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REPORT #E20-405

2019-2020 Washington Residential New Construction Code Study

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Executive Summary

The Northwest Energy Efficiency Alliance (NEEA) commissioned a research study to better understand how the 2015 Washington State Energy Code (Residential Provisions)[1] has affected new home construction and energy performance. The research team visited building code offices and single-family residences between September 2019 and January 2020. In the end, 184 houses were visited in 37 jurisdictions throughout the state. Analysis of the data provides insight into how, among options available, builders are choosing to comply with the energy code, observed levels of compliance, and expected home energy performance.

Methodology

The team applied a research design that aligned with the U.S. DOE compliance study methodology[2] as closely as possible. The structure of the 2015 Washington State Energy Code is unique in that it contains both a section for required measures that must be achieved, as well as a section where the builder earns a required number of code credits, based on selecting some measures from a longer list of credited measures. Due to this, the team modified the standard methodology by breaking the study into two phases.

Phase 1 focused on outreach to building departments and documents review to identify options selected by builders to comply with the additional energy efficiency requirements of the code. Collection and analysis of building permit data were performed to characterize code compliance based on selected credit options from Washington State Energy Credit Table R406.2. The analysis identified four items most frequently selected by builders from Table R406.2, in addition to the seven key items identified in the U.S. DOE methodology.

Phase 2 focused on site visits to houses under various stages of construction to observe construction practices and compliance with the code. The team developed a sample plan for this and collected data at homes in selected jurisdictions. Data was collected from field observations on newly constructed single-family homes to understand construction practices and building and mechanical efficiencies. Analysis of the data identified compliance rates of high-impact prescriptive and additional energy credit options of the code. The energy impact of non-compliance for each key item and overall statewide averages were also modeled

Results

From the wide variety of available options, data from Phase 1 shows that almost 92% of homes are built using just six combinations of the additional energy efficiency requirements from Table R406.2 as identified in Table ES1. The key items with the highest impact on savings are identified in Table ES2. The estimated values represent potential annual statewide savings for bringing each measure into compliance and cumulative projected statewide savings.

[1] The Washington State Energy Code, Residential Provisions document, can be found here: www.energy.wsu.edu/Documents/2015WSEC_R_final.pdf

[2] https://www.energy.gov/sites/prod/files/2018/06/f52/bto-Res-Field-Study-Methodology-060618-2.pdf

Table ES1 - % of Builders Selecting Specific Options Combinations

Code Category	Options Within Category	Credits Per Option	Option Description	Options Combination A	Option Combination B	Option Combination C	Option Combination D	Option Combination Comb. E	Option Combination Comb. F	Total Option Pct[3]
Envelope	1a	0.5	Vert Fen U 0.28; Floor R 38	●		●	●			66.2%
	1b	1.0	Vert fen U 0.25, Wall R21 + R4 Floor R38							1.2%
	1c	2.0	Vert Fen U 0.22; Ceiling R49a							0.0%
	1d	0.5	Vertical Fenestration U=0.24						●	4.1%
Air Seal	2a	0.5	3.0 ACH		●	●	●			34.6%
	2b	1.0	2.0 ACH							2.2%
	2c	1.5	1.5 ACH							0.3%
HVAC	3a/3b/3d	1.0	High Eff Furnace, Heat Pump, Ductless Heat Pump	●	●	●	●	●	●	97.6%
	3c	1.5	Ground Source Heat Pump							0.8%
	4	1.0	Ducts Inside Conditioned Space					●		8.5%
Domestic Hot Water	5a	0.5	Low Flow Showerhead and Faucets	●	●		●	●	●	85.2%
	5b	1.0	0.74 EF Fuel Fired or 2.0 EF Heat Pump Water Heater				●	●		12.2%
	5c	1.5	0.91 EF Fuel Fired or 2.0 EF NEEA Qualified Heat Pump Water Heater	●	●	●			●	87.7%
	5d	0.5	Drain Water Heat Recovery							0.2%
Renewable	6	0.0-3.0	1200 kWh annual generation							0.0%
			% Homes Using Option Combo	48.1%	20.7%	8.9%	5.0%	4.8%	4.1%	

[3] Total Option Percentage refers to the percentage of homes using each option.

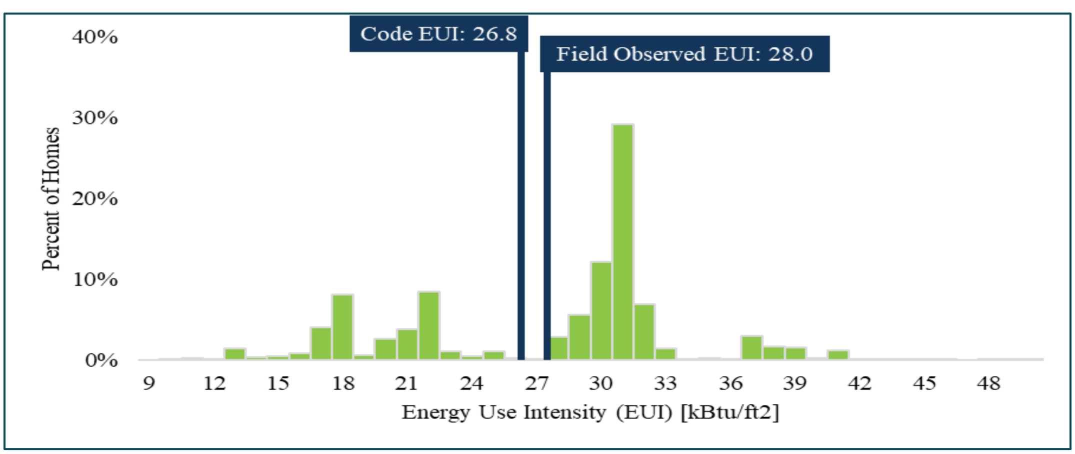
Table ES2 Estimated Annual Statewide Savings Potential in Washington

Measure	Total Energy Savings (MMBtu/year)	Total Energy Cost Savings ($/year)
Wall Insulation	25,672	328,142
Air Sealing	7,019	91,558
Duct Tightness	6,218	75,733
Low-Flow Fixtures	5,816	73,124
DHW	3,653	63,694
Ceiling Insulation	2,438	31,202
Foundation Insulation	1,116	14,028
Total	51,932	677,480

In the statewide analysis there are two sets of models: the baseline and observed. The baseline model is a weighted prototype analysis using the code requirements as inputs. The observed model uses the findings from the field data collection to estimate the implemented energy use of homes by factoring in the non-compliance findings and not allowing the above-code findings to offset those deficiencies. If a key item was found to only comply 75% of the time, then the individual model runs to build up the observed model will have an expected compliance of 75% as well.

Using this methodology to build up a random sample of homes across the state using the probability findings of the individual measures yields the results shown in Figure ES1. The bars represent the findings from the observed models and the two reference lines are the mean EUI from the baseline model (Code EUI) and the mean EUI from the observed model (Field Observed EUI). Figure ES1 indicates the impact of non-compliance observed in homes is estimated to result in energy use that is 4.5% greater than if all homes were built to just meet code (Field Observed EUI of 28.0 versus Code EUI of 26.8).

Figure ES1 Average Modeled Distribution of Regulated EUI (kBtu/ft²/year) for Homes in Washington



Acknowledgments

The project was led by CLEAResult staff with support from:

- Luke Howard – Building department outreach, permit documentation and plans review
- David Freelove of Cornerstone Integrated Industries – Builder outreach and project site data collection
- Pivotal Energy Solutions – Data collection tool development
- Mark Halverson –Pacific Northwest National Laboratory, study design and analysis consultant

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Acronyms and Abbreviations

AC	air conditioning
ACH	air changes per hour
AFUE	annual fuel utilization efficiency
AXIS	cloud-hosted data collection tool produced by Pivotal Energy Solutions
BTU	British thermal unit
cfm	cubic feet per minute
CZ	climate zone
DOE	U.S. Department of Energy
EF	energy factor
EUI	energy use intensity
HSPF	heating season performance factor
HVAC	heating, ventilation, and air conditioning
ICC	International Code Council
IECC	International Energy Conservation Code
kBtu	thousand British thermal units
kWh	kilowatt hours
MMBtu	million British thermal units
NEEA	Northwest Energy Efficiency Alliance
Pa	Pascals, unit of pressure in kilogram/(meter)(second^2)
PNNL	Pacific Northwest National Laboratory
R-value	resistance to heat flow
RESNET	Residential Energy Services Network
SEEM	Simplified Energy Enthalpy Model
SHGC	solar heat gain coefficient
U-factor	overall coefficient of heat transfer
WRNC	Washington Residential New Construction

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1. Introduction

The Northwest Energy Efficiency Alliance (NEEA) hired CLEAResult to lead the Washington Residential New Construction (WRNC) Code study, with support from Cornerstone Integrated Industries. The objective of the study is to understand compliance trends, energy impact, and to gather other insights into residential new construction under the Washington code.

A note about the Washington State Energy Code: The International Code Council produces the International Energy Conservation Code (IECC). The IECC is a prescriptive or performance-based code. The standard U.S. Department of Energy (DOE) methodology is designed to assess compliance with the IECC code using the prescriptive compliance path. Like many other states, Washington adopted the IECC, however, significant modifications to its structure are applied to include additional energy efficiency requirements discussed below.

The study is designed to produce results that are comparable to other states by applying DOE's methodology. The DOE methodology identifies the key building components and measures as required in the IECC mandatory and prescriptive sections that have the largest impact on energy consumption. DOE's methodology is designed to obtain a statistically significant sample of each of these components, assuming the home is constructed to meet the code requirements using the prescriptive path.

Unlike the basic IECC, the 2015 Washington State Energy Code (referred to as the Washington code) is not completely prescriptive. It requires builders to incorporate selected energy credit options to meet additional energy-efficiency requirements. In addition to some mandatory and prescriptive code elements (insulation, fenestration, air leakage, duct leakage), the code requires builders to select additional elements from a list of options identified in the Washington code (Table R406.2, referred to as the Energy Credit Table). Each option on the list has an associated number of energy credits and the builder must select a combination of options to meet the required number of credits, based on the size of the house.[4]

The nuanced structure of the Washington code requires a different sample design approach than states that follow the IECC directly and maintain a straightforward prescriptive code table. The modified approach was to conduct the study in two distinct phases, with the results of the first phase—document review—serving to inform the second phase—site visits and field data collection. In practice, this study adapted DOE's methodology to better serve the Washington state code by adding more key items to be collected during field inspections, while keeping the essential elements of the methodology intact.

As noted above, the Washington code requires compliance with prescriptive and additional energy credit options. For this project, the research objectives are to:

[4] The additional energy efficiency requirements, including optional measures and the associated credits required to comply, are detailed in Section R406 and Table R406.2 on page RE-34 of the 2015 Washington State Energy Code. www.energy.wsu.edu/Documents/2015WSEC_R_final.pdf An abbreviated version of Table R406.2 is found in Appendix D Table R406.2 Energy Credits (2015 Code)

- Characterize code compliance pathways, especially which additional energy credit options are commonly chosen
- Assess compliance rates of key measures with energy impacts
- Align with DOE compliance study methodology wherever appropriate to support consistent application of findings and summarize additional items identified by the project team and NEEA related to the additional energy credit options not covered by the DOE methodology (e.g., HVAC and domestic hot water)
- Analyze the energy impact of non-compliance using Simplified Energy Enthalpy Model (SEEM)[5] modeling for each key item and overall statewide average.

The report is organized into an executive summary, five major sections, and several appendices. We introduce the project in section one. We describe the energy code compliance document review which we also refer to as Phase 1 in section two. This section includes a thorough description of the document review methodology and findings. We summarize visits to residential sites—Phase 2—in section three. This section begins with a discussion of methodology which is followed by findings for individual measures and statewide analysis. We include anecdotal findings from the field work at the end of section three. In section four, we summarize statewide potential energy savings if all new residential construction met the energy code. References are listed in section five and supporting information is included in the appendices.

[5] More information on SEEM can be found in Appendix G Simplified Energy-Enthalpy Model (SEEM). SEEM is the standard modeling software for conducting prototype analysis for the Regional Technical Forum (RTF) in the Northwest.

