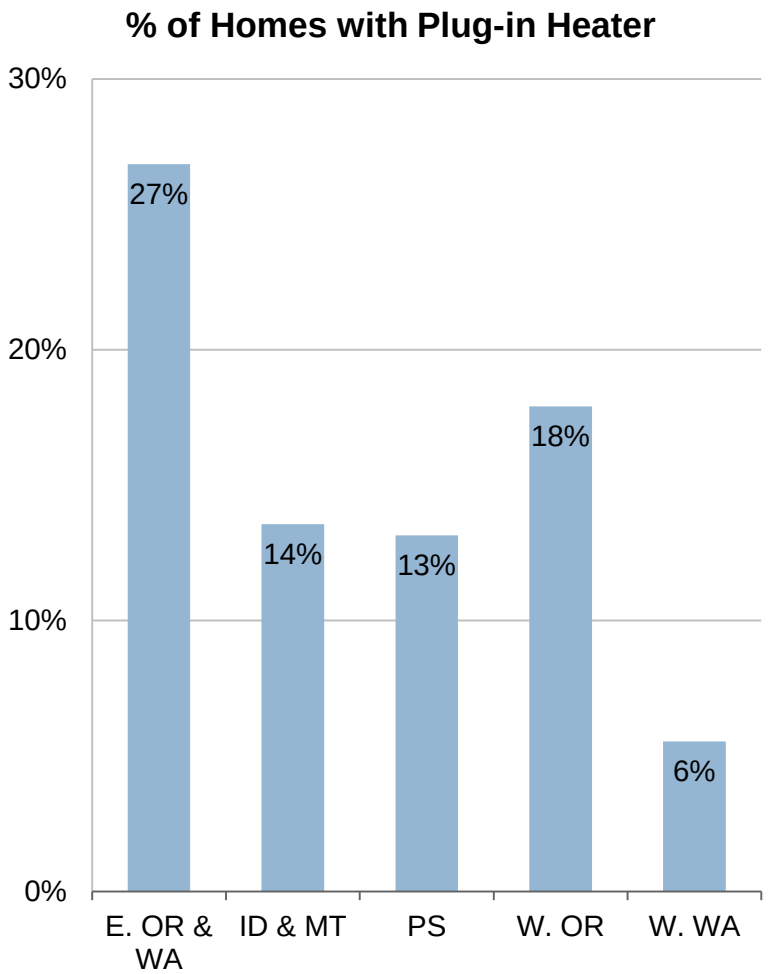
1. More than 25% of homes in the BPA region reported wood consumption. Although the proportion of homes using wood is slightly smaller, BPA region homes consume about 10% more kBtu of wood than non-BPA region homes.
2. Wood consumption is correlated with urbanization level. A higher proportion of homes in rural and suburban areas use wood, and their average kBtu consumption of wood is higher than in urban areas.

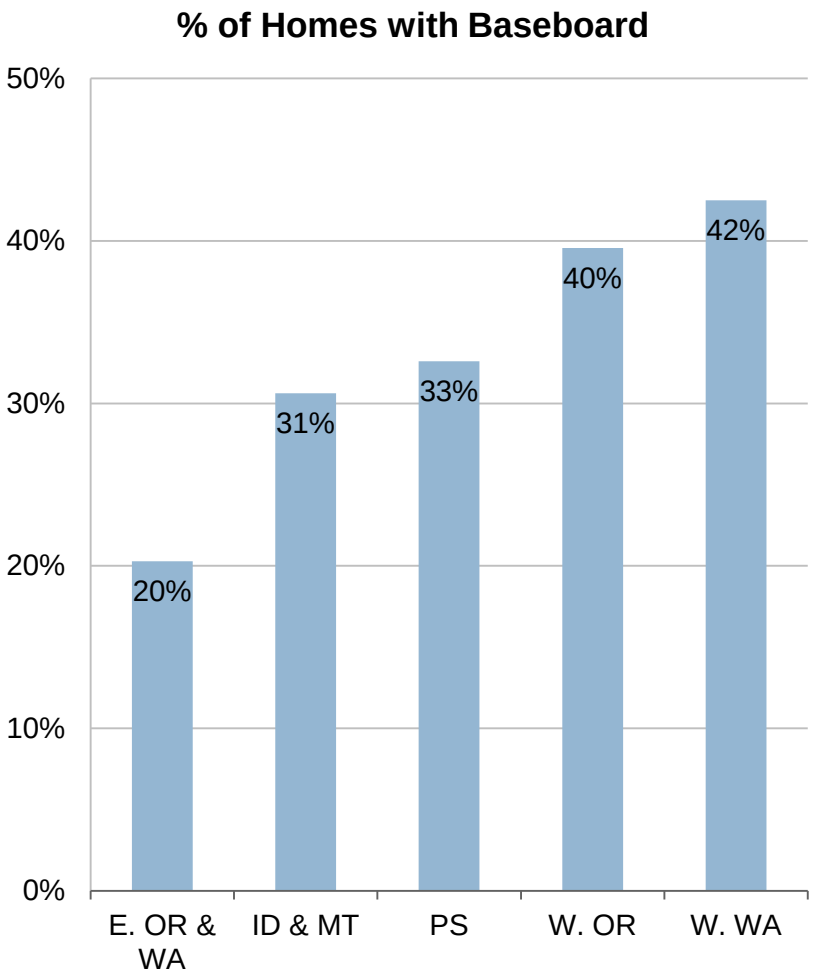


Note: Wood use is self-report data. The analysis is among homes that use electricity as primary heating fuel or wood as primary and electric as secondary. The separate analysis tables in Excel provides average annual wood consumption (kBtu).

SF – Resistance Heat

1. 15% of single-family homes in BPA region have plug-in heaters. Plug-in heaters are more prevalent in E. Oregon and Washington than in other geographic regions.
2. 33% of single-family homes in BPA region have baseboard heaters, which is higher than the non-BPA region (23%). W. Oregon and Washington have higher proportions of homes with baseboard heaters than other geographic regions.

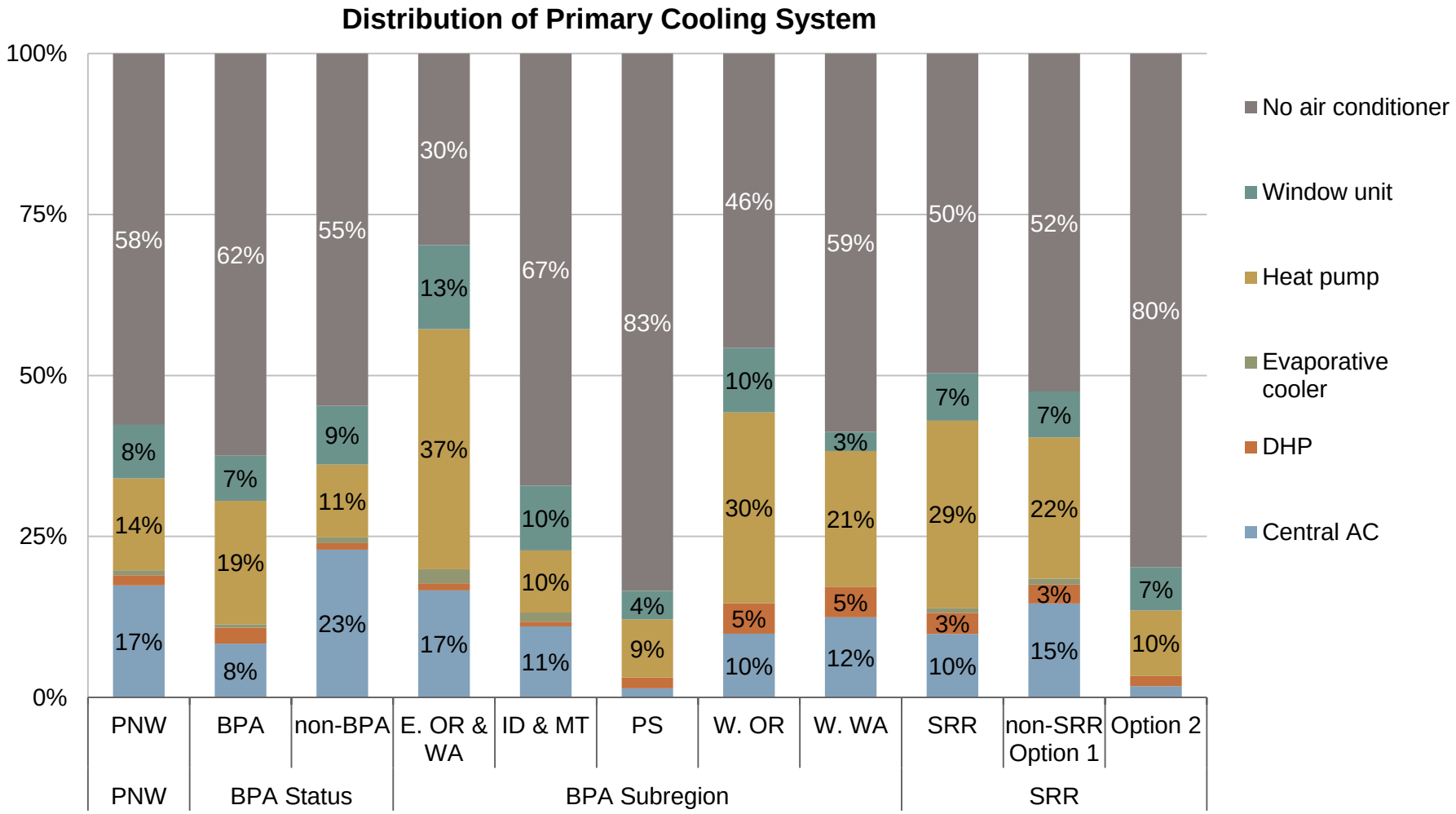




Note: These include both as primary and secondary heating systems.

SF – Cooling System

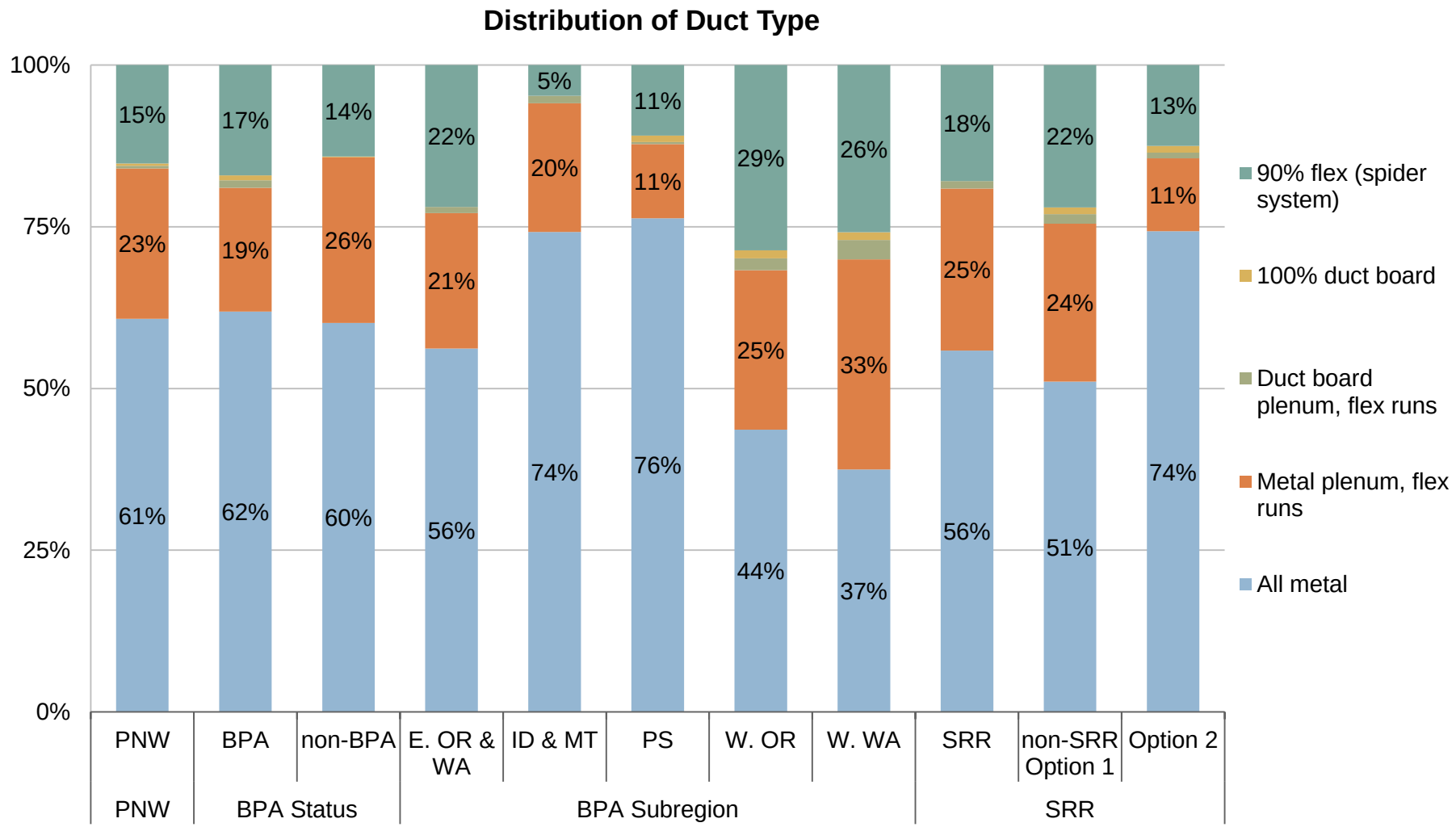
1. Within the BPA region 62% of single-family homes have no cooling system. The prevalence of cooling systems varies widely by geographic region. In the Puget Sound area 17% of homes have cooling systems, while in Eastern Oregon and Washington 70% of homes have cooling systems.
2. Heat pumps are the most common, but central AC and window units are also widely used in the BPA region.



Note: "Window unit" includes PTAC and window shaker.

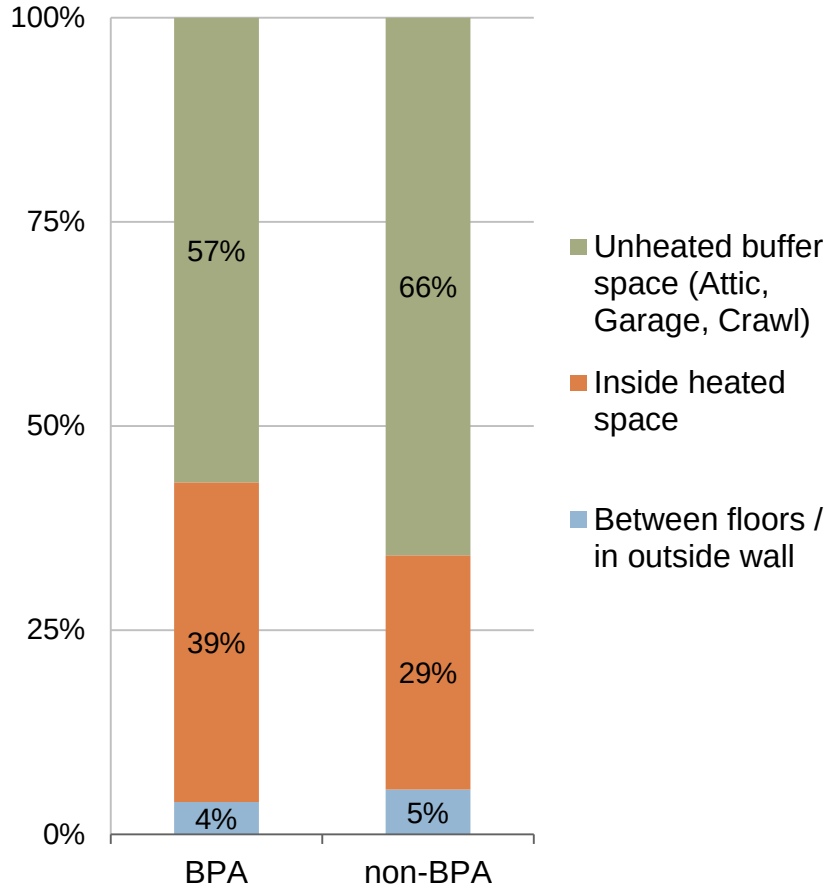
SF – Duct Types

1. In the BPA region metal ducts are the most common followed by metal plenum/flex runs and 90% flex ducts.
2. Duct type distribution varies widely by region. The majority of homes in Idaho and Montana, E. Oregon and Washington, and Puget sound have all metal duct whereas in W. Oregon and Washington metal plenum or 90% flex duct types are more widely used.

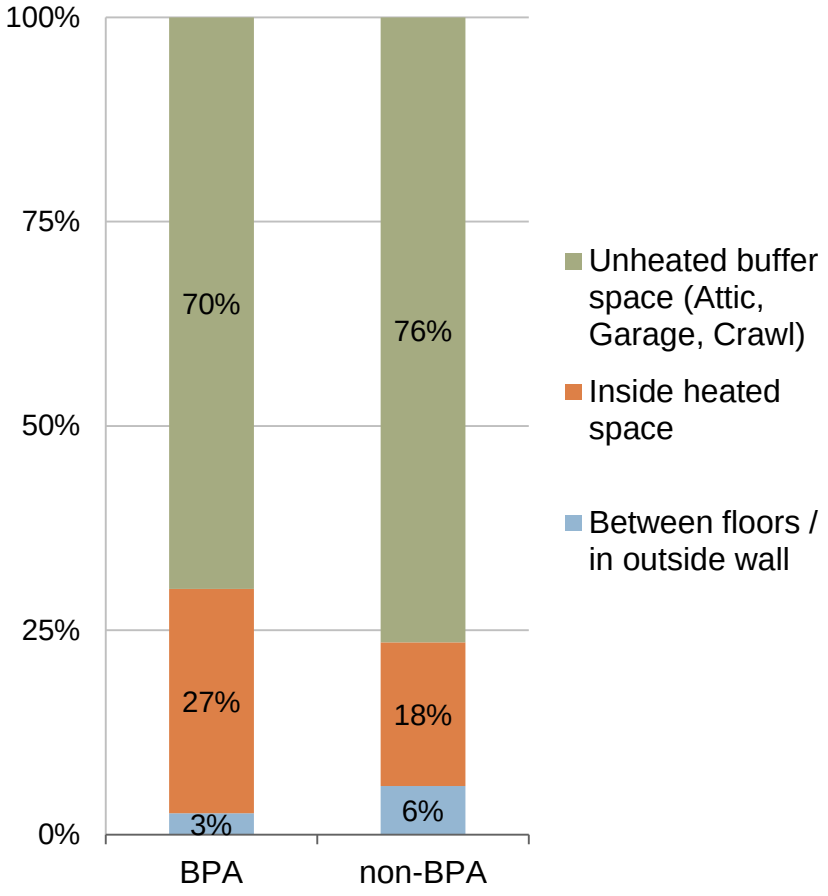


1. In the BPA region return (39%) and supply (27%) ducts are more likely to be located inside of heated space than in non-BPA region homes.
2. As the climate gets cooler, the percentage of ducts inside heated space increases. (Reader caution: small sample bases within heating climate zones 2 and 3.)