2. Document Review – Phase 1

As described above, the project team conducted the WRNC study in two phases to tailor our approach to the unique structure of the Washington energy code residential provisions. As noted above, the additional 17 energy credit options (see Appendix D) in the Washington code requires a different study approach than states that follow the IECC directly and maintain a straightforward prescriptive code table; applying the DOE methodology to all combinations of 17 options that a builder could choose to meet the additional energy credits is not feasible. The project team identified that most houses are being built using a limited combination of options that would limit the required number of houses to inspect. The team used the document review process (Phase 1) findings to inform a WRNC study strategy for Site Visits (Phase 2). In this way we could, in an operationally feasible manner, closely follow DOE methodology by focusing on the DOE key items and the additional key items found in the most common compliance paths documented in Phase 1.

Phase 1 focused on jurisdiction outreach and review of code documentation to identify the most common energy credit options builders selected to meet the energy code. Activities included review of 342 building plan sets and energy credit options at 20 jurisdictions, identified in the initial sampling plan (discussed below in Section 2.1.1). Analysis of Phase 1 data was used to define data collection targets for Phase 2, i.e. to identify the most commonly used compliance pathways and the key items selected to meet the unique Washington code credit requirements. With this information, we were able to plan for data collection of statistically meaningful samples of the DOE key items and those we identified as key option items most often selected by builders.

These activities are described in detail in the following sections.

2.1 Methodology

DOE's residential building energy code field study methodology (herein refer to the DOE methodology) is applicable to any state that adopts IECC with same code structure, with or without amendments. DOE's methodology identifies seven key items that have the greatest direct impact on residential energy consumption. These key items form the foundation of the methodology and drive the sampling, data analysis, and results assessment. Those key items are:

1. Envelope tightness (ACH at 50 Pa)
2. Windows (U-factor & SHGC[3])
3. Wall insulation (assembly U-factor)
4. Ceiling insulation (R-value)
5. Lighting (% high-efficacy)
6. Foundation insulation (assembly U-factor)
7. Duct tightness (CFM per 100 sq. ft. of conditioned floor area at 25 Pa).

The DOE methodology is directed at understanding how well key items are being incorporated into residential new construction. The methodology requires randomly selecting and observing

[3] Note that SHGC is not included in the Washington State Energy Code

each key item 63 times across the state to produce statistically significant results. The variation in required additional energy credit options in the Washington code introduces unknowns in the needed observation counts.

The structure of the Washington code required a different sample design approach than the approach used for states that follow the IECC directly and maintain a straightforward prescriptive code table. The project team collected data in Phase 1 to identify the additional energy credit options that builders selected. Builders in Washington must select enough options to achieve the minimum number of Energy Credits based on the conditioned floor area of the house as shown in Table 1 below.

Table 1 Energy Credit Requirements Based on Conditioned Floor Area

Description	Conditioned Floor Area	Required Credits
Small Dwelling Unit	<1,500 sq. ft.	1.5 credits
Medium Dwelling Unit	Between Small and Large	3.5 credits
Large Dwelling Unit	>5,000 sq. ft.	4.5 credits

Phase 1 focused on collecting data from building departments on the options identified in the Energy Credit Table (See Appendix D), which include varying numbers of credits for implementing different levels of improvements beyond the prescriptive code as shown in Table 2 below.

Table 2 Efficiency Measures and Associated Credits

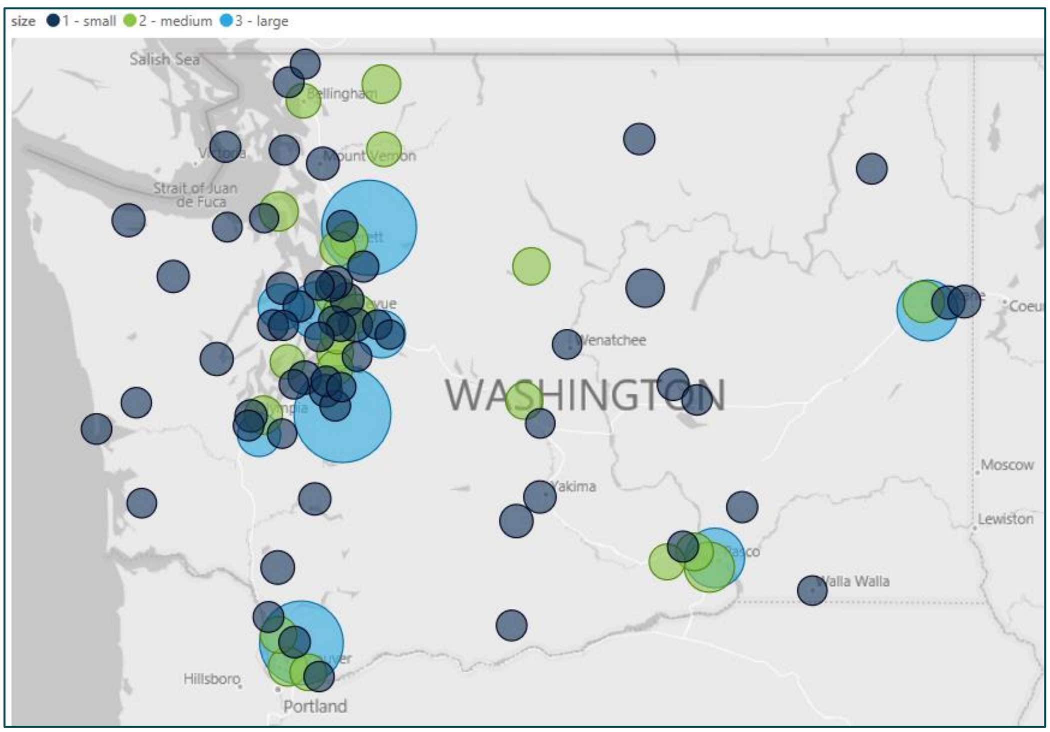
Energy Efficiency Measure Options	Potential Credits
Efficient Building Envelope	0.5–2.0
Air Leakage Control and Efficient Ventilation	0.5–1.5
High-Efficiency HVAC Equipment	1.0–1.5
High-Efficiency HVAC Distribution System	1.0
Efficient Water Heating	0.5–1.5
Renewable Electric Energy	0.5 per 1,200 kWh

To assist builders in selecting additional energy credit options, the State of Washington developed six suggested potential option combinations that utilize readily available equipment and minor envelope upgrades to satisfy the number of required credits for medium-sized homes. Appendix E Suggested Energy Credit Option Combinations includes the specific options included in each combination. Prior to collecting data in Phase 1 and considering key item compliance, the team suspected that these six combinations would be utilized for most projects. From those combinations, only three items in the DOE methodology were identified (floor insulation, window U-factor, envelope tightness) that are impacted by options in the Energy Credit Table. Among these three items, only two levels for each item, the baseline and one upgraded level, exist. In addition to the original seven key compliance items in a standard IECC-based state energy code study, we found four additional key items from the additional energy credit options (HVAC efficiency, water heater efficiency, duct location, water fixture flow rates) accounted for the vast majority of selected options for homes built in Washington. This insight allowed us to develop a Phase 2 site data collection and analysis plan to closely align with the DOE methodology, upon review and analysis of Phase 1 data.

2.1.1 Sampling

The sample design of Phase 1 is based on a qualitative goal to include a mix of small, medium, and large jurisdictions[6] spread out across the state. 301 jurisdictions were identified that comprised 90% of the projects in the state over a three-year period from 2015 to 2017 (data for 2018 was not available at the start of the project). The 301-jurisdiction sample frame comes from utilizing the DOE methodology sample frame based on the Census Building Permits Survey over a three-year period to find the average number of new home permits per year. Jurisdictions were split into the small, medium, and large categories by utilizing a methodology that makes the total quantity of homes in each of the jurisdiction size categories roughly equal. As seen in Figure 1, the distribution of the jurisdictions by average number of new home permits per year is heavily concentrated around the I-5 corridor, where the large jurisdictions are light blue, the medium jurisdictions are green, and the small jurisdictions are dark blue. The sizes of the circles represent the average number of homes per year.

Figure 1 Top 90% of Jurisdictions

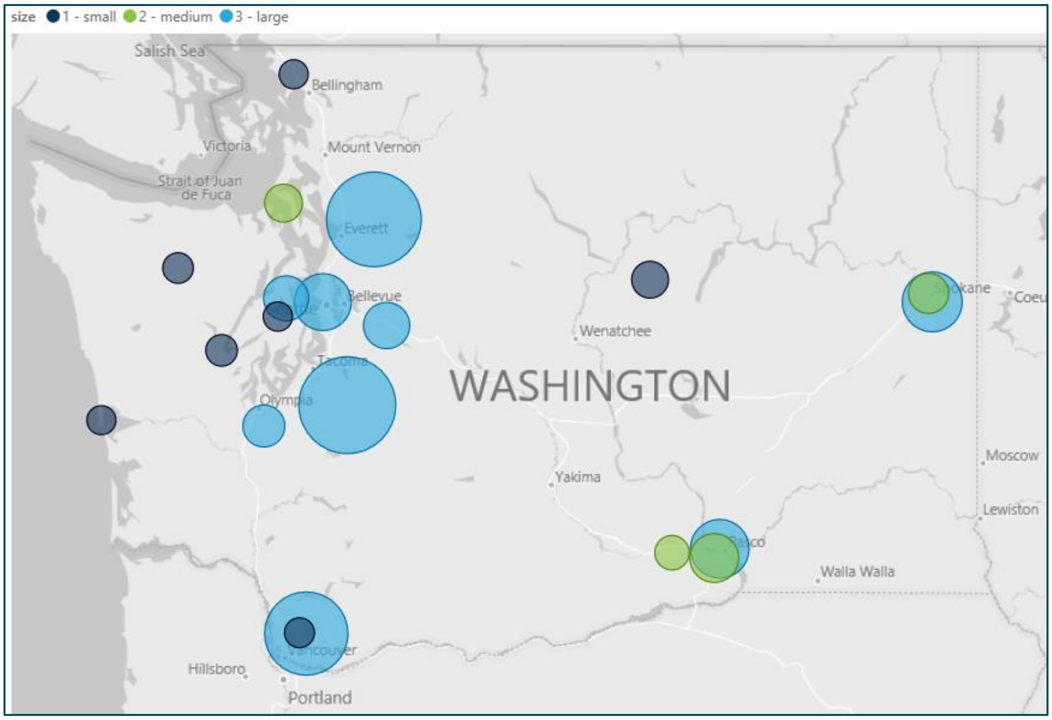


A total sample size of 20 jurisdictions for Phase 1 was selected based on the desired timeline and budget for this phase. The resulting sample is made up of seven small jurisdictions (< 171 houses), four medium jurisdictions (171–366 houses), and nine large jurisdictions (> 366

[6] Jurisdiction is defined here as a county or city with a building code department responsible for enforcing Washington State Energy Code.

houses). Jurisdictions within each group were then randomly selected for the Phase 1 sample, which produced a sample with jurisdictions of different sizes across the state, as shown in Figure 2 and listed in Table 3. Figure 2 has the same details as Figure 1 but just shows the selected sample instead of the whole sample frame.

Figure 2 Sample of Selected Jurisdictions by Size



The project team identified the following jurisdictions to contact and review data during Phase 1 and the goal for each jurisdiction is to collect information on 20–30 projects.

Table 3 Phase 1 Sample Locations

Jurisdiction	Size
Pierce County Unincorporated Area	Large
Snohomish County Unincorporated Area	Large
Clark County Unincorporated Area	Large
Spokane County Unincorporated Area	Large
Seattle	Large
King County Unincorporated Area	Large
Kitsap County Unincorporated Area	Large
Thurston County Unincorporated Area	Large
Pasco	Large
Kennewick	Medium
Island County Unincorporated Area	Medium
Spokane	Medium
Benton County Unincorporated Area	Medium
Bremerton	Small
Ferndale	Small
Ocean Shores	Small
Jefferson County Unincorporated Area	Small
Mason County Unincorporated Area	Small
Battle Ground	Small
Douglas County Unincorporated Area	Small

2.1.2 Outreach

The project team conducted outreach to code officials in the target jurisdictions outlined in the sample plan to collect data on how builders follow the prescriptive pathway with additional credit options. The project team requested access to randomly selected documentation and arranged times for field staff to visit department offices. We also used this opportunity to further inform building department staff of the field study and to request assistance for identifying houses for in-person inspections.

2.1.3 Plans Review

Our staff reviewed documentation of homes recently permitted in sampled jurisdictions. Plans and other documentation were used to identify which code credit options are being utilized by builders in each jurisdiction. Many plan sets had a sheet or callout on plans identifying the selected code credit options and some jurisdictions provided data electronically. During this process, we excluded plans that were created for alterations, additions, and other new non-single family or non-duplex units from the dataset.

2.1.4 Data Collection

An Excel workbook was created to collect data in Phase 1. This tool included the following information:

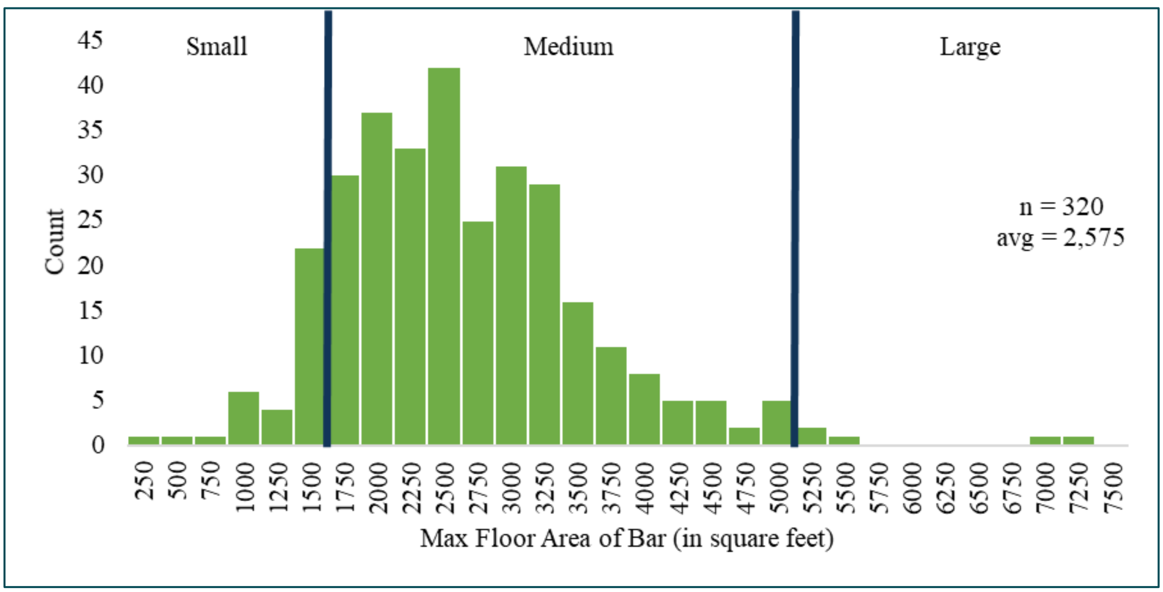
- Jurisdiction
- Dwelling size
- Energy credit options chosen
- Total credits
- Availability of HVAC sizing calculations

2.2 Document Review – Phase 1 Findings

Through our outreach efforts we were able to access 342 files from 13 jurisdictions. This is less than the 20 jurisdictions in the target sample[7].

Of the 13 jurisdictions with data, 5 are Large, 4 are Medium, and 4 are Small, compared to the targets of 9, 4, and 7, respectively.[8] The sample was divided into these size groups because, as noted earlier, energy credits option requirements vary by these house size groupings. The distribution of the number of new houses by size is shown in Figure 3.

Figure 3 Distribution of Small, Medium, and Large Homes by Floor Area



As indicated earlier, the focus of Phase 1 was to identify the common options pathways builders chose to meet the additional energy credit requirements prescribed by the state. From the data

[7] The shortfall is due to not receiving electronic files as often as anticipated, scheduling delays with individual jurisdictions, and the short timeline to move on to Phase 2.

[8] The weighted summaries are based on the size stratification, so the relative contributions of the Small, Medium, and Large groups to the overall average are not affected by this change, but both the Small and Large intra-group summaries are over-represented by these smaller samples, meaning, for instance one jurisdiction in the Large group is contributing more than expected to the overall summary of the Large jurisdictions and might skew the summary.

obtained in this phase, we found builders used more than 30 combinations of options to meet the code, but as anticipated a select few combinations of options were found in the vast majority of plans. Table 4 shows the sets of pathways most frequently selected.

Data from Phase 1 shows that almost 92% of homes are built using six combinations of the additional energy efficiency requirements from Table R406.2 as identified in Table 4. Additional observations from Phase 1 as shown in Table 4 are:

- 66.2% of houses are built using Envelope Option 1a, requiring U-28 windows and R-38 underfloor insulation.
- 34.6% of houses are built using Air Seal Option 2a, requiring tested air leakage of 3 ACH50 or less. An air leakage option is not selected for approximately 63% of houses, requiring 5 ACH50 or less.
- Over 97% of houses are built using High Efficiency HVAC Equipment Options 3a, 3b, and 3d, requiring a 94% AFUE gas furnace, 9.0 HSPF air source heat pump, or ductless heat pump.
- Over 85% of houses are built using Efficient Water Heating Option 5a, requiring low flow faucets and showerheads.
- Almost 100% of houses are built using Efficient Water Heating Option 5b or 5c, requiring efficient water heating equipment.

Table 4 Summary of Compliance Option Findings

Code Category	Options Within Category	Credits Per Option	Option Description		Options Combination A	Option Combination B	Option Combination C	Option Combination D	Option Combination Comb. E	Option Combination Comb. F[9]
Envelope	1a	0.5	Vert Fen U 0.28; Floor R 38	●		●	●			66.2%
	1b	1.0	Vert fen U 0.25, Wall R21 + R4 Floor R38							1.2%
	1c	2.0	Vert Fen U 0.22; Ceiling R49a							0.0%
	1d	0.5	Vertical Fenestration U=0.24						●	4.1%
Air Seal	2a	0.5	3.0 ACH		●	●	●			34.6%
	2b	1.0	2.0 ACH							2.2%
	2c	1.5	1.5 ACH							0.3%
HVAC	3a/3b/3d	1.0	High Eff Furnace, Heat Pump, Ductless Heat Pump	●	●	●	●	●	●	97.6%
	3c	1.5	Ground Source Heat Pump							0.8%
	4	1.0	Ducts Inside Conditioned Space					●		8.5%
Domestic Hot Water	5a	0.5	Low Flow Showerhead and Faucets	●	●		●	●	●	85.2%
	5b	1.0	0.74 EF Fuel Fired or 2.0 EF Heat Pump Water Heater				●	●		12.2%
	5c	1.5	0.91 EF Fuel Fired or 2.0 EF NEEA Qualified Heat Pump Water Heater	●	●	●			●	87.7%
	5d	0.5	Drain Water Heat Recovery							0.2%
Renewable	6	0.0-3.0	1200 kWh annual generation							0.0%
			% Homes Using Option Combo	48.1%	20.7%	8.9%	5.0%	4.8%	4.1%	

[9] Total Option Percentage refers to the percentage of homes using each option.

The most frequently selected options are described in Table 5 below.

Table 5 Description of Most Commonly Selected Compliance Options

Option Group	Option	Requirement (Abbreviated Description)
Envelope	1a	Vertical Fenestration U=0.28; Floor R-38
	1d	Vertical Fenestration U=0.24
Air Seal	2a	3.0 ACH
HVAC	3a/3b/3d	High Efficiency Furnace, Heat Pump, Ductless Heat Pump
HVAC Distribution	4	Ducts Inside Conditioned Space
Domestic Hot Water	5a	Low Flow Showerhead and Faucets
	5b	0.74 EF Fuel Fired or 2.0 EF Heat Pump Water Heater
	5c	0.91 EF Fuel Fired or 2.0 EF NEEA Qualified Heat Pump Water Heater

3. Site Visits – Phase 2

In Phase 2, we focused on field data collection of statistically valid samples of required energy code measures and selected energy code credit measures as installed and observed in homes. Once a complete set of field data was collected, we analyzed the data to understand compliance trends, energy impact, and other insights into new construction under the Washington code.

Phase 2 included visits to 184 homes in various stages of construction to assure that our field team made at least 63 observations of the seven key items identified by the DOE and the four additional key items identified in the Phase 1 analysis of Washington compliance pathways. The complete key items reviewed during site visits include:

1. Envelope tightness (ACH at 50 Pa)
2. Windows (U-factor & SHGC[10])
3. Wall insulation (assembly U-factor)
4. Ceiling insulation (R-value)
5. Lighting (% high-efficacy)
6. Foundation insulation (assembly U-factor)
7. Duct tightness (CFM per 100 sq. ft of conditioned floor area at 25 Pa).
8. HVAC efficiency
9. Water heater efficiency
10. Duct location
11. Water fixture flow rates

[10] Note that SHGC is not included as a requirement in the Washington State Energy Code

3.1 Methodology

Phase 2 aligns with previous state energy code studies[11] and investigates state-level code requirements and current construction practices. The DOE methodology was followed with customization specifically around review of additional key energy components included in the Energy Credit Table from 2015 Washington State Energy Code.

3.1.1 Sampling

The team used Phase 1 findings to inform a WRNC study strategy that follows the DOE methodology as closely as possible considering the Washington code option tables. From these findings a Phase 2 work plan was created and included:

- Details of Phase 2 sampling plan, including the houses identified as candidates in Phase 1
- Major tasks and a timeline for performing outreach, conducting site visits and reporting data
- Roles and responsibilities of team members conducting outreach and site visits
- Verification of required field inspection data points to be collected and recorded in AXIS[12], retaining the established AXIS records for any homes identified in Phase 1
- Outreach/communication process to request assistance from jurisdiction staff, homeowners, builders, and other stakeholders in selected jurisdictions

3.1.2 Data Collection

The data collection plan included parameters related to the key items, which are needed as inputs into the prototype modeling, as well as additional items that will not be used in the modeling but are informative to code compliance and/or improving understanding of building practices in the state. The data collection tool was developed to record levels of energy performance of each inspected item and to determine if each measure meets the mandatory and additional energy credit options.

CLEAResult worked with Pivotal Energy Solutions to develop a tailored data collection tool for the WRNC study using the existing AXIS platform as a foundation. The cloud-hosted AXIS software platform is currently used in above-code new homes programs throughout the Pacific Northwest. CLEAResult provided the tool to the NEEA WRNC work group for review. Consensus was reached and updates were made to the list of items to be inspected and included in the finalized AXIS tool.

Following approval of the list of items included in the data collection tool and approval of the sampling plan, the field data collection team was trained on the Washington Residential Energy Code and on the use of the data collection tool. The team reached out to building code officials in selected jurisdictions to identify homes being built at various stages of construction. In jurisdictions where we received a response from building department staff, the team used the data to randomly select builders to contact to gain access to construction sites. Where building

[11] https://www.energycodes.gov/compliance/energy-code-field-studies

[12] Cloud-hosted data collection tool produced by Pivotal Energy Solutions

department staff were not able to provide the team with construction data, we identified construction locations through contact with other sources of construction activity, such as building trades, construction organizations, or utility staff.

Blower door tests and duct leakage tests were conducted at all homes visited during final stage following RESNET® protocols[13]. RESNET protocols were also used to assign wall insulation quality grades at homes visited during rough-in stage where wall insulation could be observed. Floor insulation was viewed for both R-value and the depth of the insulated cavity. Houses with floor cavity depths greater than the standard thickness of insulation are assumed to not have insulation in contact with the subfloor. Wall insulation U-factors are degraded in energy modeling where RESNET Grade 2 or 3 were identified in wall cavities by field staff.