Distribution of space where the majority of return ventilation ducts are located

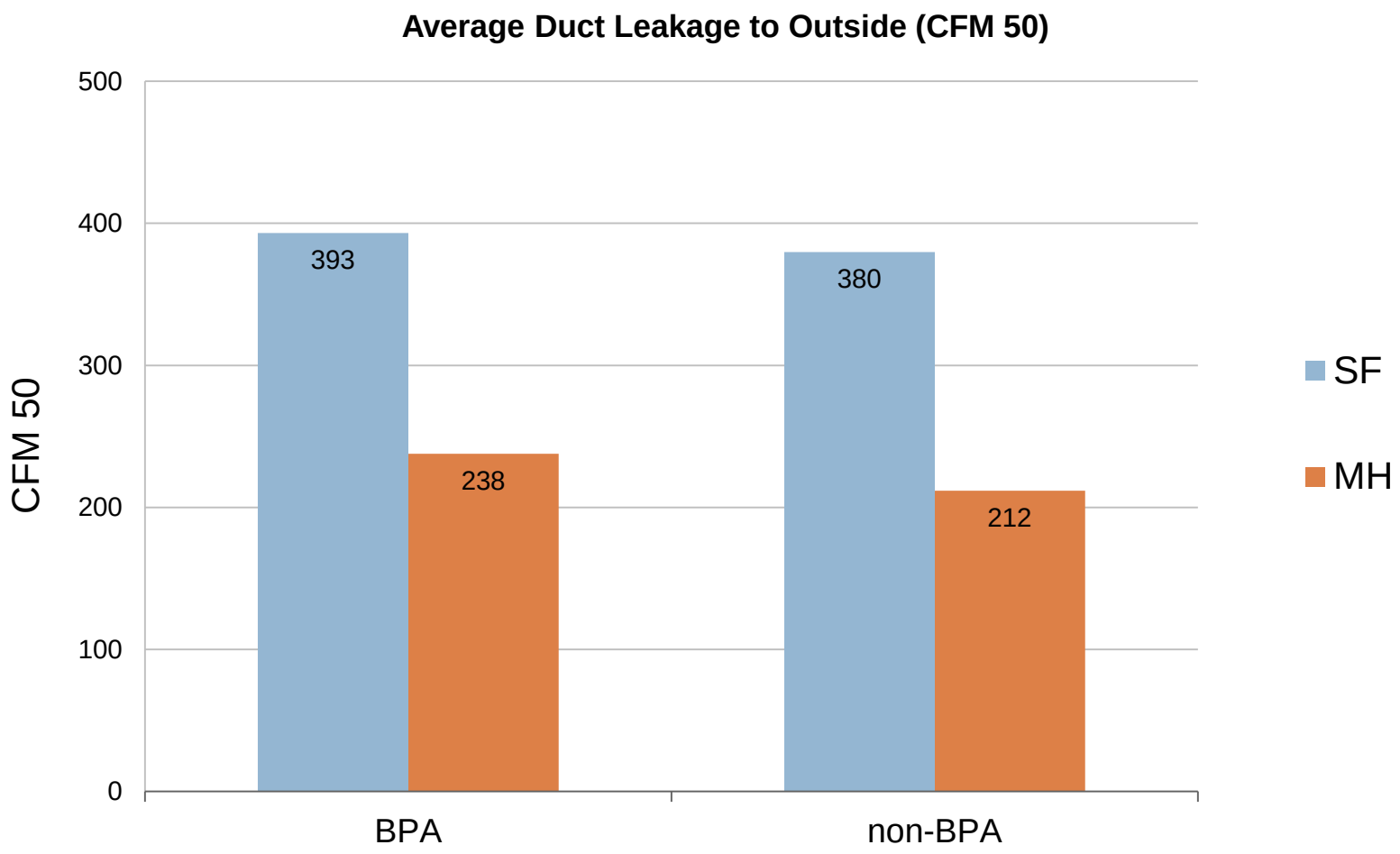


Distribution of space where the majority of supply ventilation ducts are located

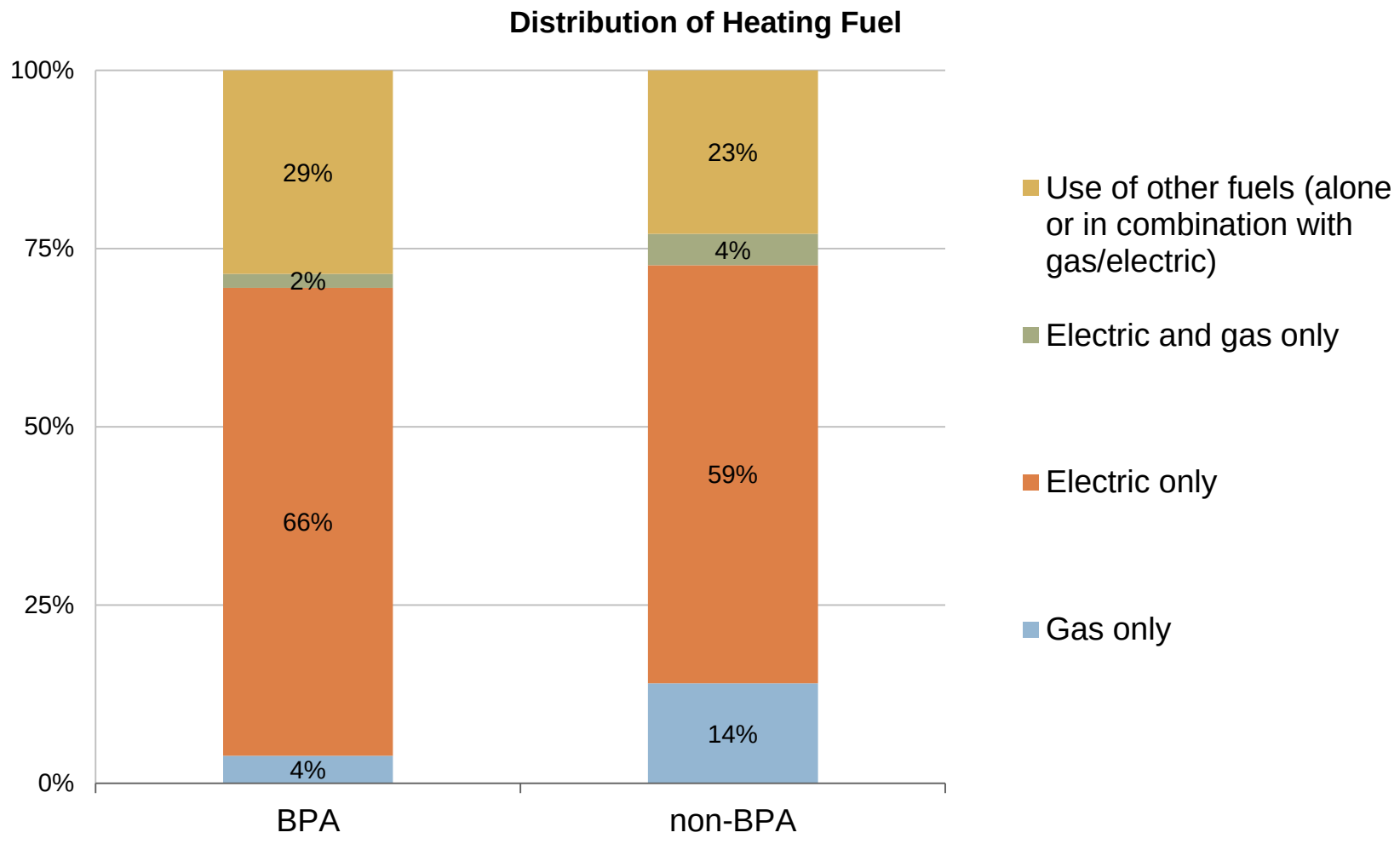


SF/MH – Duct Leakage

1. BPA and non-BPA regions are comparable in average duct leakage to outside; single-family homes have higher leakage than manufactured homes.

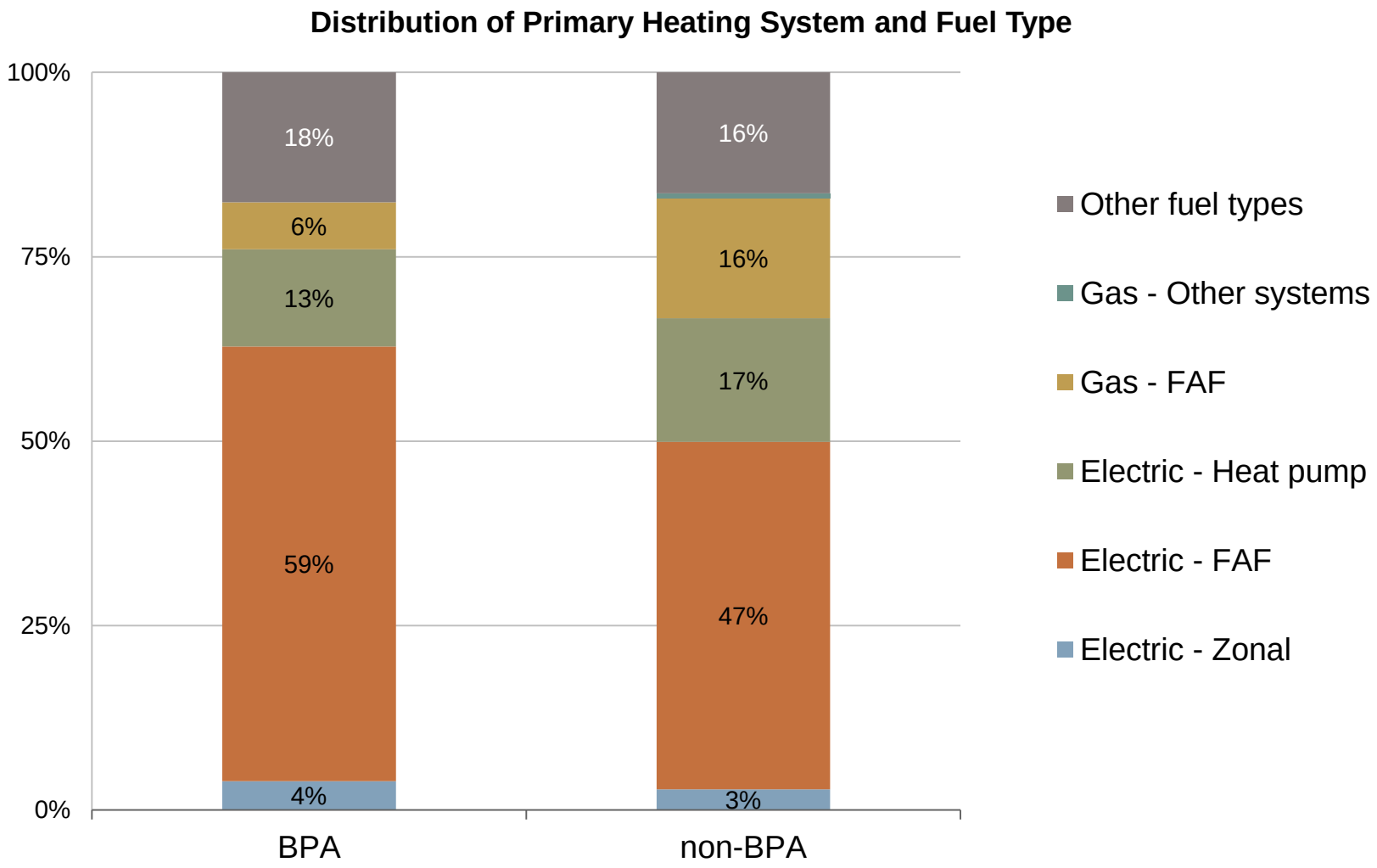


1. The BPA region has a higher percentage of electric-only heated homes than the non-BPA region. Natural gas use is lower in the BPA region than in the non-BPA region.
2. Nearly one-third of manufactured homes in the BPA region use fuel types other than electricity or natural gas for their heating system.



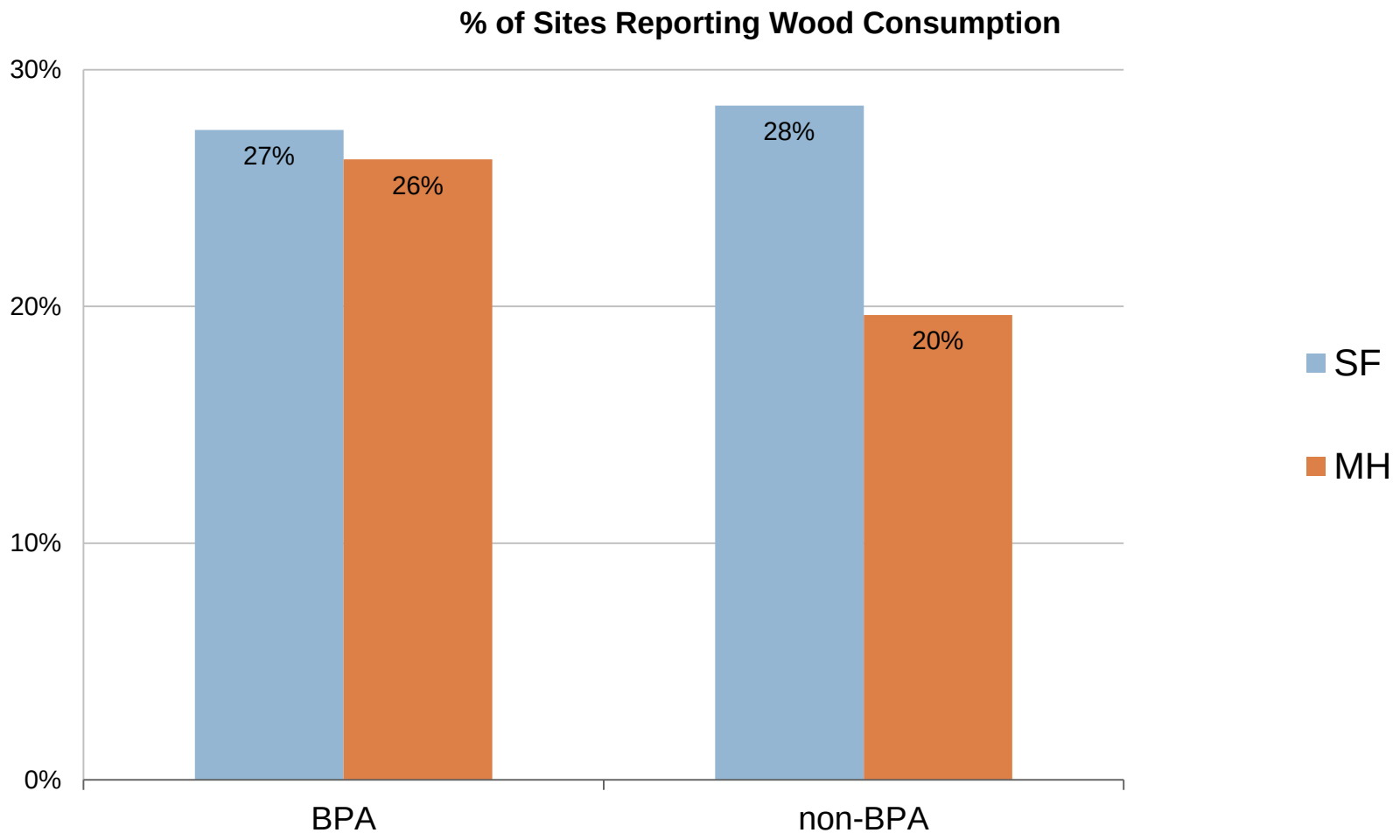
Note: Categories are mutually exclusive. “Use of other fuels” includes other fuel alone and in combination with electric and or natural gas. This includes both primary and secondary systems.

1. 76% of manufactured homes in the BPA region have electric primary heating systems. The most prevalent is electric-FAF (59%).
2. The second common is “other fuel type” systems (18%), a majority of which is heating stove.
3. A high prevalence of electric-FAF and “other fuel type” systems indicate a significant opportunities for DHP conversion.