Only installed items directly observed at a house are included in the recorded dataset. A full set of data was not gathered on any single home, and multiple visits to the same house were not made to avoid observation bias. During and after the site data collection phase, quality assurance of data was performed to ensure collection errors were communicated to all inspectors, with clarifications and resolution shared with the field team. This ensured completeness and consistency of the data prior to performing analysis.

3.1.3 Analysis

The analysis is based on a sample observing key items at least 63 times each of 11 key items listed above. This sample is based on components of the home rather than observing whole homes. Key items are defined as items in the code having the most significant impact on energy savings. In the DOE's methodology, collected data are then subject to multiple stages of analysis to identify statistical trends, estimate statewide energy use, and calculate associated measure-level savings. From section 7 of the DOE methodology, these three analyses are labeled:

1. Measure statistical analysis
2. Measure savings analysis
3. Statewide energy analysis

In the measure statistical analysis, histograms are created for each of the key items, showing the distribution of findings with an overlay showing the code requirement. These plots will follow the DOE specification from section 7.1 of the DOE methodology:

> The total sample size (n) is displayed in the top left or right corner of the graph, along with the distribution average. The metric associated with the item is measured along the horizontal axis (e.g., window U-factor is measured in Btu/ft²-hr-F), and a count of the number of observations is measured along the vertical axis. A vertical line is imposed on the graph representing the applicable code requirement (e.g., the prescriptive windows requirement in climate zone 4 is 0.35). Values to the right-hand side of this line are better than code; values to the left-hand side of this line represent areas with savings opportunities.

[13] Information on RESNET protocols can be found at https://www.resnet.us/wp-content/uploads/RESNET-Mortgage-Industry-National-HERS-Standards_3-8-17.pdf

For the measure savings analysis, the analysis framework used was the same as section 7.2 of the DOE methodology, but the modeling itself was conducted using the Regional Technical Forum's (RTF) SEEM program, a whole building simulation software[14]. SEEM is the current software used in cost effectiveness calculations for energy efficiency technologies in the Northwest and utilizes standard prototypes and assumptions for these models. In addition, SEEM is the software used in creating the Washington Energy Code point values for options, and SEEM models were used to evaluate the theoretical savings of the Washington, Oregon, Montana, and Idaho codes over the last decade for NEEA. More information about SEEM can be found in Appendix G Simplified Energy-Enthalpy Model (SEEM).

The project team conducted both the measure savings analysis and the statewide energy savings analysis using the standard SEEM prototype methodology, i.e. using the six prototype homes, four prototype HVAC systems, and Northwest climate zones for Washington. In addition to this standard setup, the findings from Phase 1 of this study were used to create the prototype distribution of common paths, utilizing the most common pathways to account for 90% of homes.

When expanding this to the statewide analysis, the Monte Carlo simulation method from the DOE approach was utilized, though the total number of models runs differed from the DOE recommendations due to the fact that Washington Code essentially has a larger number of key items to analyze. The prototypes for SEEM include variations for HVAC (4 base types), climate (6 RTF climate zone for WA), houses (6 types), and findings from Phase 1 for distribution of code option selection. Below are the details for these prototypes:

- Base HVAC types
  - Gas furnace with air conditioning
  - Gas furnace without air conditioning
  - Heat pump (ground source heat pumps are upgrades to this prototype)
  - Zonal electric resistance (ductless heat pumps are upgrades to this prototype)
- RTF climates for Washington (HZ is heating zone, CZ is cooling zone, 1 means lowest seasonal usage and 3 means highest seasonal usage) – includes percent of population
  - NW HZ1 CZ1 (82.0%)
  - NW HZ1 CZ2 (1.2%)
  - NW HZ1 CZ3 (7.2%)
  - NW HZ2 CZ1 (1.7%)
  - NW HZ2 CZ2 (7.9%)
  - NW HZ3 CZ1 (0.1%)
- House prototypes
  - 1344 square feet on crawl space
  - 1344 square feet on slab
  - 2200 square feet on crawl space
  - 2200 square feet on slab

[14] DOE used EnergyPlus in other state studies

- 2688 square feet on basement
- 5000 square feet on basement

3.2 Site Visits – Phase 2 Findings

Analysis results of the high impact key items are provided below. Energy savings analysis focuses on these items.

3.2.1 Envelope Tightness (ACH at 50 Pa)

The mandatory requirement for envelope tightness is a maximum tested air leakage value of 5.0 ACH50. Options for air leakage control reduction from the Energy Credit Table include the below maximum tested air leakage values plus efficient ventilation exceeding mandatory ventilation requirements:

Option 2a: 3.0 ACH50

Option 2b: 2.0 ACH50

Option 2c: 1.5 ACH50

Staff performed envelope tightness tests at houses visited during post-construction. Posted ACH values were recorded if they were available and can be found in Appendix F Additional Data Items. A majority of homes inspected during Phase 2 were found using the base air leakage requirement of 5.0 ACH50 or less. Option 2b, requiring 3.0 ACH50 or less was selected for 24% of homes. The permit data from Phase 1 showed that more builders planned to select more stringent tightness options than were actually found in field visits as seen in Table 6. In total, 107 blower door tests were conducted. In Table 6, as with all similar tables through the report, the Phase 1 percentages and counts are based on homes that exactly met the code requirements for medium sized homes; some homes had more than the required number of credits.

Table 6 Envelope Tightness Option Findings

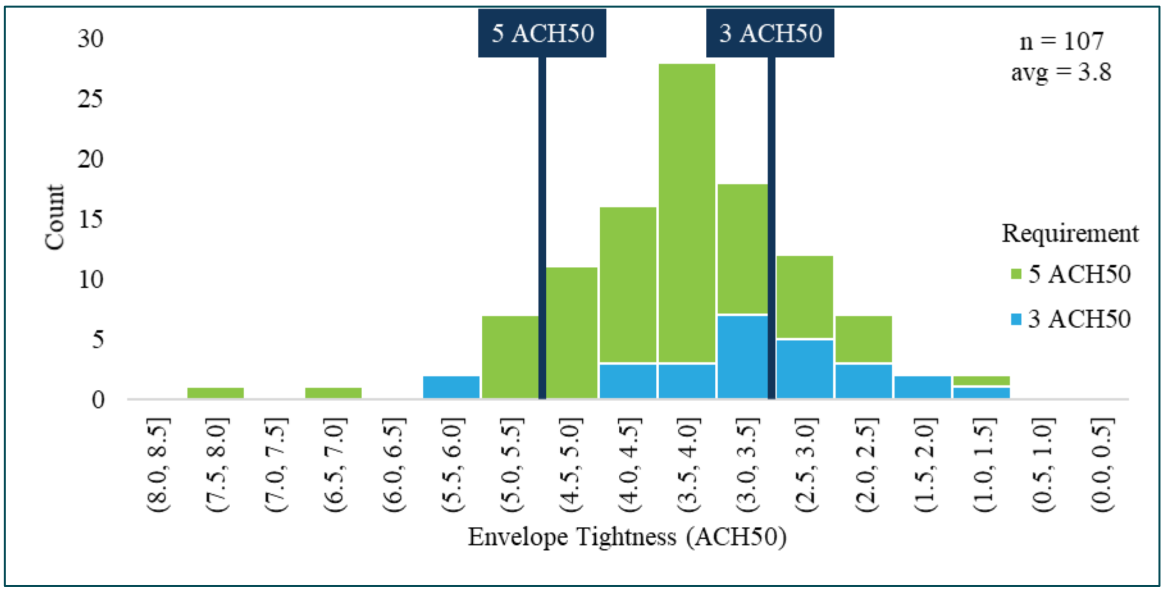
Option	ACH50	Phase 2 Count	Phase 2 Percent	Phase 1 Count	Phase 1 Weighted Percent
Base	5.0	81	76%	161	63%
2a	3.0	26	24%	82	35%
2b	2.0	0	0%	6	2%
2c	1.5	0	0%	1	0%
Total		**107**		**250**	

Table 7 Envelope Tightness Compliance Findings

Description	5 ACH50	3 ACH50	Total
Comply	72	11	83
Did Not Comply	9	15	24
Total	**81**	**26**	**107**
% Comply	89%	42%	78%
Average ACH50	4.0	3.2	3.8

The graph below uses a standard math notation in the horizontal axis for inclusive and exclusive ranges. The parenthesis means up to but not including and the bracket means up to and including.

Figure 4 Envelope Tightness Findings



Interpretation

As shown in Table 7, for homes requiring 5 ACH50 there was an 89% compliance, however for homes choosing Option 2a there was only a 42% compliance in meeting the 3 ACH50. The average of homes with a 5 ACH50 target was 4.0 ACH50 while the average for homes with a 3 ACH50 target was 3.2 ACH50.

3.2.2 Windows (U-Factor & SHGC)

The mandatory requirement for vertical fenestration is a maximum weighted U-factor of 0.30. Options for windows from the Energy Credit Table include the below maximum U-factors:

Option 1a: U=0.28 (also requires increased insulation R-values exceeding mandatory requirements)

Option 1b: U=0.25 (also requires increased insulation R-values exceeding mandatory requirements)

Option 1c: U=0.22 (also requires increased insulation R-values exceeding mandatory requirements)

Option 1d: U=0.24

As shown in Table 8, the most selected option for windows is 1a, requiring U-0.28 followed by the baseline option of U-0.30. Option 1d, requiring U-0.24 was observed in 7 instances. The other two options were not seen very much in Phase 1 or in Phase 2.

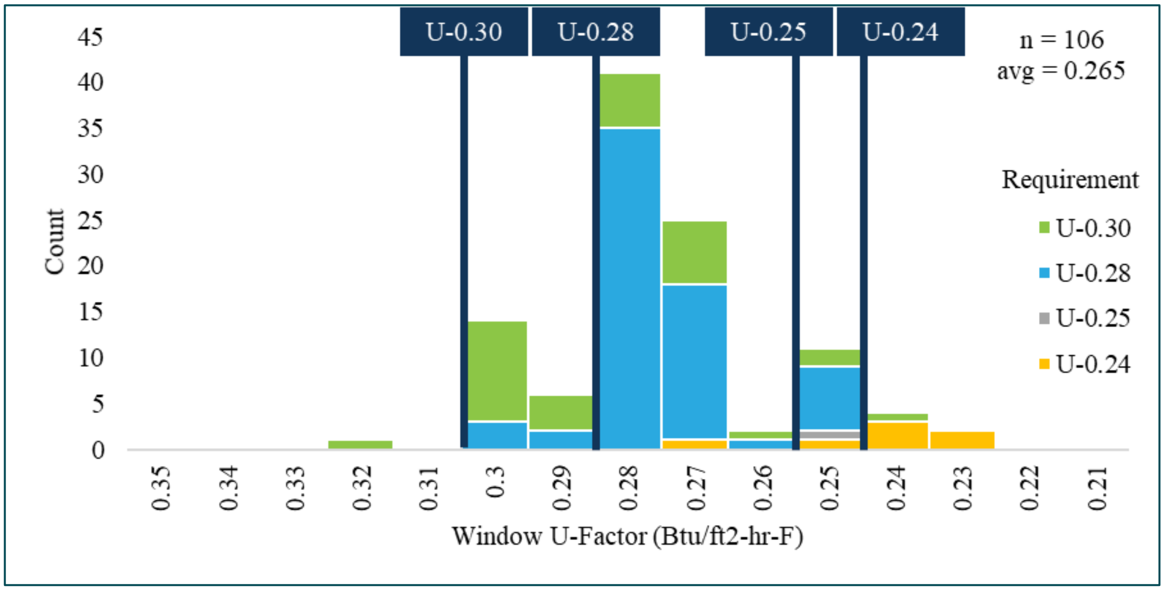
Table 8 Window U-Factor Option Findings

Option	U-Factor	Phase 2 Count	Phase 2 Percent	Phase 1 Count	Phase 1 Weighted Percent
Base	0.30	33	31%	67	29%
1a	0.28	65	61%	168	66%
1b	0.25	1	1%	4	1%
1c	0.22	0	0%	0	0%
1d	0.24	7	7%	11	4%
Total		**106**		**250**	