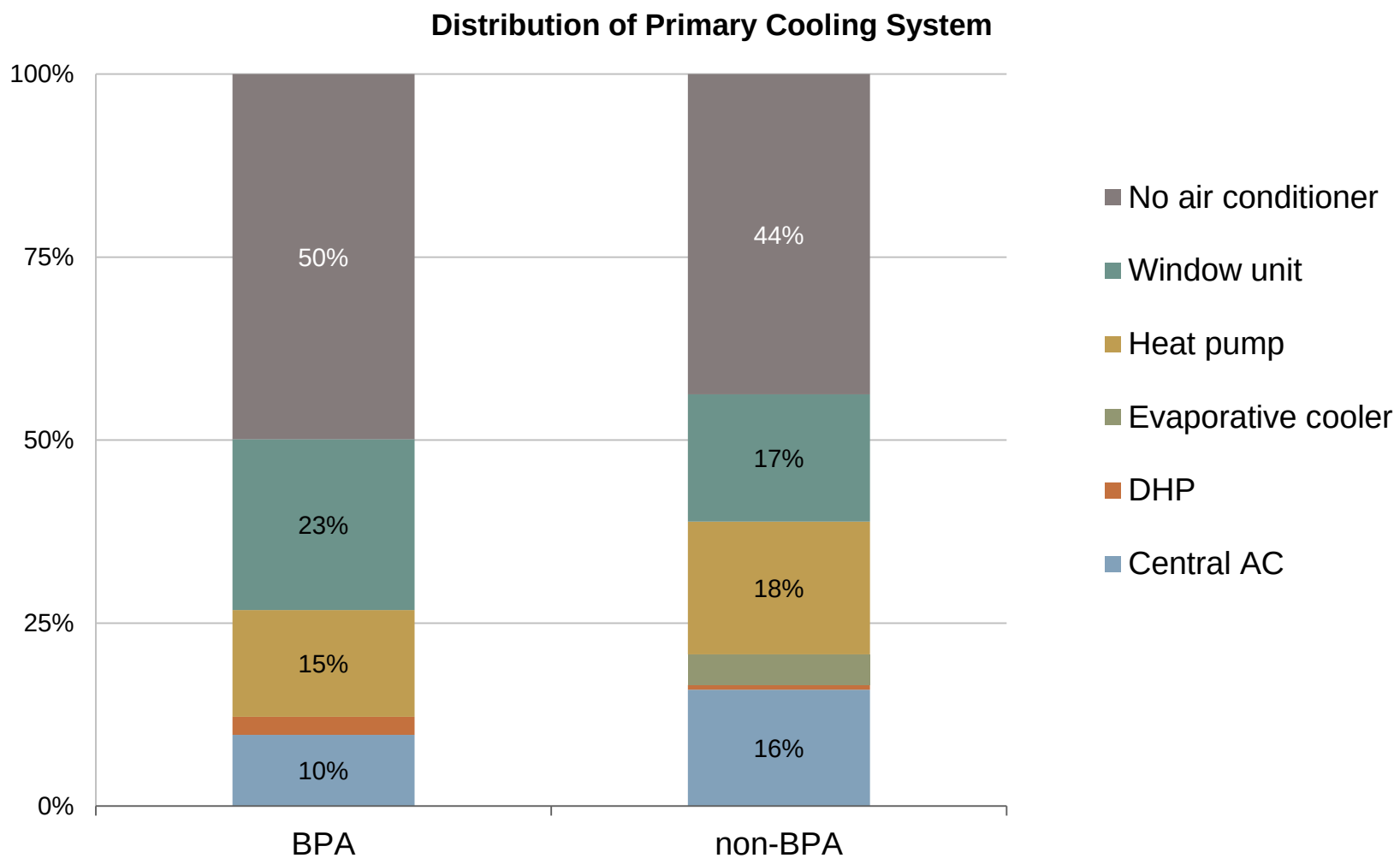
SF/MH – Wood Consumption

1. More than a quarter of homes in the BPA region reported wood consumption. A higher proportion of manufactured homes in the BPA region reported wood consumption than in the non-BPA region.



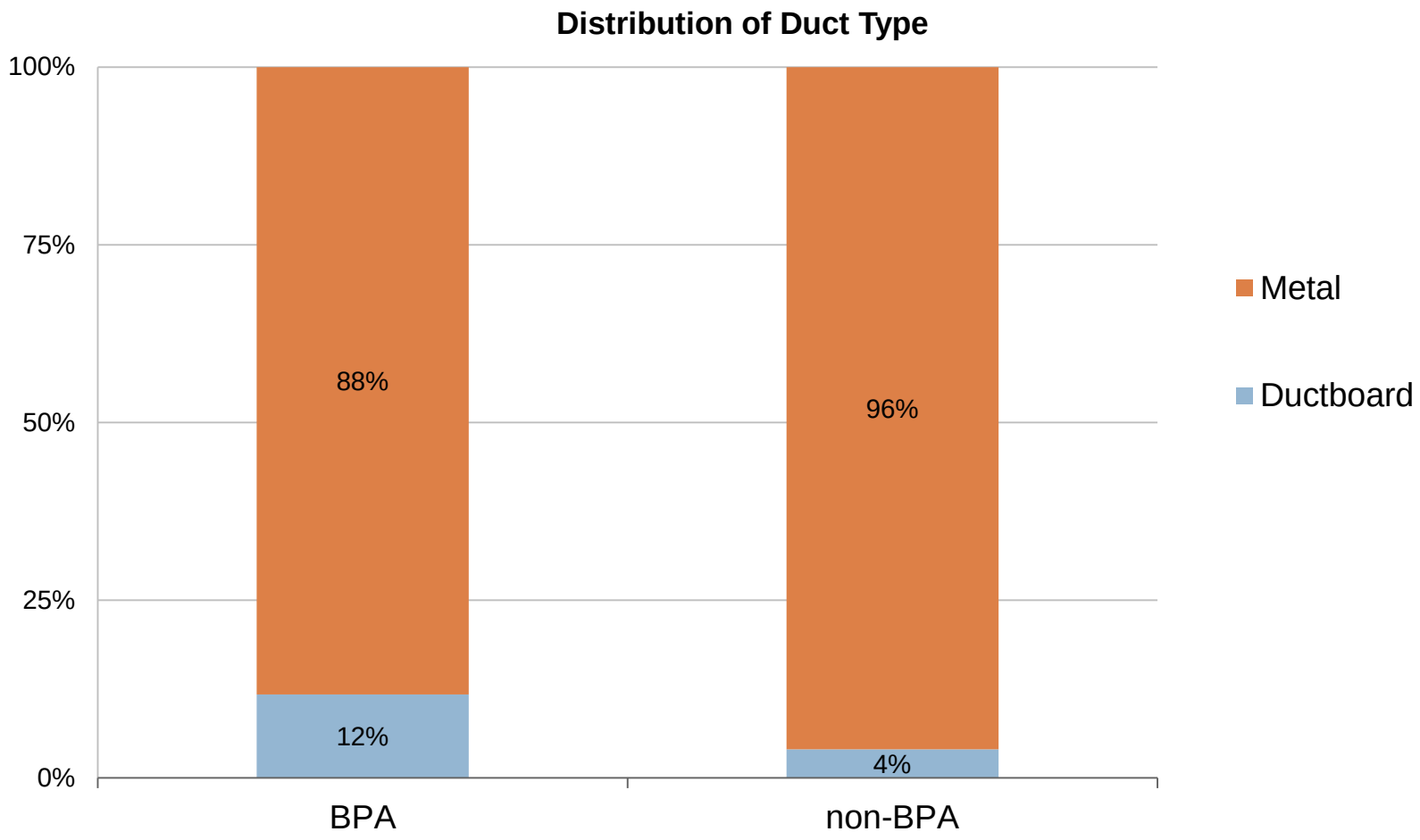
Note: Wood use is self-report data. The analysis is among homes that use electricity as primary heating fuel or wood as primary and electric as secondary.

1. Half of the manufactured homes in the BPA region have no cooling system, slightly higher than for non-BPA homes.
2. Window units are the most common type of cooling system in BPA region manufactured homes (23%).



MH – Duct Type

1. The majority of manufactured homes in the BPA region have metal ducts (88%). Slightly more homes in the BPA region use ductboard (12%) than in non-BPA region (4%).



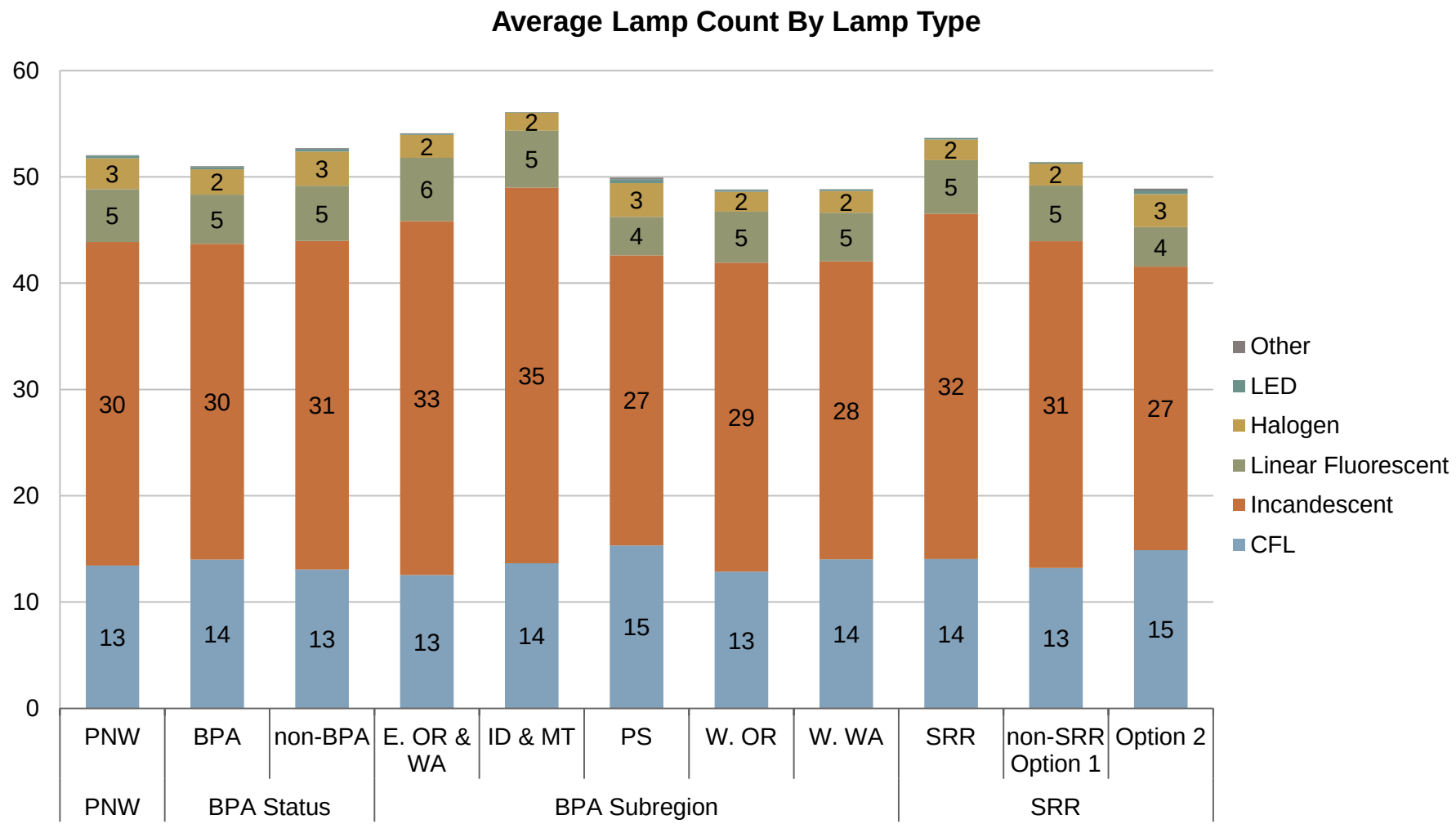
Summary – HVAC

- A lack of natural gas availability in the BPA region may explain why the proportion of homes using natural gas systems in the BPA region is smaller than in the non-BPA region. Use of electric-zonal, electric heat pump, or other non-electric non-gas systems are more prevalent compared to non-BPA regions.
- Single-family homes in E. Oregon and Washington have a high concentration of electric-FAF, which indicates opportunities for central heat pump. W. Oregon, W. Washington, and the Puget Sound area have a higher concentration of electric-zonal, which indicates opportunities for DHP measures.
- There is a high prevalence of electric-FAF among manufactured homes. There may be potential for DHP measures.
- More than a quarter of single-family homes in BPA rural areas use fuel types other than gas or electric for their primary heating system (most of which are stove heaters). 39% of rural single-family homes use fuels other than gas or electric for their secondary heating systems.
- Wood consumption in single-family homes (both prevalence and quantity) is correlated with urbanization level. Rural and suburban homes are more likely to use wood and have a higher average kBtu than urban homes.
- Plug-in heaters are used by 15% of single-family homes and baseboard heaters are used by 33% of single-family homes in the BPA region. Incidence of resistance heaters vary widely by geographic region.
- 62% of single-family homes and 50% of manufactured homes do not have a cooling system, but the use of cooling systems widely varies by geographic region. Heat pump and central AC are the most common cooling systems among single-family homes and window units are the most common among manufactured homes in the BPA region.
- On average ducts in single-family homes are leakier than ducts in manufactured homes.

Lighting (SF and MH together)

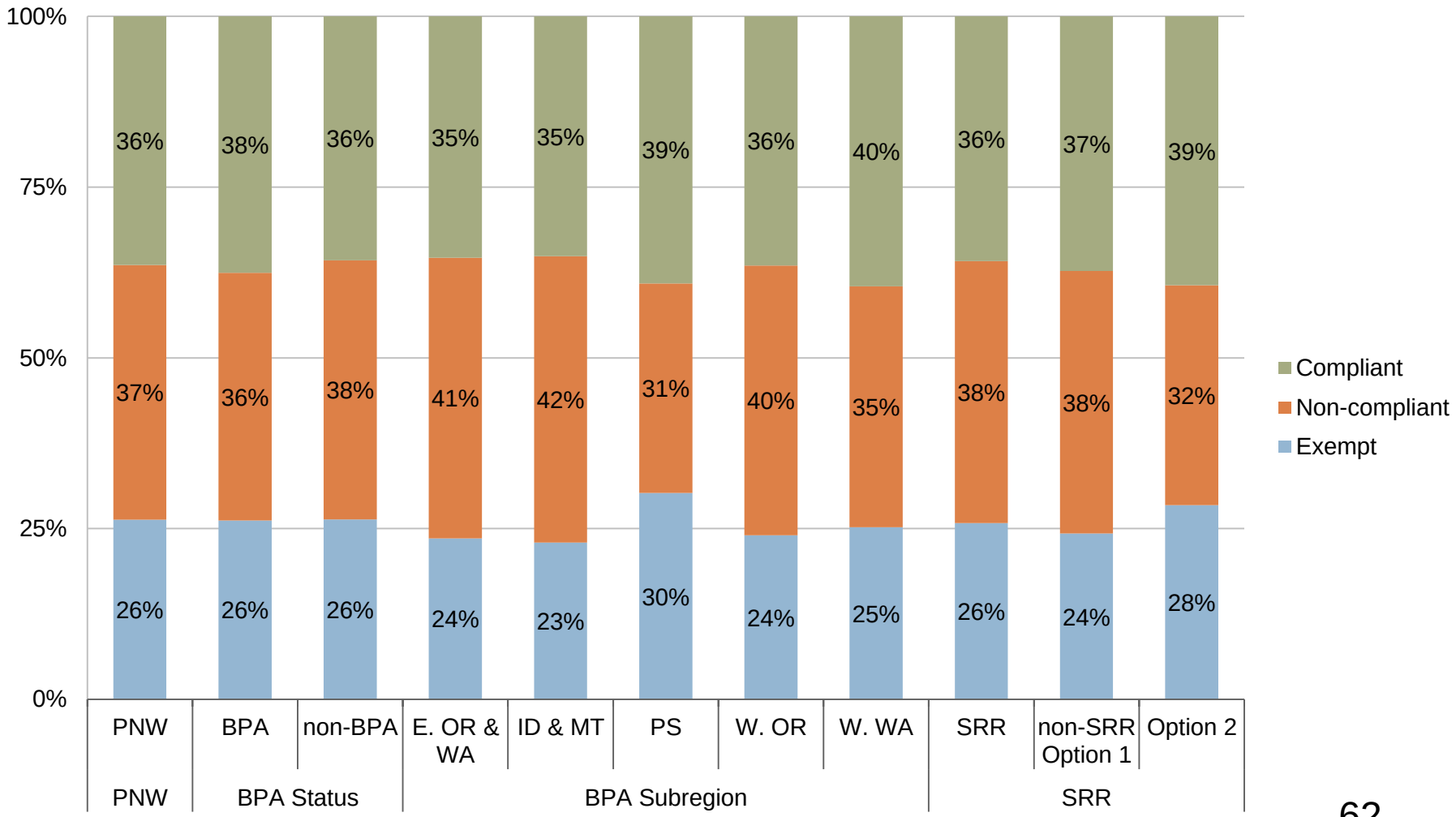
Areas	Dependent variables
Lamp type	Distribution of interior lamp type by room
Lamp type	Average lamp count by type in each room
Lamp type	Average interior lighting watts by lamp type
Lamp type	Distribution of interior lamps EISA compliance
Fixture	Distribution of lamp fixture
LPD	Average interior LPD by room
LPD	Average site-wide LPD
Exterior lighting	Distribution of exterior lamp type
Exterior lighting	Average exterior lighting watts by lamp type

1. On average BPA region homes have 51 interior lamps. Homes in rural areas tend to have more interior lamps.
2. The majority (57%) of interior lamps in the BPA region homes are incandescent. Efficient lamp types (CFL, linear fluorescent, and LED combined) comprise 38% of all interior lamps in the region.
3. BPA region homes have more CFLs (27%) than non-BPA region homes (24%). Urban areas and Puget Sound region have the highest CFL concentration among BPA region homes.