Table 9 Window U-Factor Compliance Findings

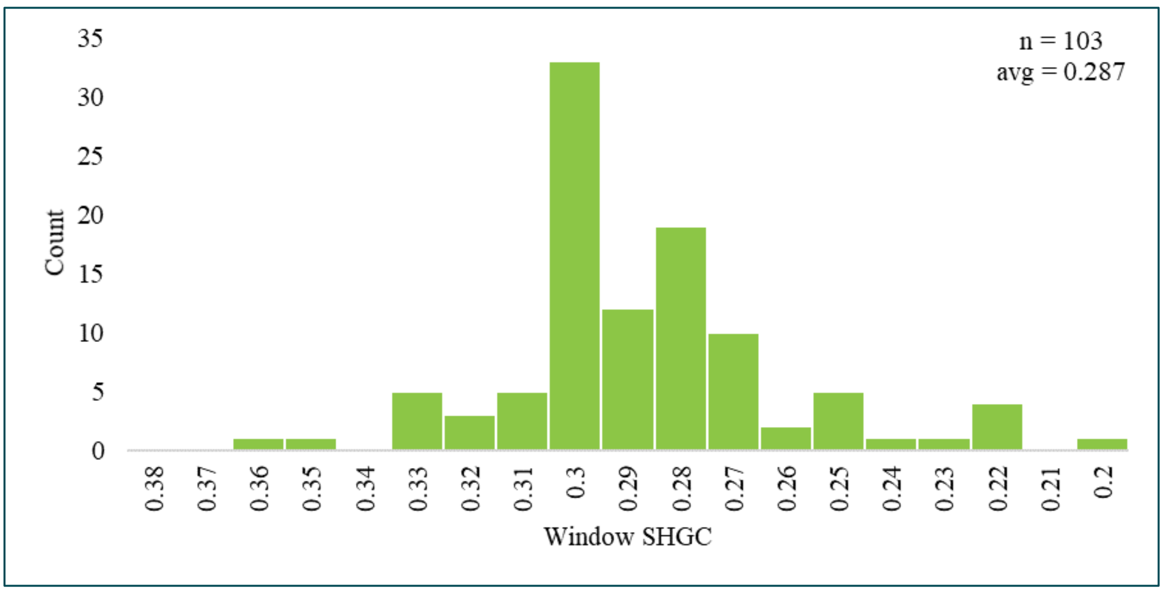
Description	0.30	0.28	0.25	0.24	Total
Comply	32	60	1	5	98
Did Not Comply	1	5	0	2	8
Total	**33**	**65**	**1**	**7**	**106**
% Comply	97%	92%	100%	71%	92%
Average	0.283	0.275	0.250	0.233	0.265

Figure 5 Window U-Factor Findings



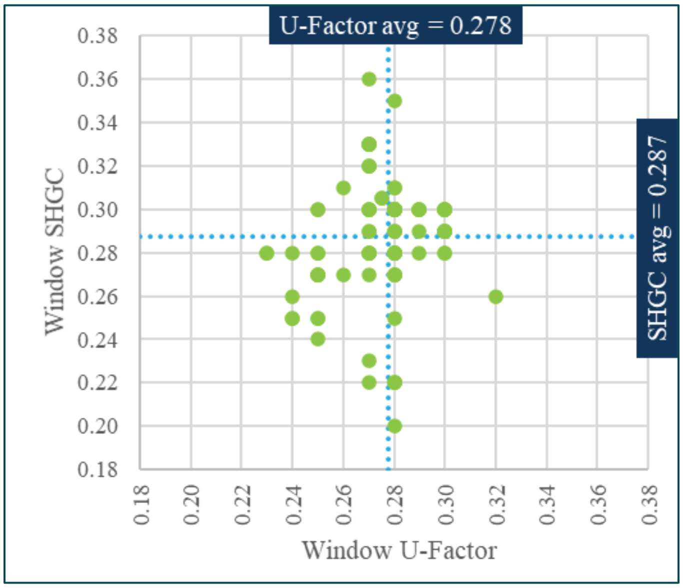
Washington energy code does not have a requirement for SHGC. Data was recorded at houses for informational purposes only[15]. The average SHGC varies widely for each average U-factor found at most houses as shown in Figure 7.

Figure 6 Window SHGC Findings



[15] SHGC was not recorded in 3 of 106 houses where window U-factors were recorded

Figure 7 Window SHGC and U-Factor Combination Findings



Interpretation

Table 9 and Figure 5 show compliance findings for windows. For homes requiring U-0.30 windows, 97% comply. For homes requiring U-0.28 windows, 92% comply. Six of the eight homes requiring U-025 or U-0.24 comply.

3.2.3 Wall insulation (Assembly U-Factor)

The mandatory requirement for wall insulation is R-21. Options for wall insulation from the Energy Credit Table include the below assemblies:

Option 1b: R-21 cavity plus R-4 continuous (also requires increased floor R-value and window U-factor exceeding mandatory requirements)

Option 1c: R-21 cavity plus R-12 continuous (also requires increased floor R-value and window U-factor exceeding mandatory requirements)

R-Value and insulation grading were reviewed during field inspections. Houses with 24 inch on-center framing were identified. Most houses with fiberglass batt insulation were found with RESNET Grade 2 insulation quality. Houses with blown-in blanket system insulation (BIBS) had RESNET Grade 1 insulation quality. U-factors of the assemblies, which represent the overall thermal performance of the wall are also provided below.

Table 10 Wall Insulation R-Value Option Findings

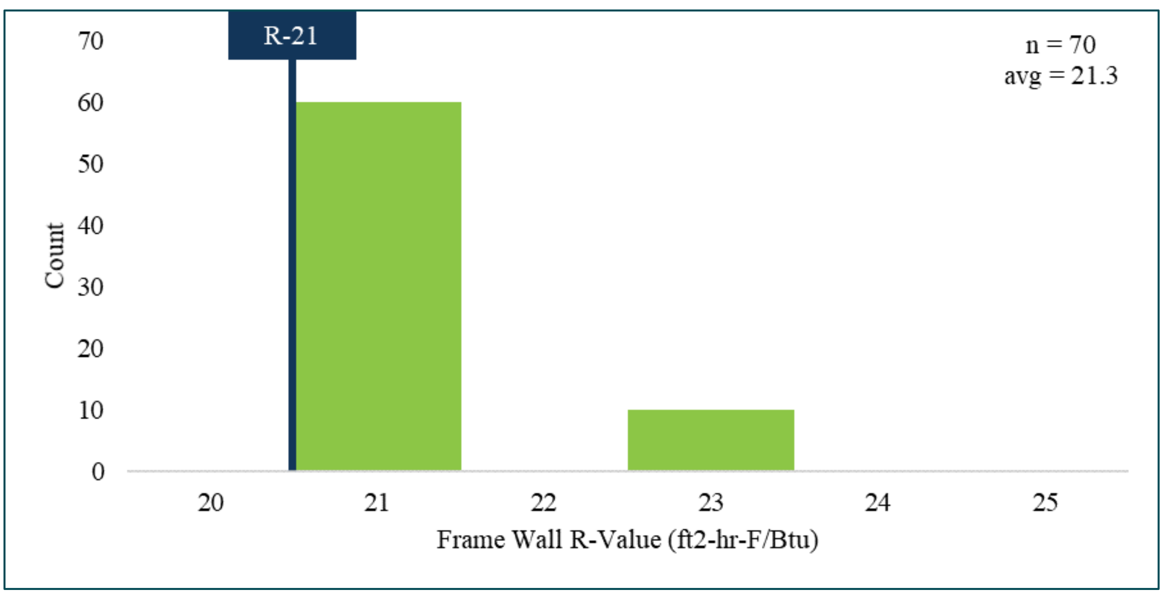
Option	R-Value	Phase 2 Count	Phase 2 Percent	Phase 1 Count	Phase 1 Weighted Percent
Base	R21	69	99%	246	99%
1b	R21+4	1	1%	4	1%
1c	R21+12	0	0%	0	0%
Total		**70**		**250**	

Table 11 and Figure 8 show compliance findings for R-21 cavity insulation, which includes both the baseline homes and the one home that used option 1b (R21+4).

Table 11 Wall Insulation Nominal Cavity Compliance Findings

Description	R21
Comply	70
Did Not Comply	0
Total	**70**
% Comply	100%
Average	21.3

Figure 8 Wall Cavity Insulation R-Value Findings



Wall U-factors are affected by cavity and continuous insulation R-Value, cavity installation quality, and framing factors. The equivalent U-factor for the R-21 wall in the energy code is 0.056 with Grade 1 insulation and the equivalent U-factor for R-21+4 wall in the energy code is

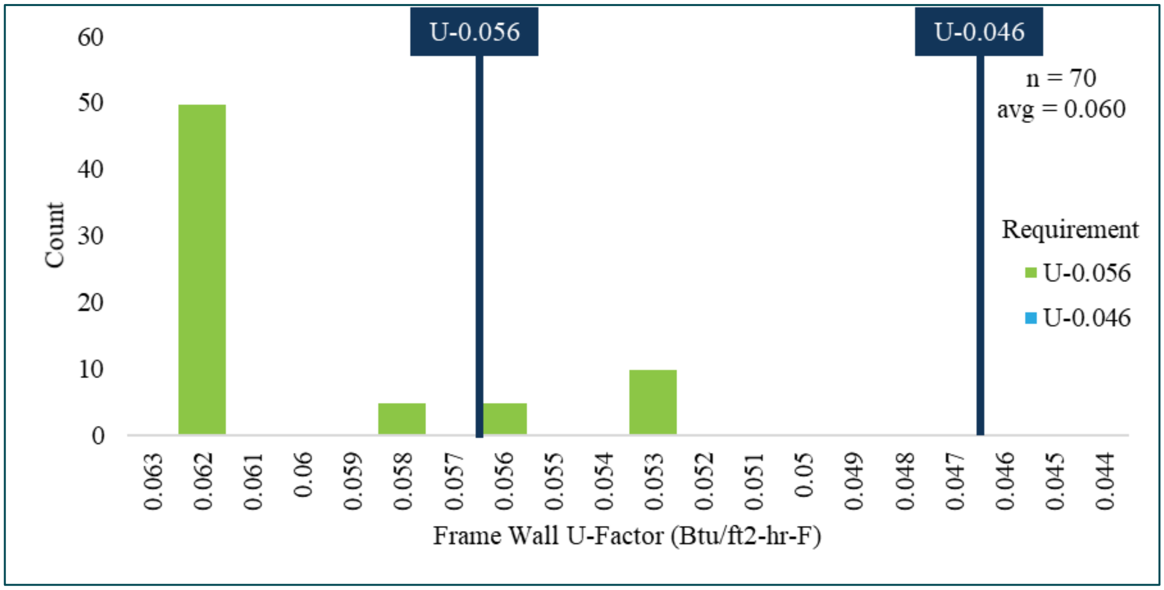
0.046 with Grade 1 insulation. Wall insulation was inspected at 70 houses. As shown in Table 12 and Figure 9,

- Five houses were found with Grade 1 wall cavity insulation with a U-factor of 0.056.
- 49 houses were found with Grade 2 wall cavity insulation with a U-factor of 0.062 (up to 2% of cavity void of insulation).
- Five homes were found with 24 inch on-center framing with Grade 2 insulation with a calculated U-factor of 0.058.
- 10 homes were found with Grade 1 blown-in cavity insulation at R-23 with an equivalent U-factor of 0.053.
- Energy Credit Option 1b was selected for one house, requiring R-21 cavity insulation plus R-4 continuous insulation with an equivalent U-factor of 0.046.

Table 12 Wall Insulation U-Factor Findings

Description	**0.056**	**0.046**
Comply	15	0
Did Not Comply	54	1
Total	**69**	**1**
% Comply	22%	0%
Average	0.060	

Figure 9 Wall Insulation U-Factor Findings



Interpretation

Every house visited during rough inspections met the cavity insulation requirement of R-21.

However, the calculated wall assembly U-factor in houses with Grade 2 insulation quality does not meet the equivalent U-factor listed in Washington code. Insulation in homes with batt insulation was generally found with Grade 2 insulation quality. Installation quality of cavity insulation, identified by compressed and missing insulation, affects the thermal performance of the walls.