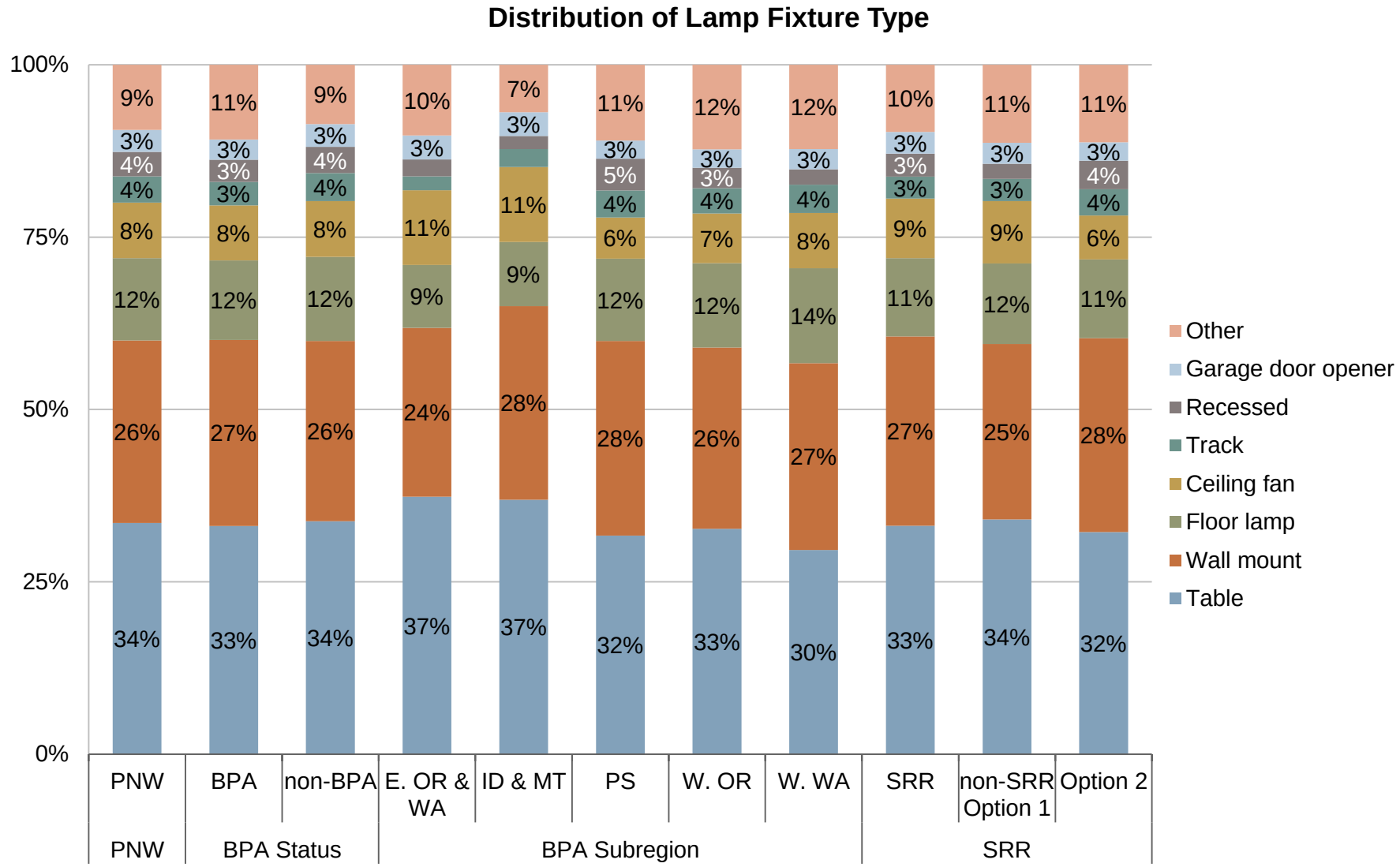
1. In the BPA region, 26% of all lamps will be exempt from the fully executed EISA standard by 2015 (78% incandescent, 20% halogen). About 38% of all lamps are currently in compliance and 36% are non-compliant.
2. Most of the compliant lamps are CFLs (70%) and some are linear fluorescent lamps (29%). Most of the non-compliant lamps are incandescent lamps (98%, 2% halogen lamps).

Distribution of interior lamps EISA compliance



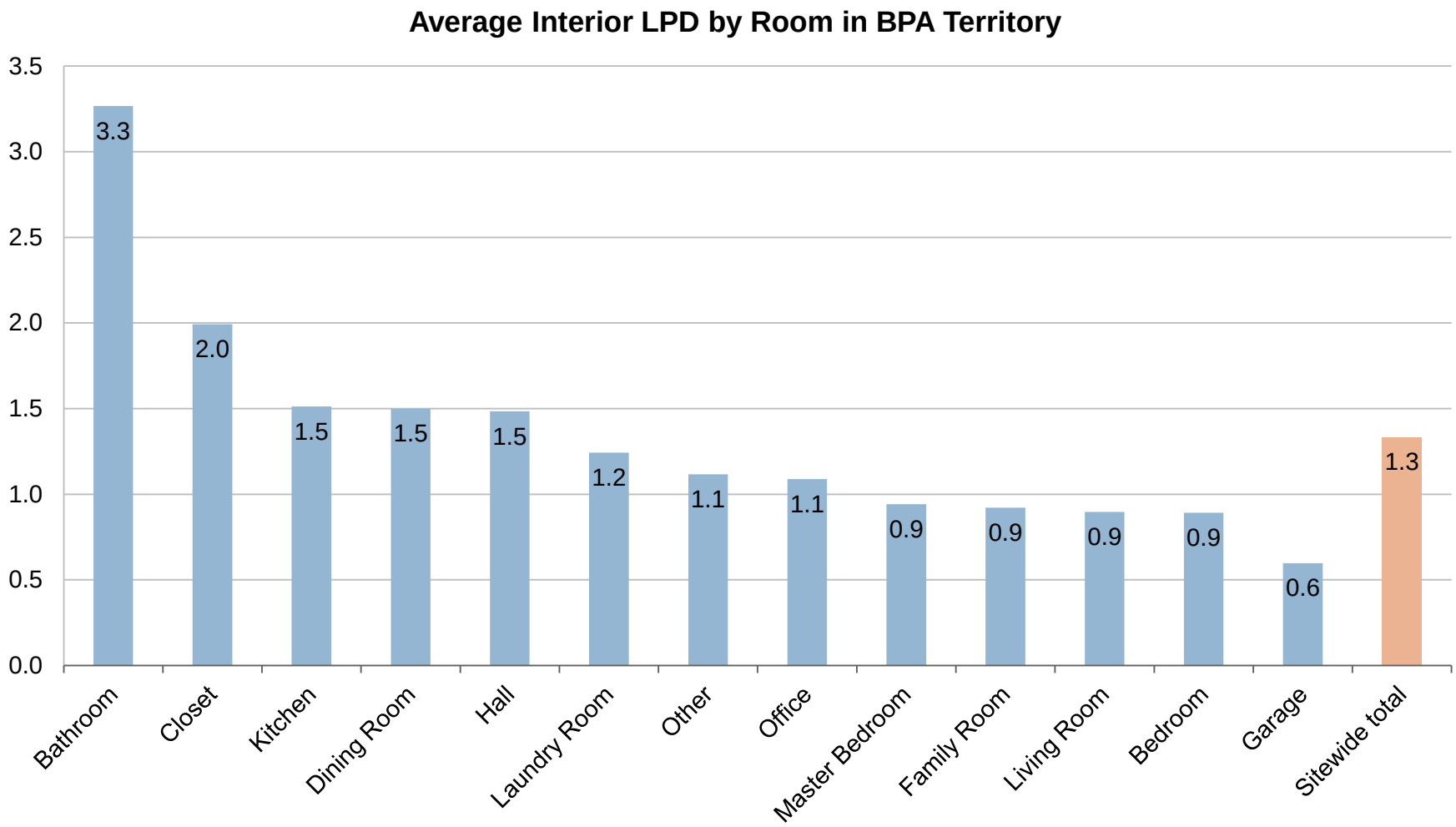
SF & MH – Interior Lighting Fixture

1. Locations of interior lighting fixtures don't appear to vary much between geographic region, level of urbanization or between the BPA and non-BPA territories.



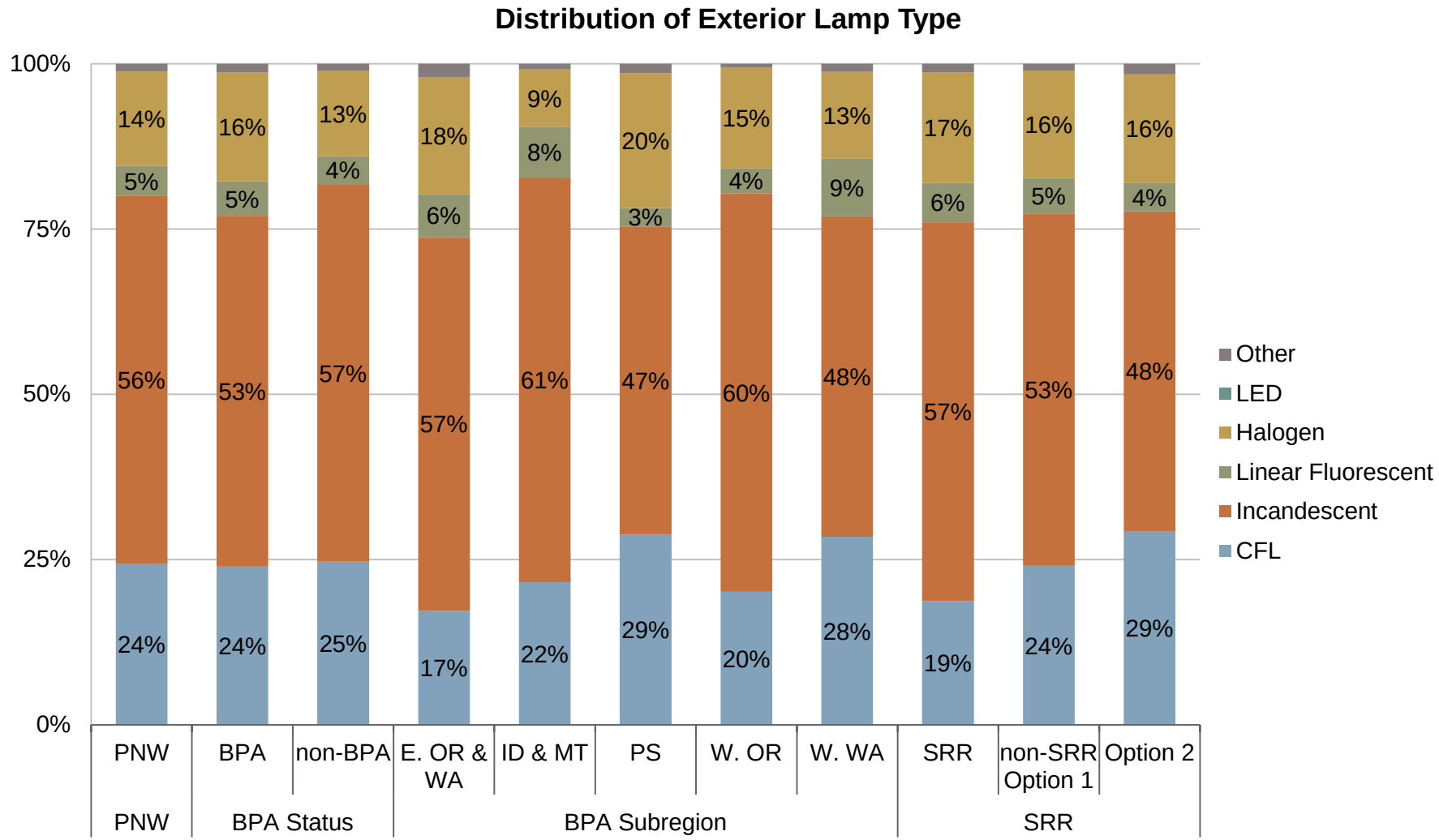
SF & MH – Interior LPD

1. Lighting Power Density (LPD)* values vary widely by room, ranging from less than 1.0 to more than 3.0.
2. LPD in bathrooms is by far the highest - twice as high as site-wide average. Lamp count is the highest in bathrooms (9 lamps on average and 18% of total lamp count per site) and there is a high concentration of incandescent lamps in bathrooms (71%).



(*) LPD (Lighting Power Density) – ratio of light output in an area and the electric power used to produce that light.

1. The majority (53%) of exterior lamps in the BPA region homes are incandescent. Efficient lamps (CFL, linear fluorescent, and LED combined) comprise only 29% of exterior lighting in BPA region homes.
2. Urban areas and Puget Sound region have the highest concentration of CFLS (29%) in the BPA region.
3. Halogen lamps are more commonly used in exterior applications than interior.



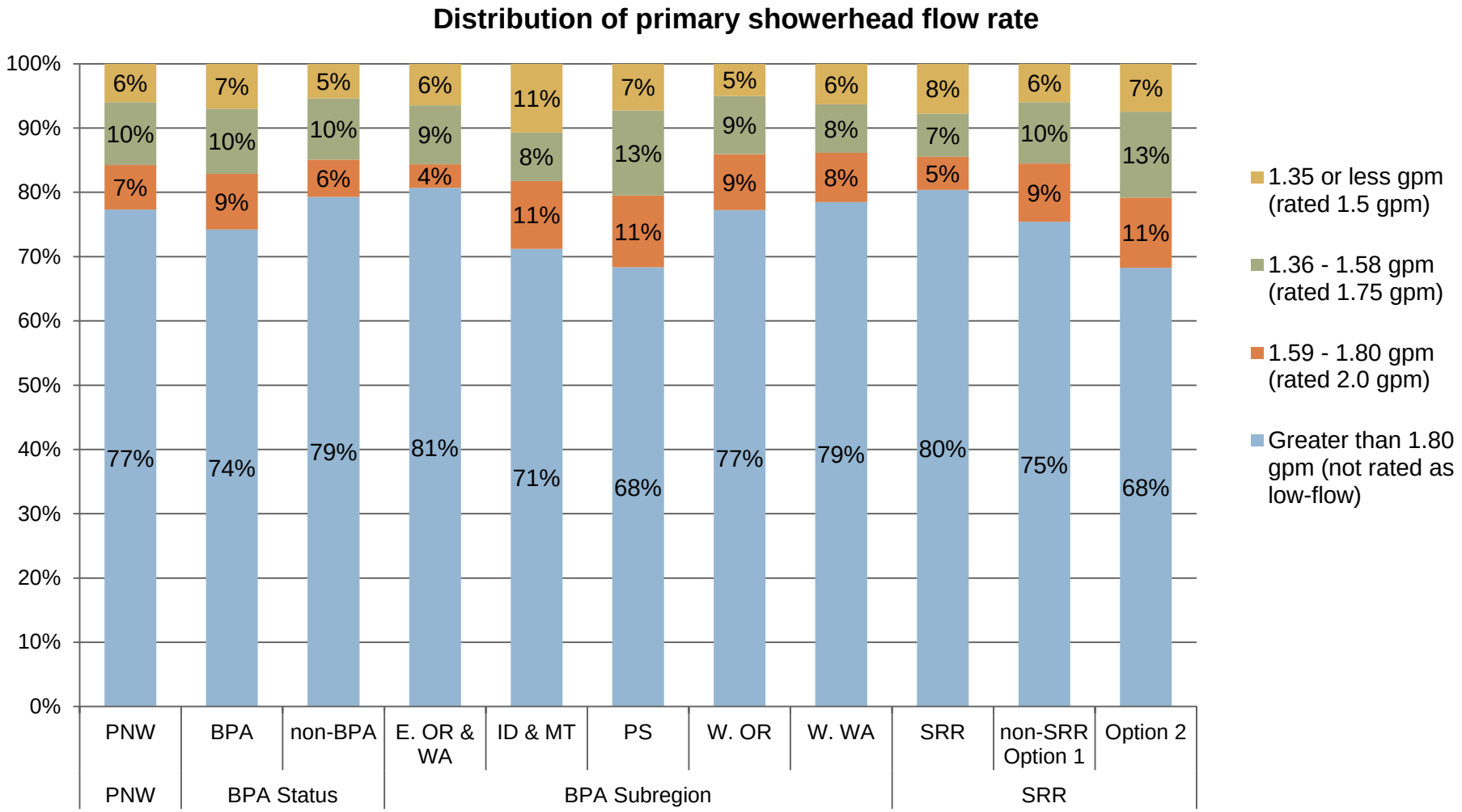
Summary – lighting

- Homes in the BPA region have on average 51 interior lamps, 68% of which are inefficient incandescent or halogen lamps.
- About 38% of all lamps are currently in compliance with the EISA standard, 36% are non-compliant, and 26% are exempt. Predominant non-compliant and exempt lamps are incandescent and halogen lamps.
- LPD vary widely by room ranging from less than 1.0 to over 3.0. The LPD in bathrooms is by far the highest with average count of 9 lamps and a high concentration of incandescent lamps (71%).
- 69% of exterior lamps in BPA region homes are incandescent or halogen lamps.

Water technologies (SF and MH together)

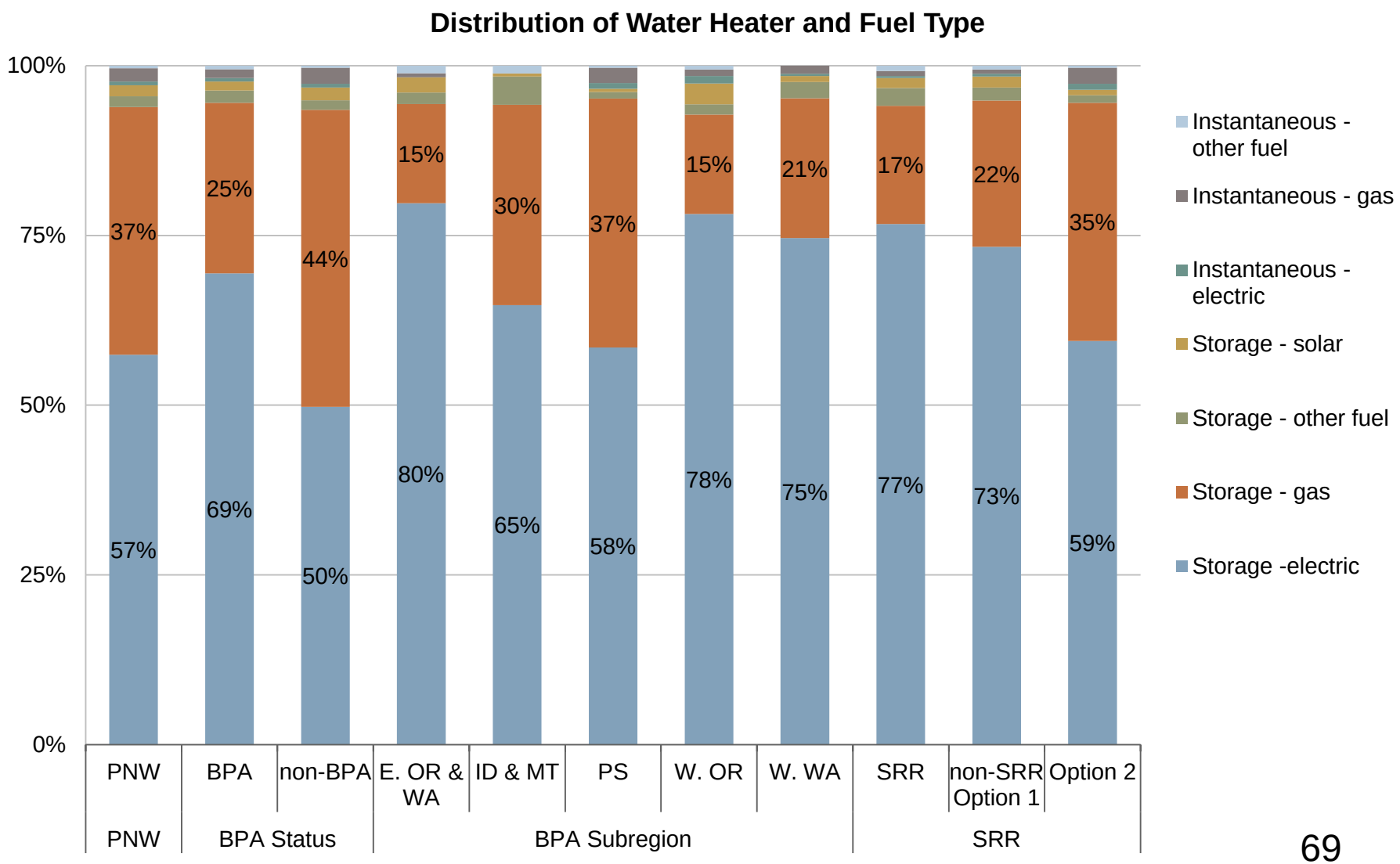
Areas	Dependent variables
Showerhead	Average showerhead count
Showerhead	Distribution of flow rate of primary showerhead
Showerhead	Average shower flow rate
Water heater	Distribution of water heater type and fuel
Water heater	Distribution of water heater location among sites using electricity for water heating and among sites where the water heater is located within conditioned space
Water heater	Distribution of water heater location among sites using electricity for water heating and among sites where the water heater is located within unconditioned space
Water heater	Distribution of water heater tank size among sites using electricity for water heating
Water heater	Distribution of water heater tank wrapped by conditioned space among sites using electricity for water heating
Water heater	Distribution of water heater year of manufacture among sites using electricity for water heating
Water heater	% of sites with water heater located in a room greater than 1,000 cubic feet among sites using electricity for water heating
Water heater	% of sites with 8 feet of vertical space above water heater

1. An overall low-flow showerhead saturation in the BPA region is only 26%. Puget Sound or urban regions have the highest saturation of low-flow showerhead (32%). Showerheads in a majority of BPA region homes remain high-flow type.



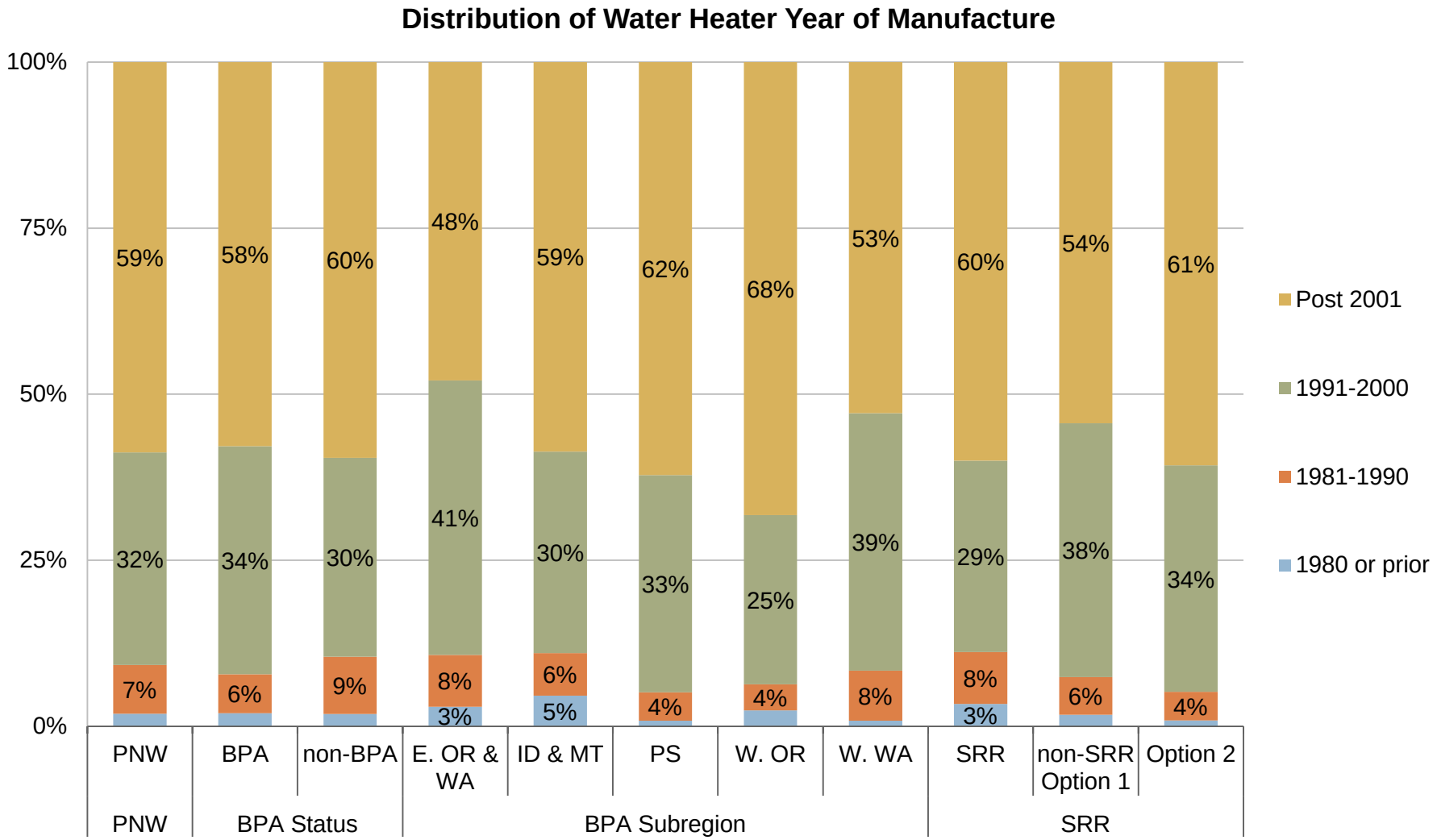
SF & MH – Water heater

1. The predominant water heater type is storage unit. In the BPA region, electricity is the most common water heater fuel. Gas storage units are more common in urban regions than in suburban or rural areas.
2. Only 2% of BPA region homes have instantaneous water heaters.



1. 58% of the water heaters in BPA region homes were manufactured after 2001.
2. W. Washington, E. Oregon and E. Washington have the highest proportions of older water heaters.

SF & MH – Water heater

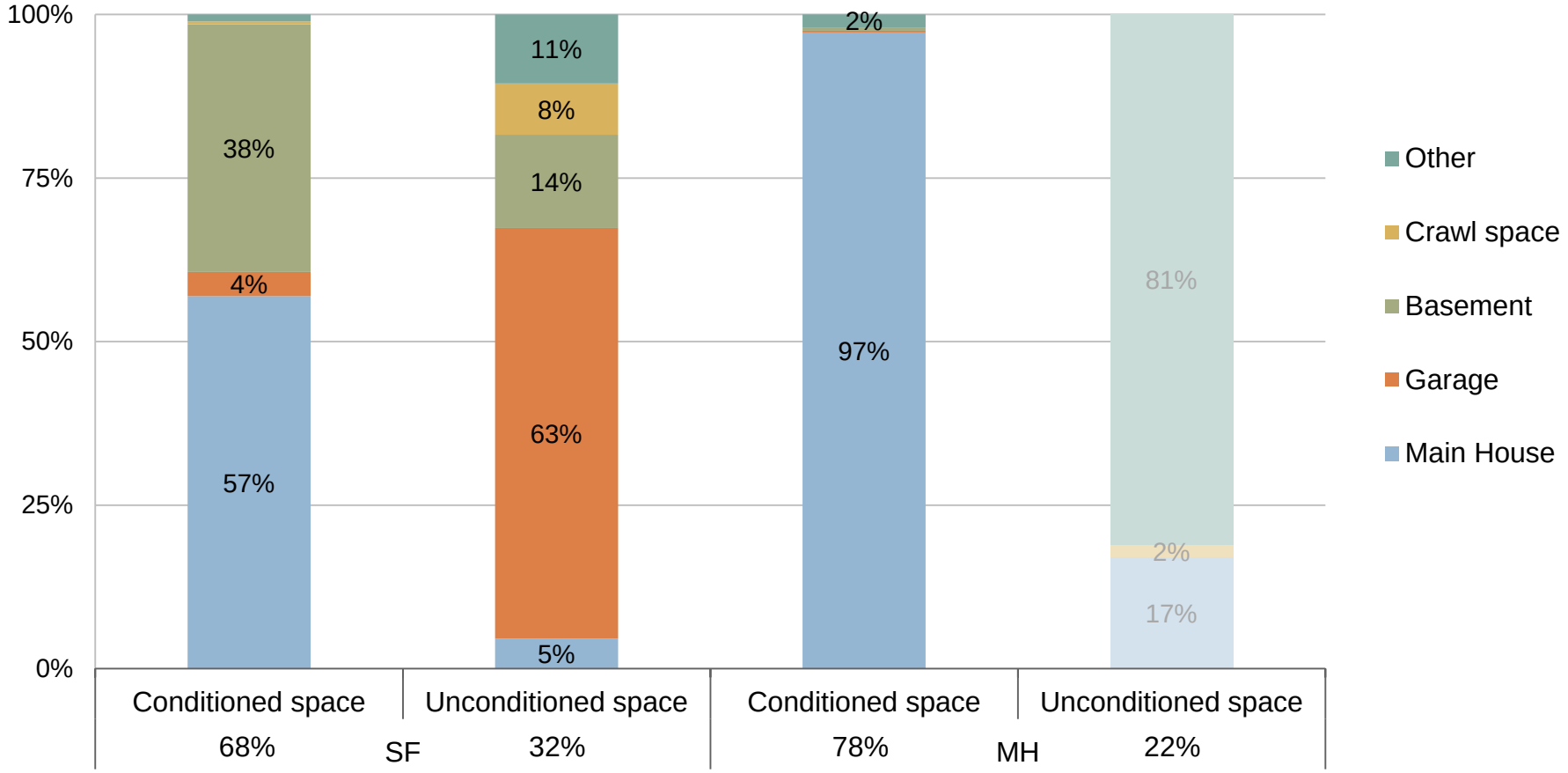


Note: Analysis is only among sites using electricity for water heating.

SF & MH – Water heater

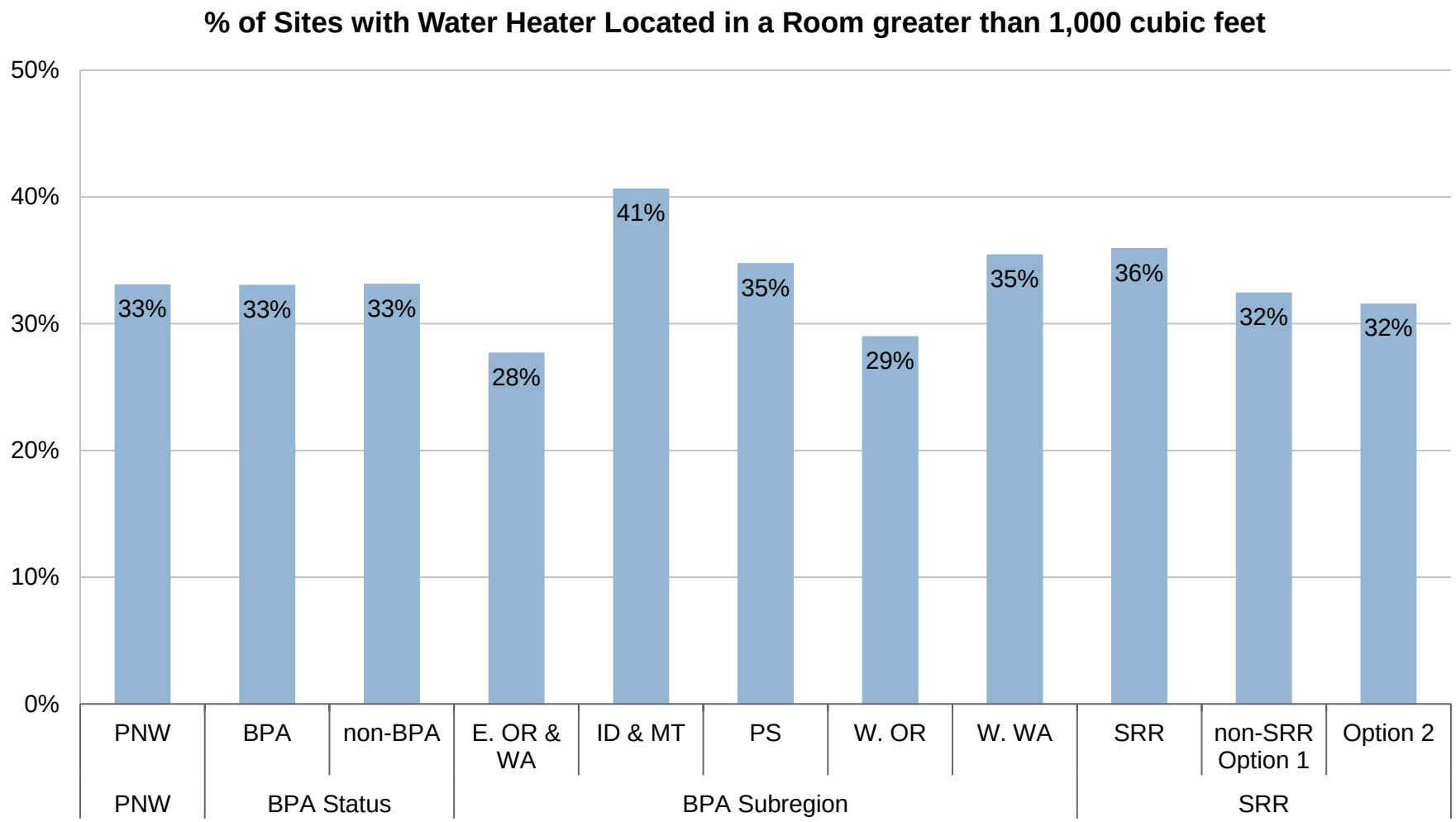
1. The majority of homes' water heaters are in a conditioned space (68% for single-family and 78% for manufactured homes.
2. Most of the water heaters in a conditioned space of single-family homes are either in the main house (57%) or in a conditioned basement (38%). The majority of conditioned space water heaters in manufactured homes are located in the main house.
3. Water heaters located in unconditioned space of single-family homes are most commonly in a garage (63%), unconditioned basements (14%) or crawl spaces (8%).

Distribution of Water Heater Location by Space Condition in BPA Territory



Note: Analysis is only among sites using electricity for water heating. Shaded color bars indicate small bases (< 68).

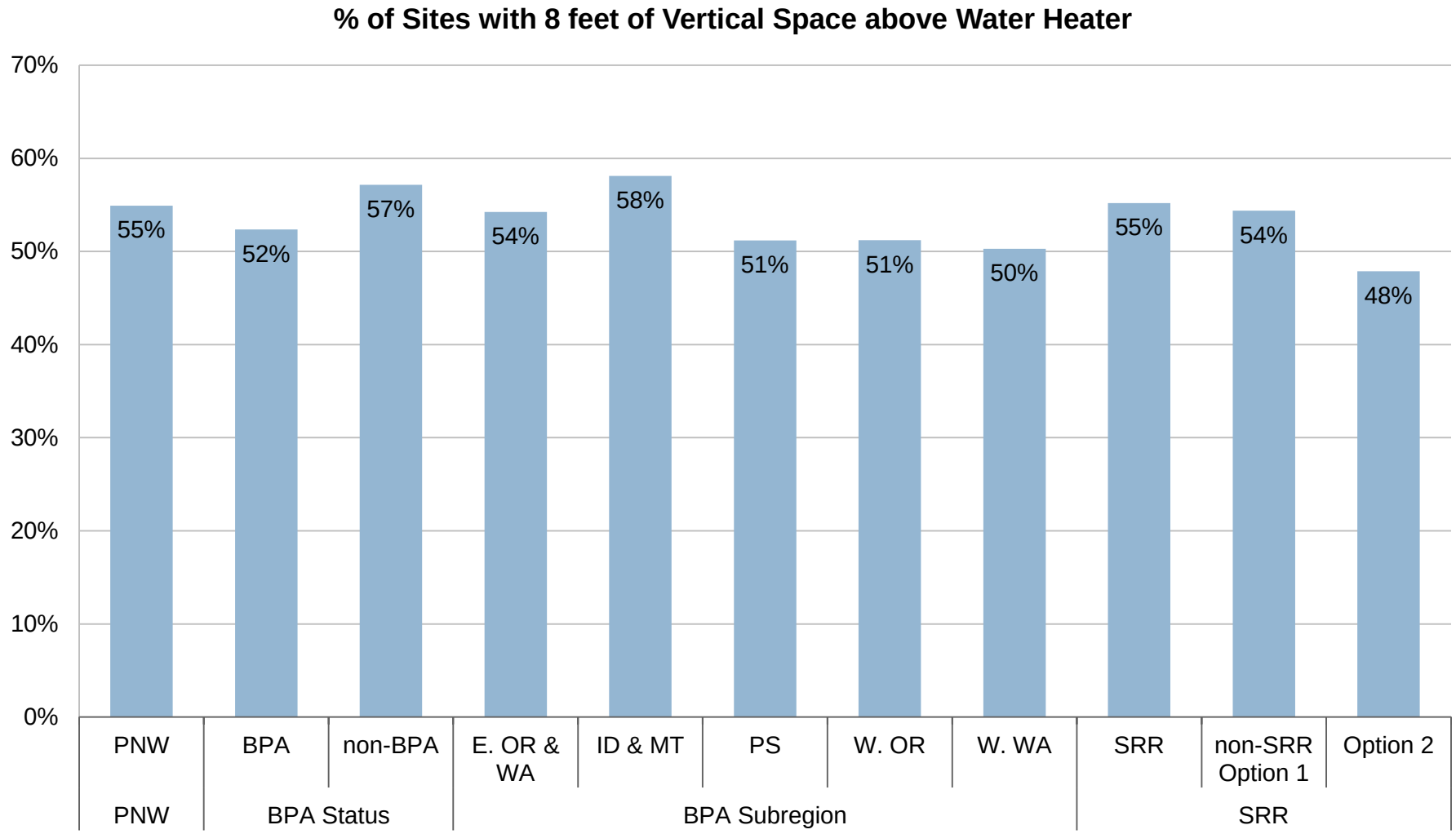
1. One-third of region's water heaters are located in a room greater than 1,000 cubic feet. This limits the number of unvented heat pump water heater installations.
2. The proportion of homes with water heaters in a room greater than 1,000 cubic feet varies by geographic region.