3.2.4 Ceiling Insulation (R-Value)

The mandatory requirement for ceiling insulation is R-49 (for rafter or joist vaulted ceilings or where the full uncompressed insulation extends over the wall of the top plate at eaves, the insulation requirement is R-38). The project team identified if the full uncompressed insulation extends over the wall of the top plate at eaves. Options for ceiling insulation from the Energy Credit Table include the below assemblies:

Option 1c: R-49 Advanced (also requires increased floor R-Value and window U-factor exceeding mandatory requirements)

As shown in Table 13, Option 1c was not selected for any houses visited in Phase 2.

Table 13 Ceiling Insulation R-Value Option Findings

Option	R-Value	Phase 2 Count	Phase 2 Percent	Phase 1 Count	Phase 1 Weighted Percent
Base	R-38/49	107	100%	250	100%
1c	R-49a	0	0%	0	0%
Total		**107**		**250**	

As shown in Table 14, six houses were found requiring a base ceiling insulation level of R-38 and 101 requiring R-49. Insulation in 85% of ceilings were found in compliance with the required base R-Value.

Table 14 Ceiling Insulation R-Value Compliance Findings

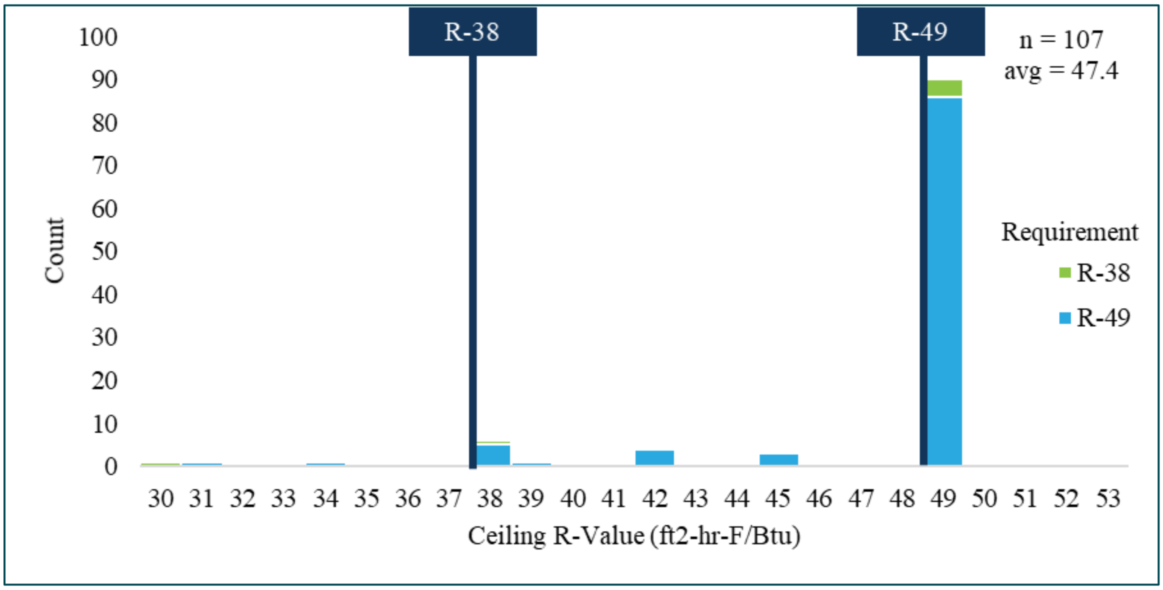
Description	R-38	R-49	Total
Comply	5	86	91
Did Not Comply	1	15	16
Total	**6**	**101**	**107**
% Comply	83%	85%	85%
Average	44.0	47.6	47.4

As shown in Table 14 and Figure 10.

- Five houses were found with full R-38 or greater ceiling insulation above exterior walls, meeting the code requirement. One house requiring R-38 ceiling insulation did not meet the code requirement

- 86 homes with R-49 insulation met the code requirement but did not have full levels of insulation above exterior walls. 15 homes requiring R-49 ceiling insulation were found with less than that amount.

Figure 10 Ceiling Insulation R-Value Findings



Interpretation

Minimal potential improvement for ceiling insulating practices was identified. 85% of homes met the R-Value requirement. 91 of 107 observations meet the R-Value requirement. Additional discussion of ceiling U-factors can be found in Appendix H Ceiling and Floor Insulation U-Factor Findings.

3.2.5 Lighting (% High-Efficacy)

The mandatory requirement is a minimum of 75% of lamps in permanently installed locations to be high-efficacy lamps. High-efficacy requirements are:

- Compact fluorescent lamp
- T-8 or smaller linear fluorescent lamp
- Or lamps with a minimum efficacy of
  - 60 lumens per watt for lamps over 40 watts
  - 50 lumens per watt for lamps over 15 watts to 40 watts
  - 40 lumens per watt for lamps 15 watts or less
  - LED bulbs

The field team identified whether the code-required 75 percent of high-efficacy lamps were installed. In cases where less than 100% of lamps were found to be high efficacy, the percentage of high-efficacy lamps was recorded. As shown in Table 16 and Figure 11, in 96% of the cases, all lamps were found to be high-efficacy LED and some compact fluorescent lamps were found. LED lamps are considered to meet high-efficacy requirements.

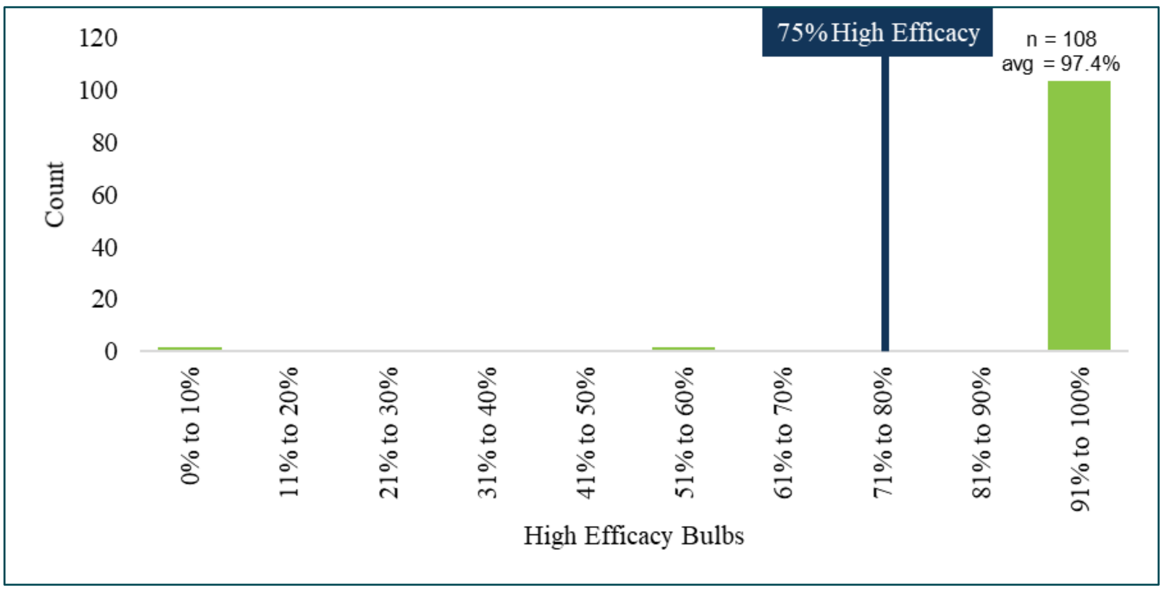
Table 15 High-Efficacy Lighting Findings

Option	%HE	Phase 2 Count	Phase 2 Percent	Phase 1 Count	Phase 1 Weighted Percent
Base	75%	108	100%	250	100%
Total		**108**		**250**	

Table 16 High-Efficacy Lighting Compliance Findings

Description	75% High Efficacy
Comply	104
Did Not Comply	4
Total	**108**
% Comply	96%
Average	95.7%

Figure 11 High Efficacy Lighting Findings



Interpretation

Minimal lighting that does not meet the high-efficacy definition was identified. Compliance with the 75% high-efficacy lighting requirement was met at 104 of 108 houses.

3.2.6 Foundation Insulation

The mandatory insulation requirements are R-30 for framed floor and R-10 for slabs. Below-grade walls require R-15 continuous insulation on the interior of the wall or R-21 cavity insulation. Options for wall insulation from the Energy Credit Table include the below assemblies:

Option 1a: Floor R-38, Slab on grade R10 perimeter and under entire slab, below-grade slab R-10 perimeter and under entire slab. (Also requires window U-factor exceeding mandatory requirements.)

Option 1b: Floor R-38, Basement Wall R-21 plus R-5 continuous, slab on grade R10 perimeter and under entire slab, below-grade slab R-10 perimeter and under entire slab. (Also requires increased wall R-value and window U-factor exceeding mandatory requirements.)

Option 1c: Floor R-38, Basement Wall R-21 plus R-12 continuous, slab on grade R10 perimeter and under entire slab, below-grade slab R-10 perimeter and under entire slab. (Also requires increased wall R-value and window U-factor exceeding mandatory requirements.)

Most houses had unconditioned vented crawl spaces. No un-vented crawl spaces were identified. If observable, R-values were obtained during rough-in or final inspections. Minimal numbers of slab-floor insulation were observable.

Overall

Foundation type was not recorded during the Phase 1 data collection, so Table 17 shows the overall option selection comparison between Phase 2 and Phase 1, which has very close alignment with Option 1a being selected for two-thirds of homes and one-third without a shell insulation upgrade.

Table 17 Overall Wall Insulation Option Findings

Option	Phase 2 Count	Phase 2 Percent	Phase 1 Count	Phase 1 Weighted Percent
Base	64	35%	78	33%
1a	119	65%	168	66%
1b	1	1%	4	1%
1c	0	0%	0	0%
Total	**184**		**250**	

Basement Wall

There were not many basement walls in the study and most did not comply with code as shown in Table 19.

Table 18 Basement Wall Insulation Option Findings

Option	R-Value	Count	Phase 2
Base	R21 / R15	4	100%
1b	R21+5	0	0%
1c	R21+12	0	0%
Total		**4**	

Table 19 Basement Wall Cavity Insulation Compliance Findings

Description	R21/R15
Comply	1
Did Not Comply	3
Total	**4**
% Comply	25%
Average Cavity	21.0
Average Interior Continuous	18.0

Slab on Grade

Slab on grade insulation was not viewed in many instances, and they all met code. All additional energy credit options and base have R-10 as the requirement, with the additional energy credit options requiring insulation to be installed at the perimeter and fully under the slab while the base requires just perimeter insulation.

Table 20 Slab on Grade Insulation Option Findings

Option	R-Value	Count	Phase 2
Base/1a/1b/1c	10	4	100%
Total		**4**	

Table 21 Slab on Grade Insulation Compliance Findings

Description	R-10
Comply	4
Did Not Comply	0
Total	**4**
% Comply	100%
Average	10.0

Floor Insulation

Framed-floor cavity insulation was inspected during post-construction visits and also at some homes visited during rough-in. Table 22 shows that Option 1a was selected for 84 of 123 houses where framed-floor cavity insulation was observed in Phase 2 of the study, requiring R-38 insulation. As shown in Table 23, all houses where R-30 was required met the code requirement. 67 of 84 installations met the R-38 requirement.