Note: Analysis is only among sites using electricity for water heating.

1. About half of the sites have at least 8 feet of vertical space above the water heater.

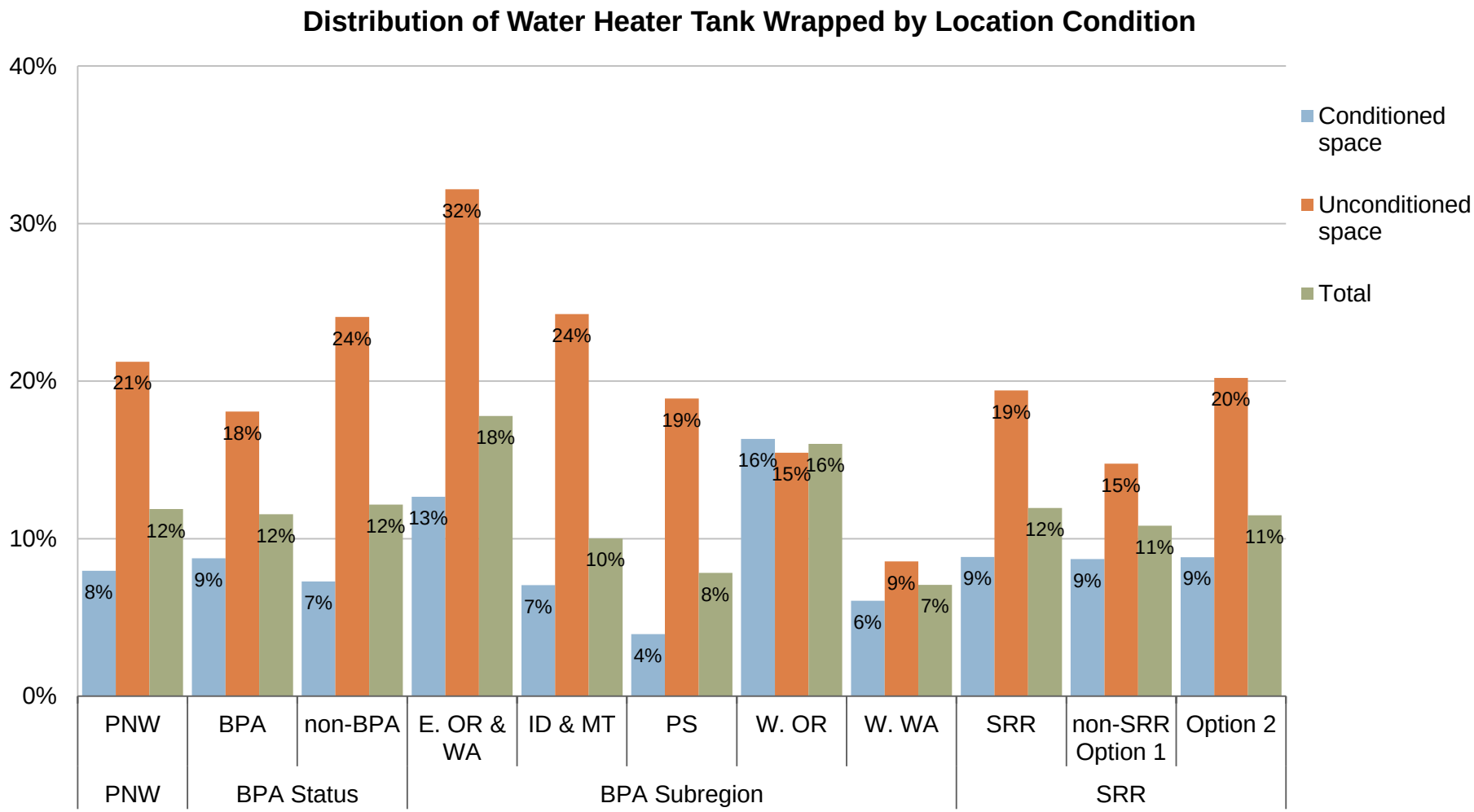
SF & MH – Water heater



Note: Analysis is only among sites using electricity for water heating.

1. In BPA region homes, 12% of electric water heaters are wrapped. Water heaters located in unconditioned space are twice as likely to be wrapped as water heaters in conditioned space.
2. The prevalence of wrapped water heaters in unconditioned space varies widely by geographic region. Homes in E. Oregon and Washington have the greatest proportion of wrapped water heaters (32%) followed by Idaho and Montana (24%.

SF & MH – Water heater



Note: Analysis is only among sites using electricity for water heating.

Summary – water technologies

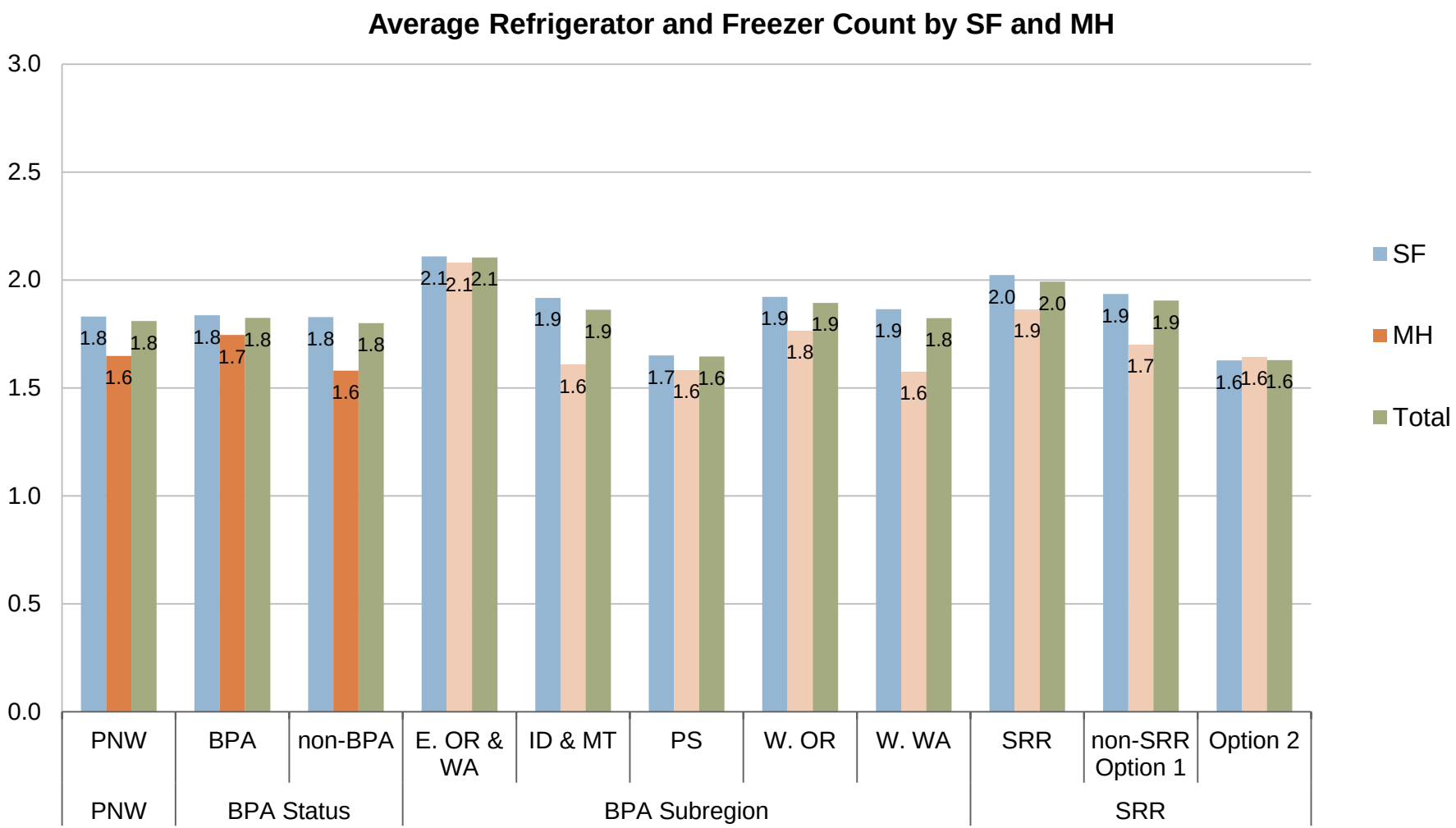
- 26% of BPA region homes use low-flow showerheads. Showerheads in a majority of BPA region homes remain high-flow type, suggesting a possible efficiency opportunity.
- The majority of homes in the BPA region have storage unit water heaters (98%). Electricity is the most common water heater fuel. Gas storage units are more common in urban areas than in suburban or rural areas.
- More than half of the water heaters in the BPA region (58%) were manufactured after 2001. The prevalence of older water heaters varies by geographic region.
- The majority of homes' water heaters are in a conditioned space (68% for single-family and 78% for manufactured homes). Most of the water heaters in a conditioned space of single-family homes are either in the main house (57%) or in a conditioned basement (38%). The majority of water heaters in manufactured homes are located in the main house (97%).
- In BPA region homes, 12% of electric water heaters are wrapped. A larger percentage of water heaters in unconditioned space are wrapped than water heaters located in conditioned space. The prevalence of wrapped water heaters in unconditioned space varies widely by geographic region – colder climate regions have much higher penetration.

Appliances (SF and MH together)

Areas	Dependent variables
Refrigerator and freezer	Average refrigerator and freezer count
Refrigerator and freezer	Distribution of refrigerator and freezer manufacture age
Refrigerator and freezer	% of Energy Star refrigerator and freezer

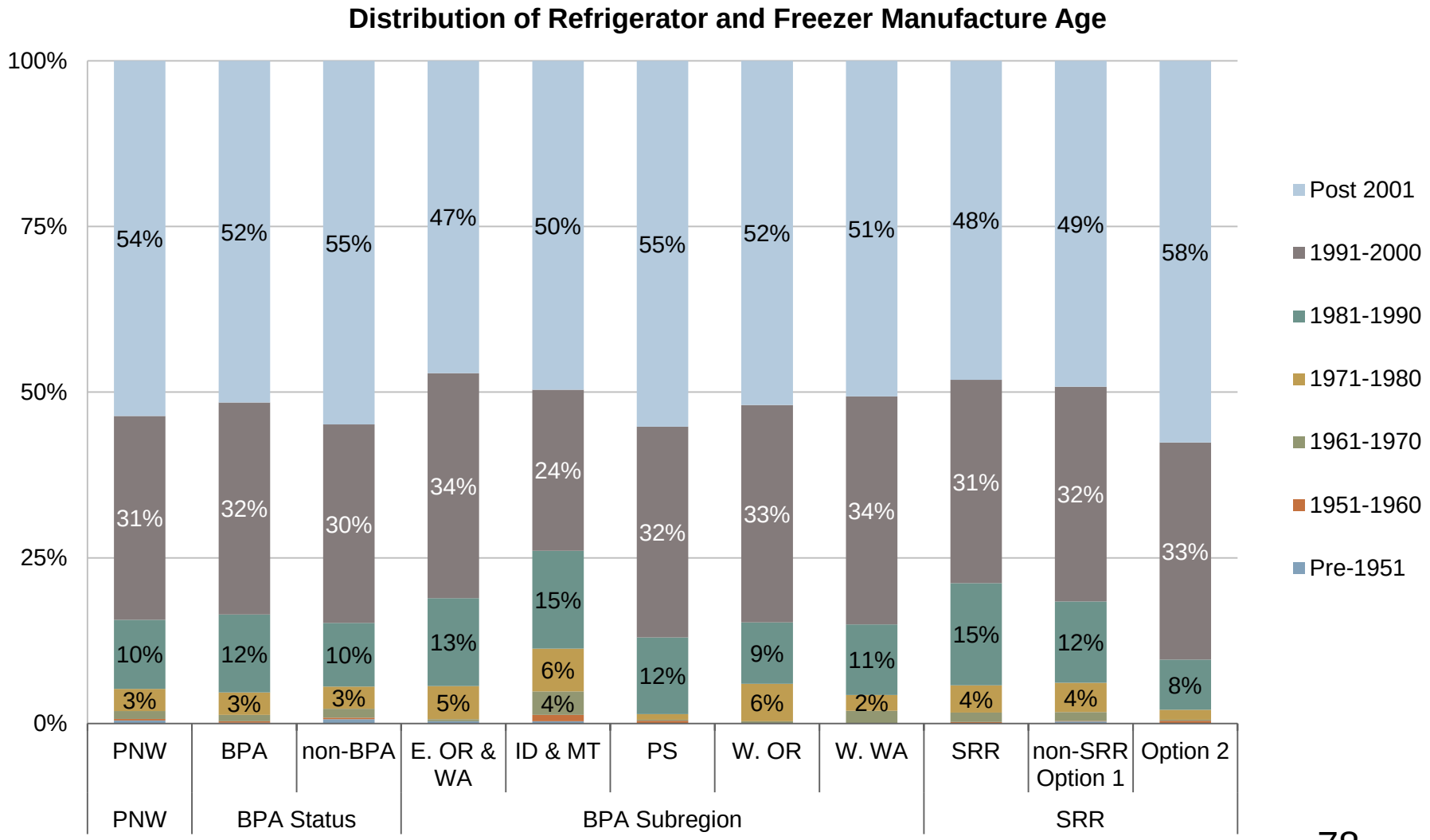
SF & MH – Refrigerator and Freezer

1. On average homes in the BPA region have 1.8 refrigerators/freezers. Single-family homes have slightly more refrigerators/ freezers than manufactured homes.
2. The refrigerator/freezer count is correlated with urbanization level. Rural homes have more than suburban or urban homes.

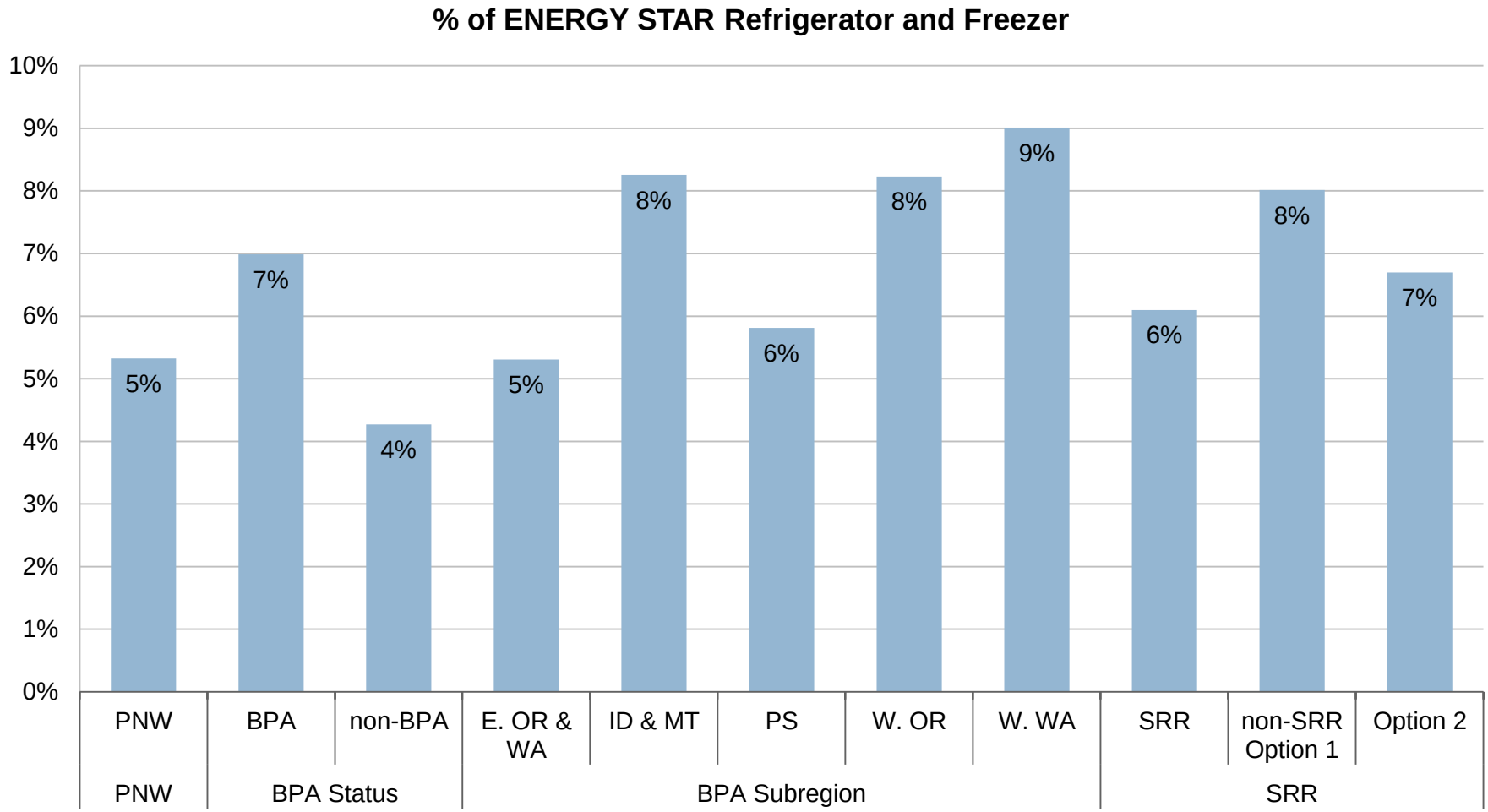


Note: Shaded color bars indicate small bases (< 30).

1. More than half of the refrigerators/freezers in the BPA region (52%) were manufactured after 2001.
2. Rural and suburban regions have higher concentrations of old refrigerators/freezers. 21% of refrigerators/freezers in rural areas and 19% of refrigerators/freezers in suburban areas were purchased before 1991.
3. E. Oregon and Washington have the greatest proportion of refrigerators/freezers purchased before 1991.



1. Only 7% of refrigerators/freezers in BPA region homes are Energy Star. This is slightly more than in the non-BPA region.
2. Energy Star refrigerators/freezers are more common in W. Washington, W. Oregon, Idaho and Montana than in Puget Sound, E. Oregon and Washington.



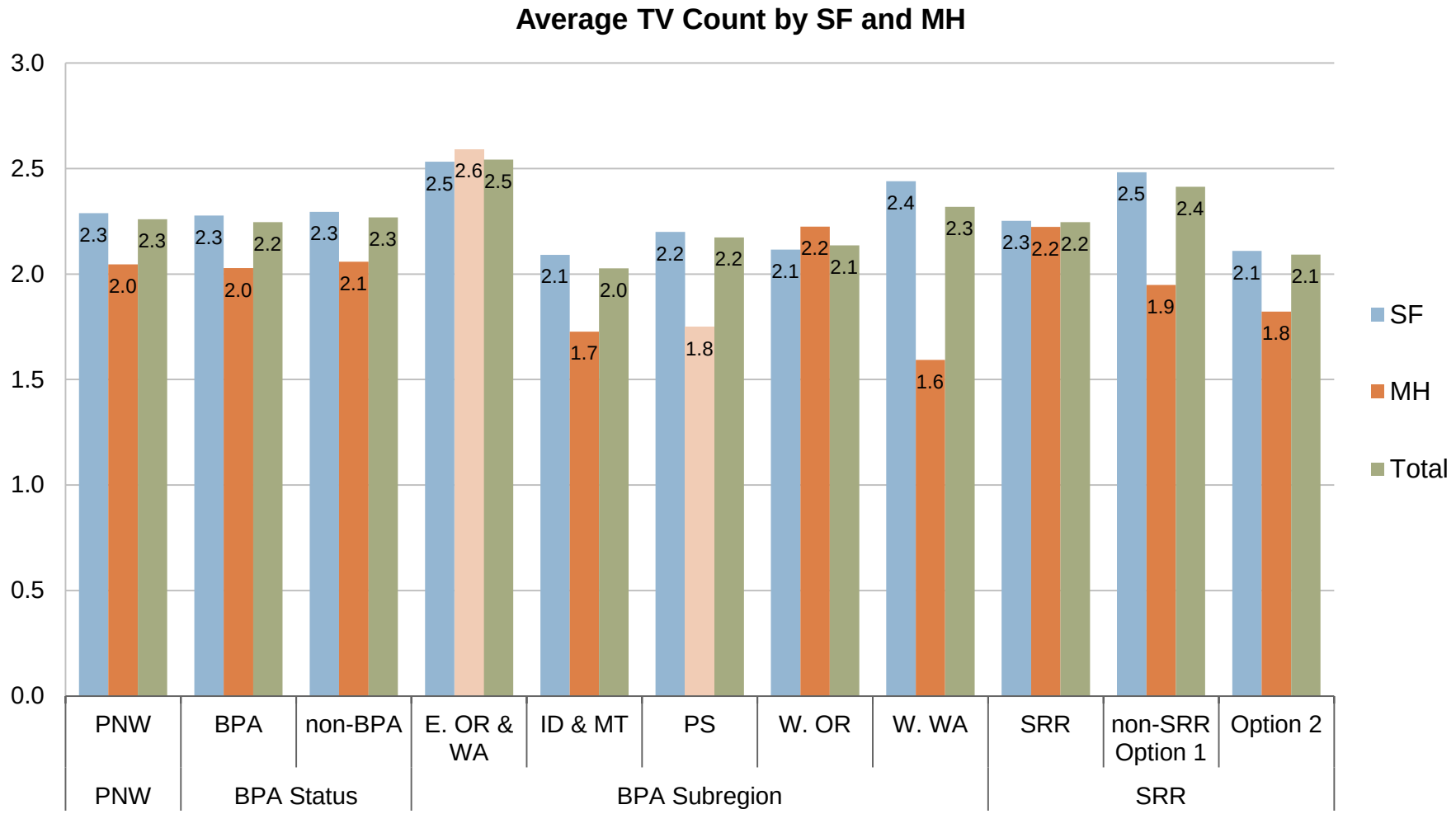
Note: Ecotope clarified that Energy Star status was verified with make and model number on the manufacturers websites which showed the Energy Star status at the time of manufacture.

Electronics (SF and MH together)

Areas	Dependent variables
TV	Average TV count
TV	Average TV count per occupant
TV	Distribution of TV type
Computers	Average computer count
Computers	Average computer count per occupant
Computers	Distribution of computer type

SF & MH – TV

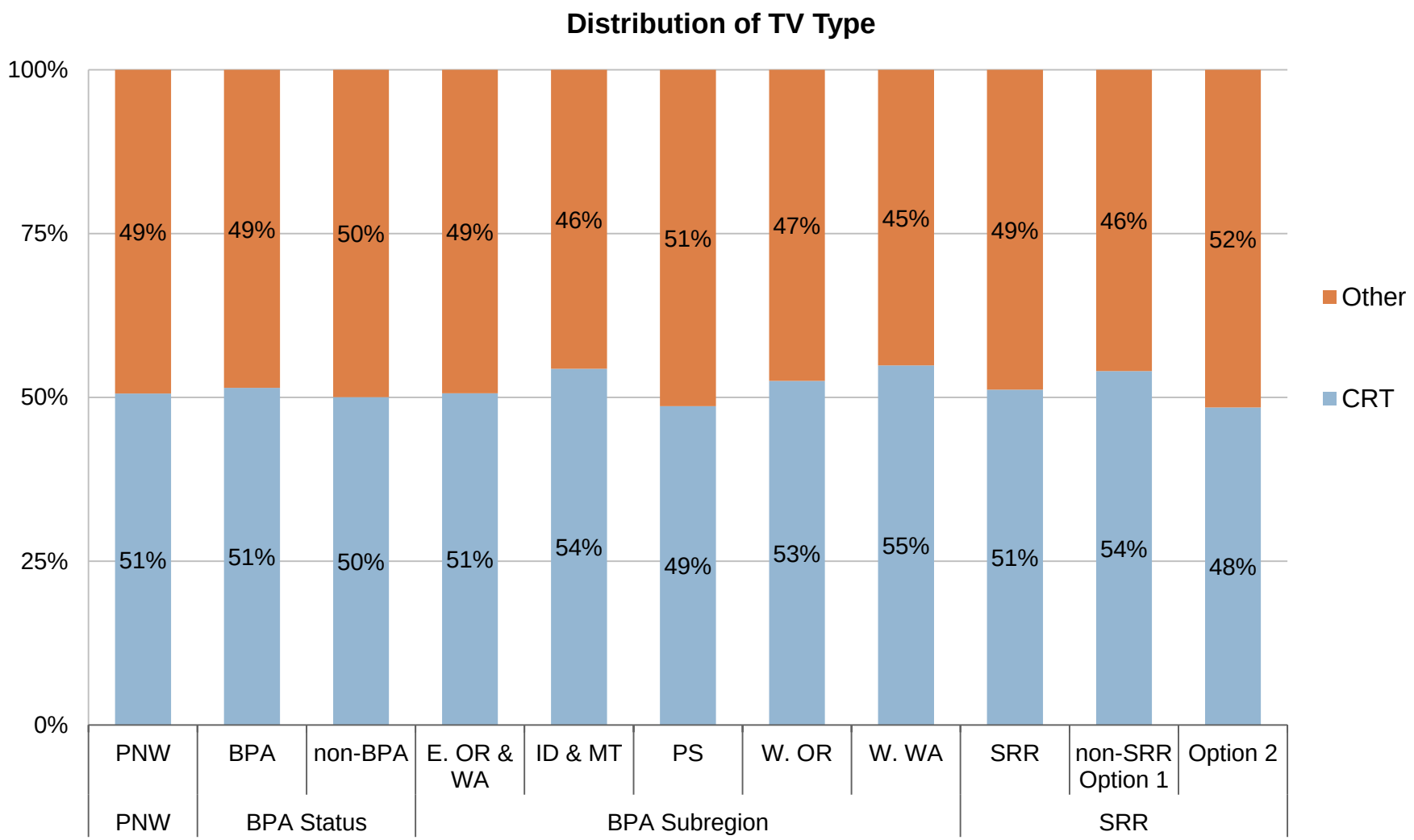
1. On average homes in the BPA region have 2.2 TVs. The average number of TVs in single-family homes is slightly larger than in manufactured homes.
2. Rural and suburban homes tend to have more TVs than urban homes.



Note: Shaded color bars indicate small samples (< 30).

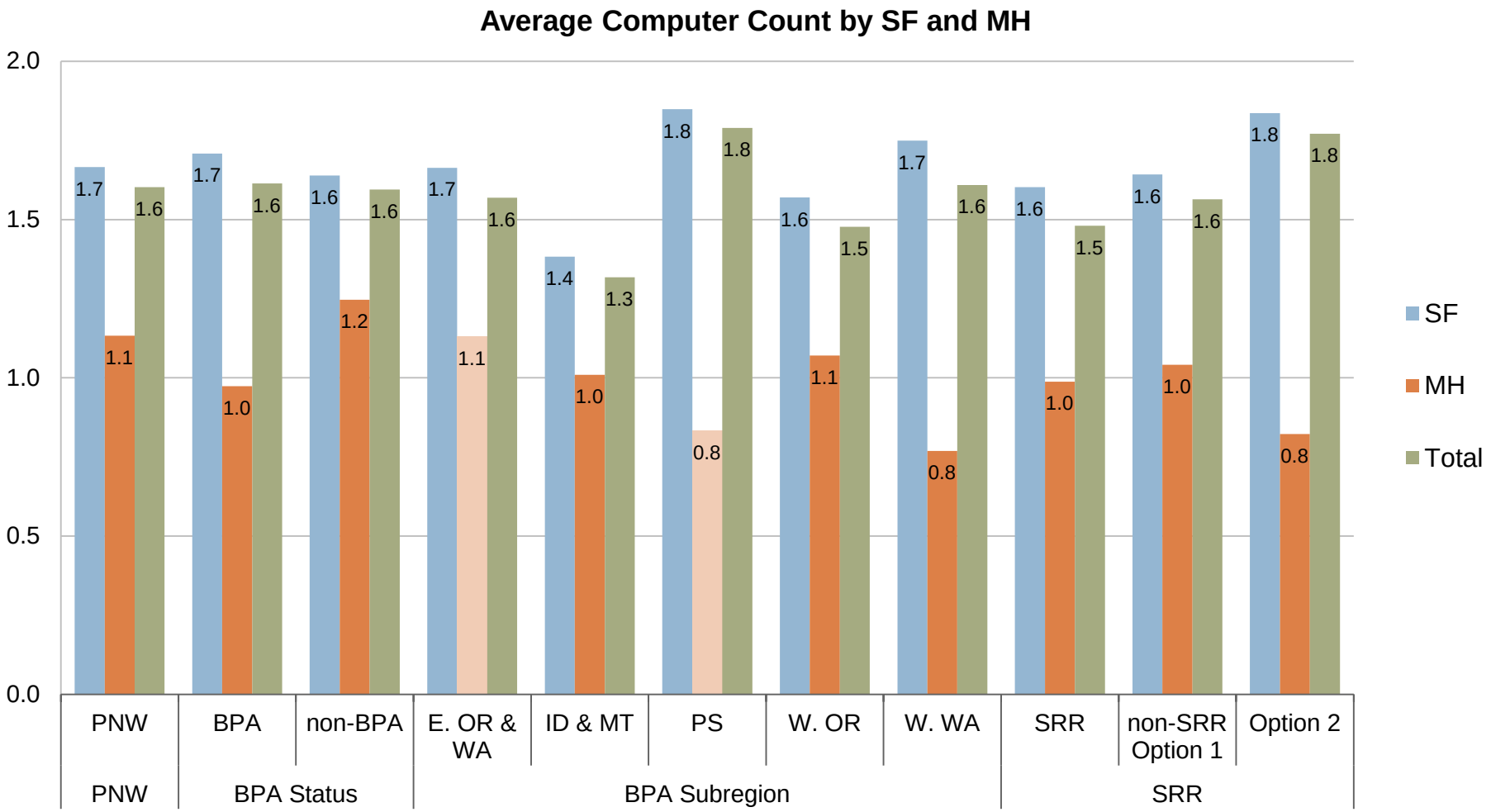
1. Non-CRT TVs account for about half of the TVs in the BPA region and non-BPA region homes. These proportions are similar across BPA regions.

SF & MH – TV



1. On average BPA region homes have 1.6 computers. Average computer count in manufactured homes is less than in single-family homes.
2. The average computer count is correlated with urbanization level. Urban homes have more computers on average than rural or suburban homes.
3. The average computer count varies with geographic region. The Puget Sound region has the highest average.

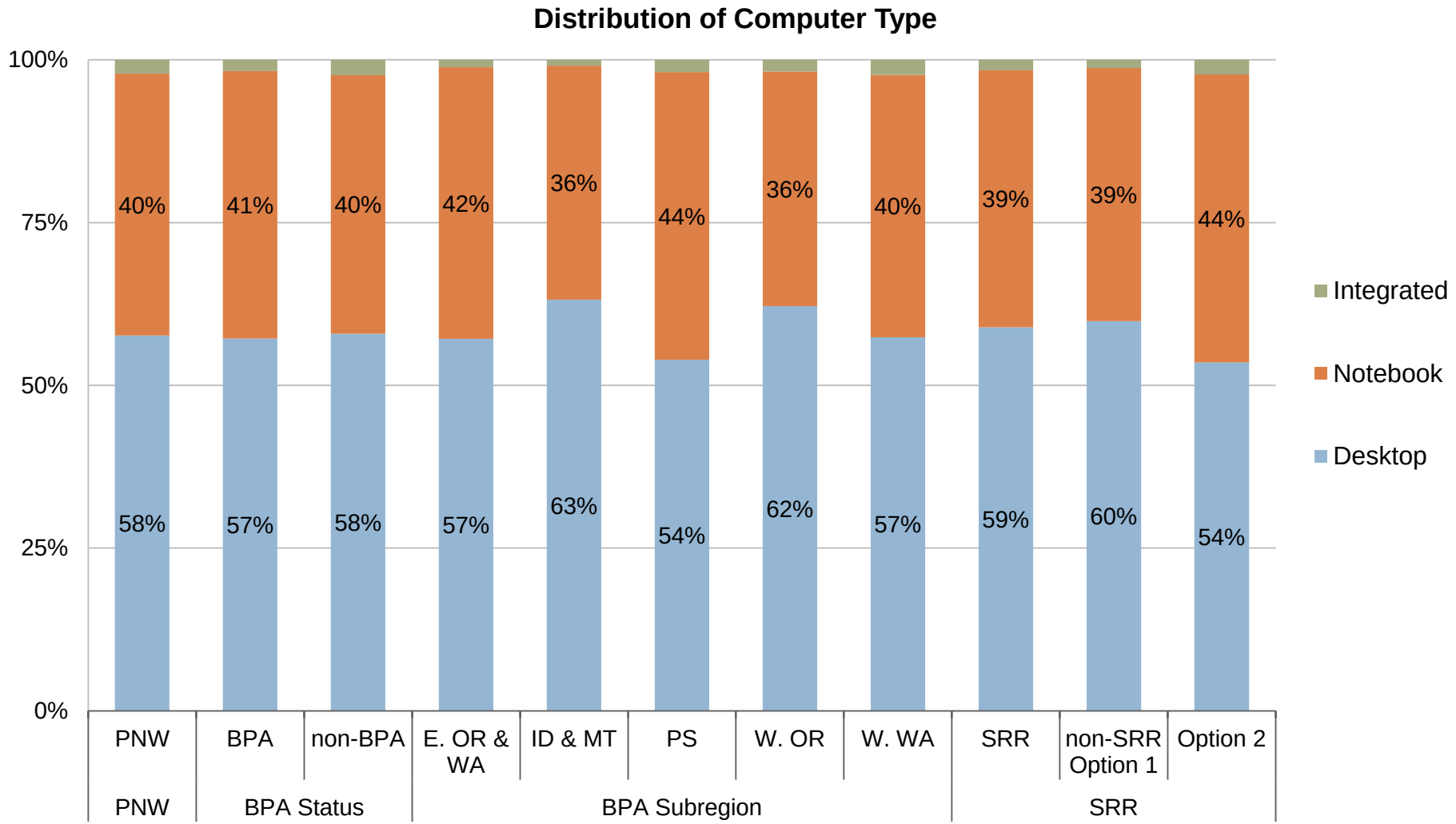
SF & MH – Computers



Note: Shaded color bars indicate small samples (< 30).

1. The majority of computers in the BPA region are desktop (57%).
2. Urban homes have a greater proportion of notebook computers than rural or suburban homes.