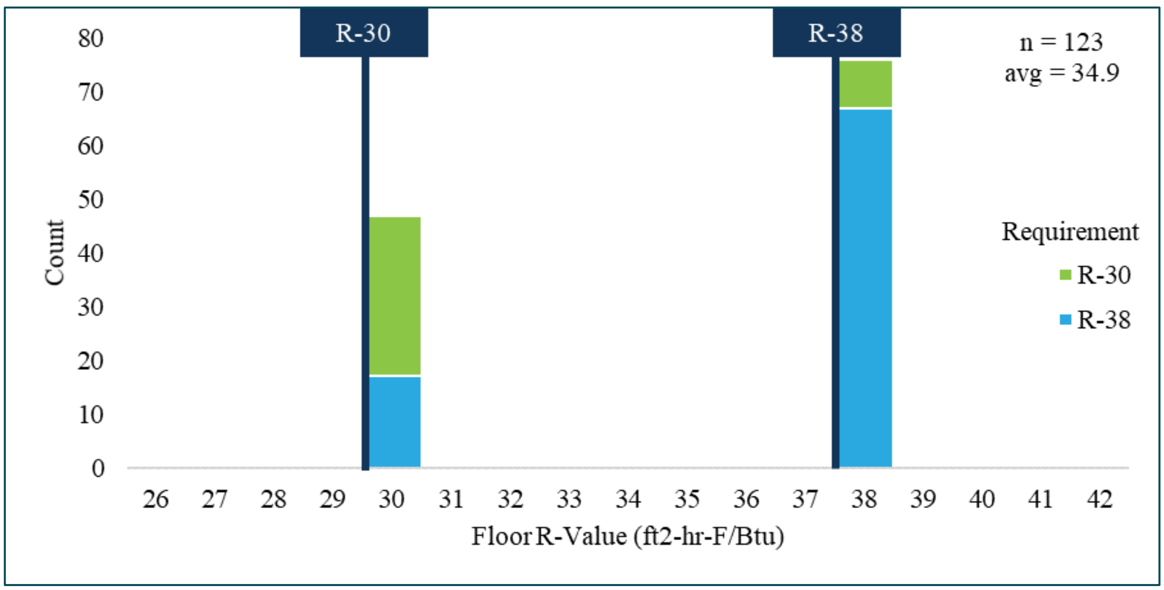
Table 22 Floor Insulation Option Findings

Option	R-Value	Count	Phase 2
Base	30	39	32%
1a	38	84	68%
1b	38	0	0%
1c	38	0	0%
Total		**123**	

Table 23 Floor Insulation R-Value Compliance Findings

Description	R-30	R-38	Total
Comply	39	67	106
Did Not Comply	0	17	17
Total	**39**	**84**	**123**
% Comply	100%	80%	86%
Average	31.8	36.4	34.9

Figure 12 Floor Insulation R-Value Findings



3.2.7 Duct tightness (CFM per 100 sq. ft of Conditioned Floor Area at 25 Pa)

The mandatory requirement for duct tightness with air handler installed is a maximum total leakage of 4 CFM25 per 100 sq. ft. (3 CFM25 if the air handler is not yet installed) tested at rough-in or a maximum leakage to outdoors of 4 CFM25 per 100 sq. ft. tested at post-construction. No options for duct tightness are offered from the Energy Credit Table.

Total duct leakage tests were performed at post-construction phase. Posted duct leakage values were recorded if available and can be found in Appendix F Additional Data Items. Table 25 shows that 49% of duct systems that were tested during Phase 2 complied with the code requirement. Figure 13 and Figure 14 show the tested and adjusted leakage rates at homes visited. Duct leakage was adjusted from the tested value for homes with all ducts found inside conditioned space by updating those leakage values to zero. 59% of duct systems meet the code requirement with the adjustment.

Table 24 Duct Leakage Option Findings[16]

Option	Duct Leak	Phase 2 Count	Phase 2 Percent	Phase 1 Count	Phase 1 Weighted Percent
Base	4 CFM25/ 100 sqft	61	74%	250	100%
Non-Ducted Heat	N/A	21	26%	Not Recorded	
Total		**82**		**250**	

Table 25 Duct Leakage Compliance Findings

Description	4 CFM25/100 sqft	Adjusted
Comply	30	36
Did Not Comply	31	25
Total	**61**	**61**
% Comply	49%	59%
Average	4.6	4.0

[16] Original target of 66 duct seal tests were not completed due to homes inspected during post-construction with ductless heat pumps installed.

Figure 13 Duct Leakage Findings

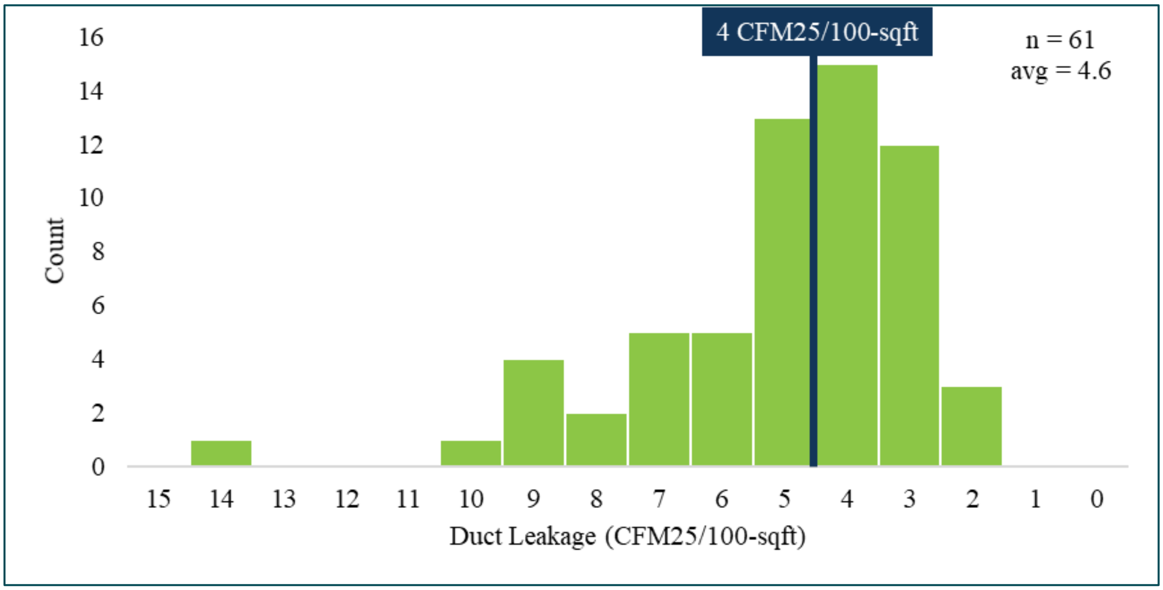
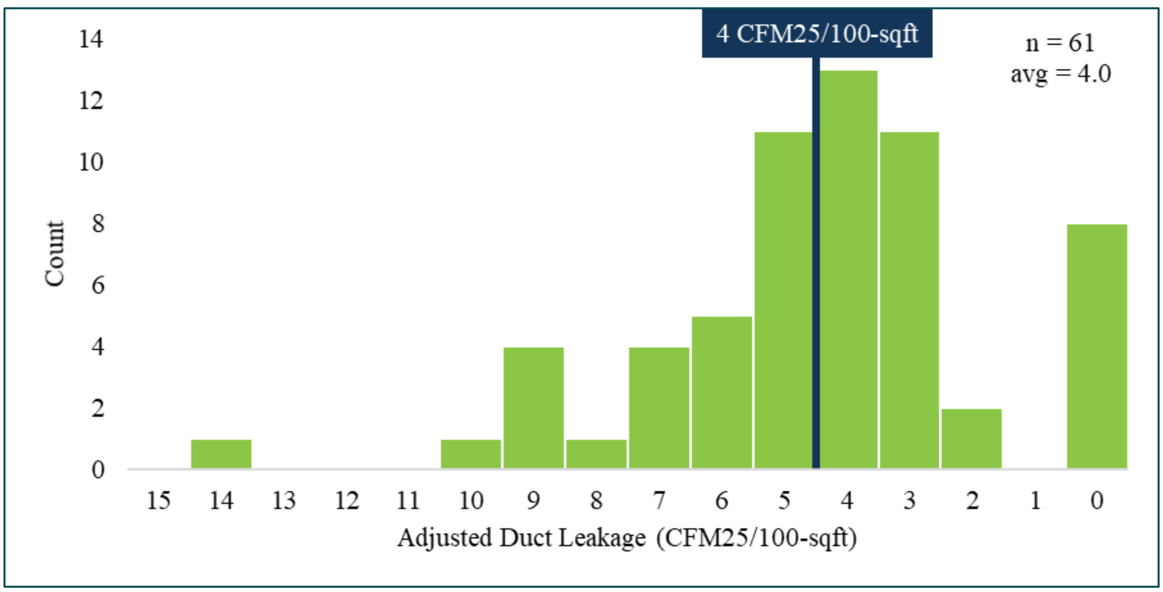


Figure 14 Adjusted Duct Leakage Findings (Ducts Inside Set to 0)



Interpretation

The average total duct leakage of 61 houses is 4.6 CFM25/100 sq. ft. 49% of the raw leakage observations meet the Washington code requirement for duct leakage.

The average adjusted total duct leakage of 61 houses is 3.6 CFM25/100 sq. ft. 59% of the adjusted leakage observations meet the Washington code requirement for duct leakage. Ducts are completely in conditioned space in eight of 61 tested houses, two of which met the code requirement with the raw tested duct leakage rate.

3.2.8 HVAC Efficiency

Washington energy code requires heating and cooling equipment to have an efficiency rating meeting the minimum required by federal law. Options for high-efficiency HVAC from the Energy Credit Table include the below measures:

3a: Fuel-fired furnace with a minimum AFUE of 94% or fuel-fired boiler with minimum AFUE of 92%

3b: Air-source heat pump with minimum HSPF of 9.0

3c: Closed-loop ground source heat pump with a minimum COP of 3.3 or open loop water source heat pump with a maximum pumping hydraulic head of 150 feet and minimum COP of 3.6

3d: Ductless split system heat pump with zonal control

Efficiency levels for HVAC equipment were identified by the model numbers and associated efficiency values found in the Air-Conditioning, Heating, & Refrigeration Institute (AHRI) Directory of Certified Performance. Model numbers of HVAC equipment found onsite were recorded, and efficiencies were looked up on the AHRI Directory.

The following tables display the Option 3 HVAC upgrades. These options are specific to the technology, so the blanks in the tables represent situations that are not possible. Table 26 provides a count of the selected HVAC efficiency options and the heat source used for each option. HVAC upgraded efficiency options were not selected for eight houses, meaning 96% of homes chose an upgraded efficiency option. Table 27 shows the percentage of homes where each technology was observed, and the selected energy credit option used to meet the code. Table 27 is a row-wise normalization of Table 26, except for the Total column in Table 27 is the overall distribution of HVAC technologies.