SF & MH – Computers



Summary – Appliances and Electronics

- More than half of the refrigerators and freezers in BPA region homes (52%) were bought after 2001.
- Rural and suburban regions have higher concentrations of old refrigerators. More than a quarter of refrigerators in Idaho and Montana were purchased before 1990, suggesting substantial efficiency opportunities.
- Only 7% of refrigerators and freezers in the BPA region are Energy Star at the time of manufacture. Due to frequent changes in Energy Star specifications, we recommend conducting further analysis by comparing the national Energy Star saturation of new unit purchases with that of the RBSA equipment in recent years (from 2008).
- BPA region homes have on average 2.2 TVs. Non-CRT TVs account for half of the TVs in the BPA region.
- On average homes in the BPA region have 1.6 computers. Manufactured homes have fewer computers on average than single-family homes.
- More than half of the computers in the BPA region are desktop. Notebook computers comprise 41% of the computers in BPA region homes.

Appendix A - Summary Statistics

Table A.1: Building Characteristics

AREAS	SUMMARY STATISTICS	DATABASE	METHODOLOGICAL DETAILS
Building vintage	Distribution of building vintage		
Building type	Distribution of building type		
Square footage	Distribution of square footage of conditioned space by building type		
Square footage	Average square footage of conditioned space by building type		
Square footage	Average square footage of conditioned space by building vintage		
Cubic volume	Distribution of cubic volume of conditioned space by building type		
Cubic volume	Average cubic volume of conditioned space by building type		
Cubic volume	Average cubic volume of conditioned space by building vintage		
Ceiling type	Distribution of ceiling type (location of ceiling insulation)	SF only	Area weighted proportion for multiple iterations of ceiling types. Percents represent proportions of different ceiling types among all the sampled sites.
Foundation	Distribution of foundation	SF only	
Natural gas use	% of sites with verified use of natural gas by building type		The variable indicates whether natural gas bills were both provided and able to be analyzed.
Building tenure	% of owner-occupied housing unit by building type		
Number of floor	Distribution of the number of floors	SF only	
Window area fraction	Average % of window area		Calculated ratio of window area square footage over site conditioned square footage.
Number of residents	Average number of residents		

Table A.2: Envelope

AREAS	SUMMARY STATISTICS	DATABASE	METHODOLOGICAL DETAILS
Attic insulation	Distribution of attic insulation level		Area weighted proportion for multiple iterations of attic insulations.
Attic insulation	Distribution of attic insulation level by vintage		Area weighted proportion for multiple iterations of attic insulations.
Floor insulation	Distribution of insulation level of floors above crawlspaces among sites without crawl space wall insulation		Area weighted proportion for multiple iterations of floor insulations.
Floor insulation	Distribution of insulation level of floors above crawlspaces by vintage among sites without crawl space wall insulation		Area weighted proportion for multiple iterations of floor insulations.
Wall insulation	Distribution of framed wall insulation level		Area weighted proportion for multiple iterations of wall insulations.
Wall insulation	Distribution of framed wall insulation level by vintage		Area weighted proportion for multiple iterations of wall insulations.
Window U value	Distribution of window U-value of wood, vinyl, fiberglass, single pane window	Aggregated U value in MH	Window area weighted for multiple iterations of the same windows.
Window U value	Distribution of window U-value of wood, vinyl, fiberglass, double pane window	Aggregated U value in MH	Window area weighted for multiple iterations of the same windows.
Window U value	Distribution of window U-value of wood, vinyl, fiberglass, triple pane window	Aggregated U value in MH	Window area weighted for multiple iterations of the same windows.
Window U value	Distribution of window U-value of metal single pane window	Aggregated U value in MH	Window area weighted for multiple iterations of the same windows.
Window U value	Distribution of window U-value of metal double pane window	Aggregated U value in MH	Window area weighted for multiple iterations of the same windows.
Window U value	Distribution of window U-value of metal triple pane window	Aggregated U value in MH	Window area weighted for multiple iterations of the same windows.
Window U value	Distribution of U-value of primary window type		
Blow door test	Distribution of ACH50 (air changes calculated at 50 Pa pressure)		
Blow door test	Average ACH50 by vintage		

Table A.3: HVAC

AREAS	SUMMARY STATISTICS	DATABASE	METHODOLOGICAL DETAILS
Heating system and fuel	Distribution of primary heating equipment and fuel type		Oil, propane, pellets, wood fuel type are collapsed under "- other fuel". Heatpump - electric includes GSHP-electric and Heatpumpdualfuel-electric. Weighted proportions for multiple iterations with the same weight value in HVACPrimaryWeights.
Heating system and fuel	Distribution of secondary heating equipment and fuel type		Oil, propane, pellets, wood fuel type are collapsed under "- other fuel". Heatpump - electric includes GSHP-electric and Heatpumpdualfuel-electric. Weighted proportions for multiple secondary systems assuming equal distribution of use.
Heating system and fuel	Distribution of heating fuel		
Heating system and fuel	Average annual reported wood consumption (kBtu)		Analysis is among sites that use electricity as primary heating fuel or wood as primary and electric as secondary.
Efficiency	Average efficiency of primary heating equipment type/fuel		For multiple iterations, maximum efficiency equipment was selected for primary equipment type/fuel.
Efficiency	Average efficiency of secondary heating equipment type/fuel	SF only	Average value was selected for secondary equipment type/fuel when multiple iterations.
Resistance heat	Average plug-in heater count among sites with plug-in heater		Analysis is among sites with plug-in heater.
Resistance heat	Average baseboard count among sites with baseboard	SF only	Analysis is among sites with baseboard.
Cooling system	Distribution of primary cooling equipment type		Proportions are weighted to account for multiple iterations of primary cooling equipment (multiple primary equipment with the same weight value).
Cooling system	Average SEER of primary cooling equipment		Analysis is among sites with central AC or heatpump.
Cooling system	% of sites reporting window AC		
Cooling system	Average window AC unit count among sites with window AC		Analysis is among sites with window AC (PTAC and window shaker combined).
Ducts	Distribution of duct type by heating climate zone		

Areas	Summary Statistics	Database	Methodological Details
Ducts	% of homes with ducted systems with >50% or more supply ducts in accessible unconditioned space by heating climate zone	SF only	Analysis is among sites with ducts and electric primary heating system.
Ducts	% of homes with ducted systems with >50% of supply ducts in conditioned space by heating climate zone	SF only	Analysis is among sites with ducts and electric primary heating system.
Ducts	% of homes with ducted systems with >50% of return ducts in unconditioned space by heating climate zone	SF only	Analysis is among sites with ducts and electric primary heating system.
Ducts	Distribution of space where the majority of return ventilation ducts are located by heating climate zone		
Ducts	Distribution of space where the majority of supply ventilation ducts are located by heating climate zone		
Ducts	Average total unconditioned surface area of all return ducts by heating climate zone	SF only	
Ducts	Average total unconditioned surface area of all supply ducts by heating climate zone	SF only	
Ducts	Average duct leakage to outside, CFM50, by heating climate zone	SF only	Summing return and supply duct leakage values.
Ducts	Average tested duct leakage ratio at half plenum pressure divided by tested air handler flow rate by heating climate zone	SF only	Summing return and supply duct leakage ratio values.
Ducts	Average % of good duct condition by climate zone by heating climate zone	SF only	

Table A.4: Lighting

Areas	Summary Statistics	Database	Methodological Details
Lamp type	Distribution of interior lamp type by room	SF and MH combined	Used counts of all lamps by type at each sites. Denominator is a total lamp count not a total number of sites.
Lamp type	Average lamp count by type in each room	SF and MH combined	Used counts of all lamps by type at each sites. Denominator is a total number of sites.
Lamp type	Average interior lighting watts by lamp type	SF and MH combined	Used counts of all lamps by type at each sites. Denominator is a total lamp count not a total number of sites.

Areas	Summary Statistics	Database	Methodological Details
Lamp type	Distribution of interior lamps EISA compliance	SF and MH combined	Used counts of all lamps by type at each sites. Denominator is a total lamp count not a total number of sites.
Fixture	Distribution of lamp fixture	SF and MH combined	Used counts of all fixtures by type at each sites. Denominator is a total lamp fixture not a total number of sites.
Lighting Power Density	Average interior LPD by room	SF and MH combined	Summed average LPD by room at each sites. Denominator is a total number of sites with each room type.
Lighting Power Density	Average sitewide LPD by building type	SF and MH combined	Summed average LPD by room at each sites. Denominator is a total number of sites.
Exterior lighting	Distribution of exterior lamp type	SF and MH combined	Used counts of all lamps by type at each sites. Denominator is a total lamp count not a total number of sites.
Exterior lighting	Average exterior lighting watts by lamp type	SF and MH combined	Used counts of all lamps by type at each sites. Denominator is a total lamp count not a total number of sites.

Table A.5: Water Technologies

Areas	Summary Statistics	Database	Methodological Details
Showerhead	Average showerhead count	SF and MH combined	
Showerhead	Distribution of flow rate of primary showerhead	SF and MH combined	
Showerhead	Average shower flow rate	SF and MH combined	
Water heater	Distribution of water heater type and fuel	SF and MH combined	
Water heater	Distribution of water heater location	SF and MH combined	Analysis is among sites using electricity for water heating and among sites where the water heater is located within conditioned space
Water heater	Distribution of water heater tank size	SF and MH combined	Analysis is among sites using electricity for water heating
Water heater	Distribution of water heater tank wrapped by conditioned space	SF and MH combined	Analysis is among sites using electricity for water heating
Water heater	Distribution of water heater year of manufacture	SF and MH combined	Analysis is among sites using electricity for water heating
Water heater	% of site with water heater located in a room greater than 1,000 cubic feet	SF and MH combined	Analysis is among sites using electricity for water heating

Areas	Summary Statistics	Database	Methodological Details
Water heater	% of site with 8 feet of vertical space above water heater	SF and MH combined	Analysis is among sites using electricity for water heating

Table A.6: Appliances

Areas	Summary Statistics	Database	Methodological Details
Refrigerator and freezer	Average refrigerator and freezer count	SF and MH combined	
Refrigerator and freezer	Distribution of refrigerator and freezer manufacture age	SF and MH combined	Used counts of all refrigerator and freezer by manufacture age at each sites. Denominator is a total refrigerator and freezer count not a total number of sites.
Refrigerator and freezer	% of Energy Star refrigerator and freezer	SF and MH combined	Denominator is a total refrigerator and freezer count not a total number of sites.

Table A.7: Electronics

Areas	Summary Statistics	Database	Methodological Details
TV	Average TV count	SF and MH combined	
TV	Average TV count per occupant	SF and MH combined	
TV	Distribution of TV type	SF and MH combined	Used counts of all TVs at each sites. Denominator is a total TV count not a total number of sites.
Computers	Average computer count	SF and MH combined	
Computers	Average computer count per occupant	SF and MH combined	
Computers	Distribution of computer type	SF and MH combined	Used counts of all computers at each sites. Denominator is a total computer count not a total number of sites.

Appendix B - Utility Domains

Table B.1: Utility Domains

Utility Name	BPA Status	BPA Sub-region	SRR Status
Benton Rural Electric Assn	BPA	Eastern Oregon and Washington	SRR
Blachly-Lane Cnty Coop El Assn	BPA	Western Oregon	SRR

Utility Name	BPA Status	BPA Sub-region	SRR Status
Bonners Ferry Electric Department, City of	BPA	ID_MT	SRR
Canby Utility Board	BPA	Western Oregon	non-SRR Option 1
Central Electric Coop Inc	BPA	Eastern Oregon and Washington	SRR
Central Lincoln People's Ut Dt	BPA	Western Oregon	non-SRR Option 1
City of Ashland	BPA	Western Oregon	non-SRR Option 1
City of Bandon	BPA	Western Oregon	SRR
City of Blaine	BPA	PS	SRR
City of Burley	BPA	ID_MT	non-SRR Option 1
City of Centralia	BPA	WWA	non-SRR Option 1
City of Cheney	BPA	Eastern Oregon and Washington	non-SRR Option 1
City of Ellensburg	BPA	Eastern Oregon and Washington	non-SRR Option 1
City of Forest Grove	BPA	Western Oregon	non-SRR Option 1
City of Milton-Freewater	BPA	Eastern Oregon and Washington	non-SRR Option 1
City of Monmouth	BPA	Western Oregon	SRR
City of Plummer	BPA	ID_MT	SRR
City of Richland	BPA	Eastern Oregon and Washington	non-SRR Option 1
City of Soda Springs	BPA	ID_MT	SRR
City of Springfield	BPA	Western Oregon	Option 2
City of Troy	BPA	ID_MT	SRR
City of Weiser	BPA	ID_MT	SRR
Clatskanie Peoples Util Dist	BPA	Western Oregon	non-SRR Option 1
Clearwater Power Company	BPA	ID_MT	SRR
Columbia Basin Electric Cooperative, Inc.	BPA	Eastern Oregon and Washington	SRR
Columbia Power Coop Assn Inc	BPA	Eastern Oregon and Washington	SRR
Columbia Rural Elec Assn, Inc	BPA	Eastern Oregon and Washington	SRR
Consumers Power, Inc	BPA	Western Oregon	SRR
Coos-Curry Electric Coop, Inc	BPA	Western Oregon	non-SRR Option 1
Douglas Electric Coop, Inc	BPA	Western Oregon	SRR
Elmhurst Mutual Power & Light Co	BPA	PS	SRR

Utility Name	BPA Status	BPA Sub-region	SRR Status
Emerald People's Utility Dist	BPA	Western Oregon	SRR
Eugene City of	BPA	Western Oregon	Option 2
Fall River Rural Elec Coop Inc	BPA	ID_MT	SRR
Farmers Electric Company, Ltd	BPA	ID_MT	SRR
Flathead Electric Coop Inc	BPA	ID_MT	non-SRR Option 1
Glacier Electric Coop, Inc	BPA	ID_MT	SRR
Hood River Electric Coop	BPA	Eastern Oregon and Washington	non-SRR Option 1
Idaho Cnty L&P Coop Assn, Inc	BPA	ID_MT	SRR
Idaho Falls City of	BPA	ID_MT	non-SRR Option 1
Inland Power & Light Company	BPA	Eastern Oregon and Washington	SRR
Kootenai Electric Coop Inc	BPA	ID_MT	SRR
Lane Electric Coop Inc	BPA	Western Oregon	SRR
McMinnville City of	BPA	Western Oregon	non-SRR Option 1
Midstate Electric Coop, Inc	BPA	Eastern Oregon and Washington	SRR
Missoula Electric Coop, Inc	BPA	ID_MT	SRR
Modern Electric Water Company	BPA	Eastern Oregon and Washington	non-SRR Option 1
Northern Lights, Inc	BPA	ID_MT	SRR
Northern Wasco County PUD	BPA	Eastern Oregon and Washington	non-SRR Option 1
Ohop Mutual Light Company, Inc	BPA	PS	SRR
Okanogan County Electric Cooperative, Inc.	BPA	Eastern Oregon and Washington	SRR
Orcas Power & Light Coop	BPA	PS	SRR
Oregon Trail El Cons Coop, Inc	BPA	Eastern Oregon and Washington	non-SRR Option 1
Peninsula Light Company	BPA	PS	SRR
Port Angeles City of	BPA	WWA	non-SRR Option 1
Public Utility District No 1 (Wahkiakum Co)	BPA	WWA	SRR
Public Utility District No 2 (Pacific Co)	BPA	WWA	non-SRR Option 1
PUD No 1 of Benton County	BPA	Eastern Oregon and Washington	non-SRR Option 1
PUD No 1 of Clallam County	BPA	WWA	non-SRR Option 1
PUD No 1 of Clark County	BPA	WWA	non-SRR Option 1

Utility Name	BPA Status	BPA Sub-region	SRR Status
PUD No 1 of Cowlitz County	BPA	WWA	non-SRR Option 1
PUD No 1 of Ferry County	BPA	Eastern Oregon and Washington	SRR
PUD No 1 of Franklin County	BPA	Eastern Oregon and Washington	non-SRR Option 1
PUD No 1 of Grays Harbor Cnty	BPA	WWA	non-SRR Option 1
PUD No 1 of Klickitat County	BPA	Eastern Oregon and Washington	SRR
PUD No 1 of Lewis County	BPA	WWA	SRR
PUD No 1 of Mason County	BPA	WWA	SRR
PUD No 1 of Okanogan County	BPA	Eastern Oregon and Washington	non-SRR Option 1
PUD No 1 of Pend Oreille Cnty	BPA	Eastern Oregon and Washington	non-SRR Option 1
PUD No 1 of Skamania Co	BPA	WWA	SRR
PUD No 2 of Grant County	BPA	Eastern Oregon and Washington	SRR
PUD No 3 of Mason County	BPA	WWA	non-SRR Option 1
Ravalli County Elec Coop, Inc	BPA	ID_MT	SRR
Rupert City of	BPA	ID_MT	SRR
Salem Electric	BPA	Western Oregon	non-SRR Option 1
Salmon River Electric Coop Inc	BPA	ID_MT	SRR
Seattle City of	BPA	PS	Option 2
Snohomish County PUD No 1	BPA	PS	Option 2
Tacoma City of	BPA	PS	Option 2
Tillamook Peoples Utility Dist	BPA	Western Oregon	non-SRR Option 1
Umatilla Electric Cooperative Association	BPA	Eastern Oregon and Washington	SRR
United Electric Co-op, Inc	BPA	ID_MT	non-SRR Option 1
USBIA-Mission Valley Power	BPA	ID_MT	SRR
Vera Irrigation District #15	BPA	Eastern Oregon and Washington	non-SRR Option 1
Vigilante Electric Coop, Inc	BPA	ID_MT	SRR
Wasco Electric Coop, Inc	BPA	Eastern Oregon and Washington	SRR
West Oregon Electric Coop Inc	BPA	Western Oregon	SRR
Avista Corp	non-BPA		
Idaho Power Co	non-BPA		

Utility Name	BPA Status	BPA Sub-region	SRR Status
NorthWestern Corporation	non-BPA		
PacifiCorp	non-BPA		
Portland General Electric Co	non-BPA		
PUD No 1 of Chelan County	non-BPA		
PUD No 1 of Douglas County	non-BPA		
Puget Sound Energy Inc	non-BPA		