Table 26 HVAC Efficiency Option Findings

Description	Base	3a	3b	3c	3d	Total
Gas Furnace	3	138	—	—	—	141
Propane Furnace	0	1	—	—	—	1
Air Source Heat Pump	0	—	13	—	—	13
Ground Source Heat Pump	0	—	—	2	—	2
Ductless Heat Pump	5	—	—	—	16	21
Not Observable	0	5	1	0	0	6
Total	**8**	**144**	**14**	**2**	**16**	**184**

Table 27 HVAC Efficiency Option Share of Total

Description	Base	3a	3b	3c	3d	Total	Option Upgraded
Gas Furnace	2%	75%	—	—	—	77%	98%
Propane Furnace	0%	1%	—	—	—	1%	100%
Air Source Heat Pump	0%	—	7%	—	—	7%	100%
Ground Source Heat Pump	0%	—	—	1%	—	1%	100%
Ductless Heat Pump	3%	—	—	—	9%	11%	76%
Not Observable	0%	3%	1%	0%	0%	3%	100%
Total	**4%**	**82%**	**7%**	**1%**	**8%**	**100%**	**96%**

Table 28 HVAC Efficiency Compliance Findings

Description	Base Furnace	3a: 94% AFUE Furnace	3b: 9.0 HSPF ASHP	3c: 3.6 COP GSHP	Base DHP	3d: 8.5 HSPF DHP	Overall
Comply	2	132	9	1	4	8	156
Did Not Comply	0	1	3	0	0	0	4
Total	**2**	**133**	**12**	**1**	**4**	**8**	**160**
% Comply	100%	99%	75%	100%	100%	100%	98%
Average	96.0	95.6	8.8	4.8	11.1	10.8	

The graphs below use the standard math notation identified in section 3.2.1. For example in the below Figure 16, the groups of [8.5, 9.0) and [9.0, 9.5) are not overlapping, it means that a 9.0 will be included in the latter interval but not the former interval because of the square bracket next to the 9.0 in the second interval and the parenthesis next to the 9.0 in the first interval

Figure 15 Furnace Efficiency (AFUE) Findings

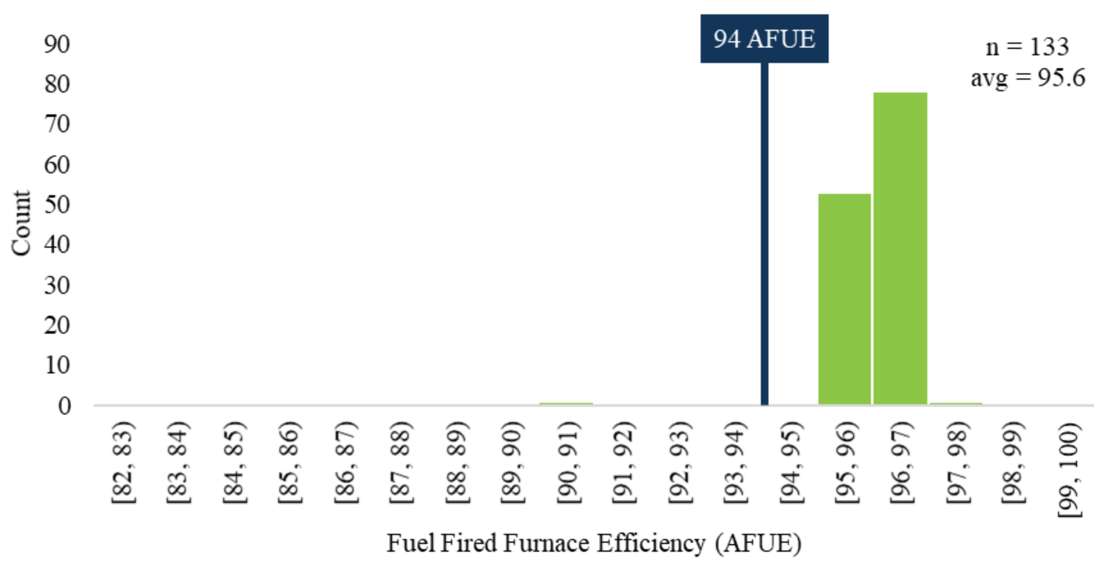


Figure 16 Air Source Heat Pump Efficiency (HSPF) Findings

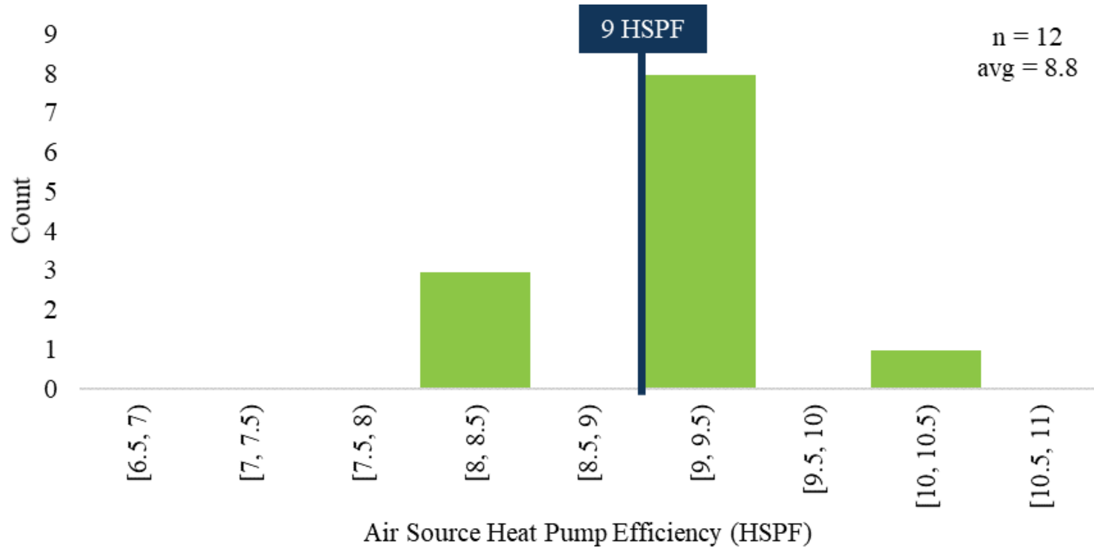


Figure 17 Ground Source Heat Pump Efficiency (COP) Findings

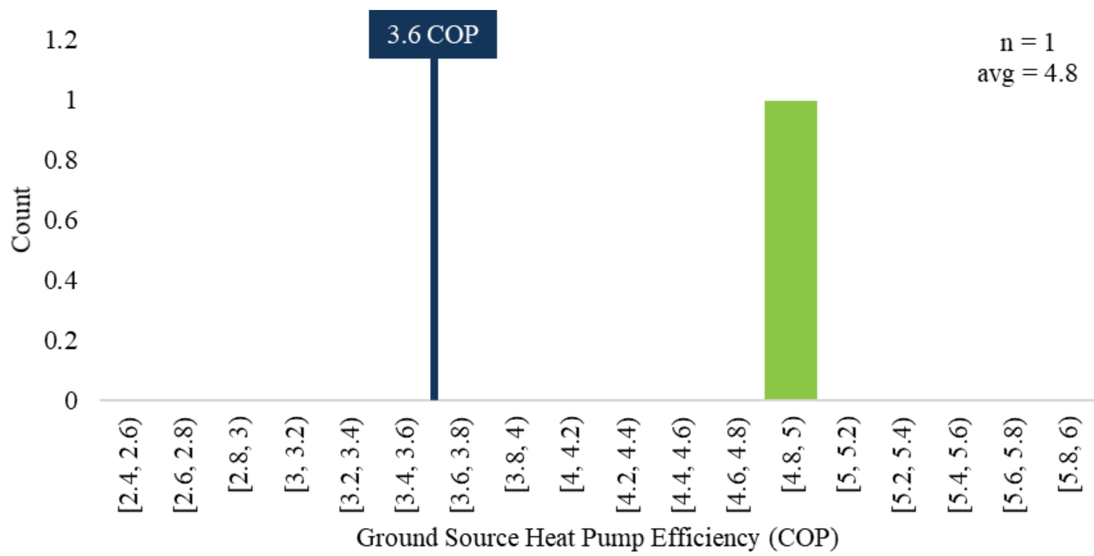
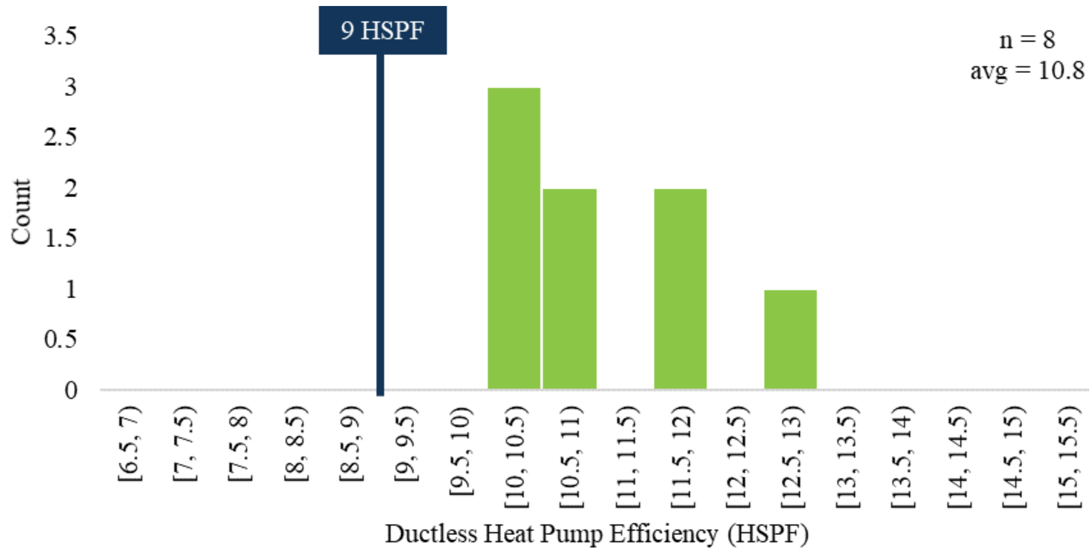


Figure 18 Ductless Heat Pump Efficiency (HSPF) Findings



Interpretation

HVAC efficiency is selected as a compliance option for almost all houses. Table 28 and Figures 15-18 show that the efficiency requirement for gas furnaces was met at all but only one house. The efficiency requirement for air source heat pumps was met at nine of 12 houses.

3.2.9 Water Heater Efficiency

Washington energy code requires water heating equipment to have an efficiency rating meeting the minimum required by federal law. Options for high-efficiency water heating equipment from the Energy Credit Table include the below measures:

5b: Fuel-fired water heater with a minimum EF of 0.74 or water heated by a ground source heat pump meeting the requirements of Option 3c

5c: Fuel-fired water heater with a minimum EF of 0.91 or electric heat pump water heater with a minimum EF of 2.0 and meeting the standards of NEEA's Northern Climate Specifications for Heat Pump Water Heaters or Solar water heating providing a rated minimum savings of 85 therms or 2000 kWh

5d: Drain water heat recovery unit that captures waste-water heat from all the showers and has a minimum efficiency of 40% if installed for equal flow or a minimum efficiency of 52% if installed for unequal flow

Efficiency levels for water heating equipment were identified by the model numbers and associated efficiency values found in the AHRI Directory of Certified Performance. Model numbers were recorded for equipment found onsite, and efficiencies were looked up on the AHRI Directory.

Table 29 shows the number of homes where each technology was observed, and the selected energy credit option used to meet the code. Note that Option 5c was selected 39 of 40 instances where heat pump water heaters were installed. The EF requirement for electric water heaters is the same for Options 5b and 5c. However, Option 5c requires the water heater to also meet the standards of NEEA's Northern Climate Specifications for Heat Pump Water Heaters and is worth 1.5 credits compared to one credit for Option 5b.

Table 29 Water Heater Efficiency Option Findings

Description	Base	5b	5c	Total
Gas Conventional	1	0	2	3
Gas Tankless	0	14	52	66
Propane Tankless	2	0	0	2
Electric Conventional	0	0	2	2
Heat Pump Water Heater	0	1	39	40
Ground Source Heat Pump	0	0	1	1
Total	**3**	**15**	**96**	**114**

Table 30 Water Heater Efficiency Option Findings

Description	Base	5b	5c	Total	Option Upgraded
Gas Conventional	1%	0%	2%	3%	67%
Gas Tankless	0%	12%	46%	58%	100%
Propane Tankless	2%	0%	0%	2%	0%
Electric Conventional	0%	0%	2%	2%	100%
Heat Pump Water Heater	0%	1%	34%	35%	100%
Ground Source Heat Pump	0%	0%	1%	1%	100%
Total	**3%**	**13%**	**84%**	**100%**	**97%**

Table 31 provides compliance findings for each required efficiency level, based on the federal minimum or selected Efficient Water Heating Option. Overall, the compliance rate is 77%, but almost all the non-compliance is due to the Option 5c non-compliance. Option 5c requires a 0.91 EF tankless gas or 2.0 EF heat pump water heater meeting NEEA's Northern Climate Specifications for Heat Pump Water Heaters. Figure 19 and Figure 20 show the distribution of water heater efficiency for fuel-fired water heaters and heat pump water heaters, respectively. Three observed water heaters did not have efficiency recorded.

Table 31 Required Water Heater Efficiency Compliance Findings

Description	0.74 EF Gas	0.91 EF Gas	2 EF Electric	0.9 EF Electric	Overall
Comply	14	29	40	2	85
Did Not Comply	0	24	2	0	26
Total	**14**	**53**	**42**	**2**	**111**
% Comply	100%	55%	95%	100%	77%
Average	0.851	0.908	3.360	0.920	

Figure 19 Fuel Fired Water Heater Findings (Conventional and Tankless)

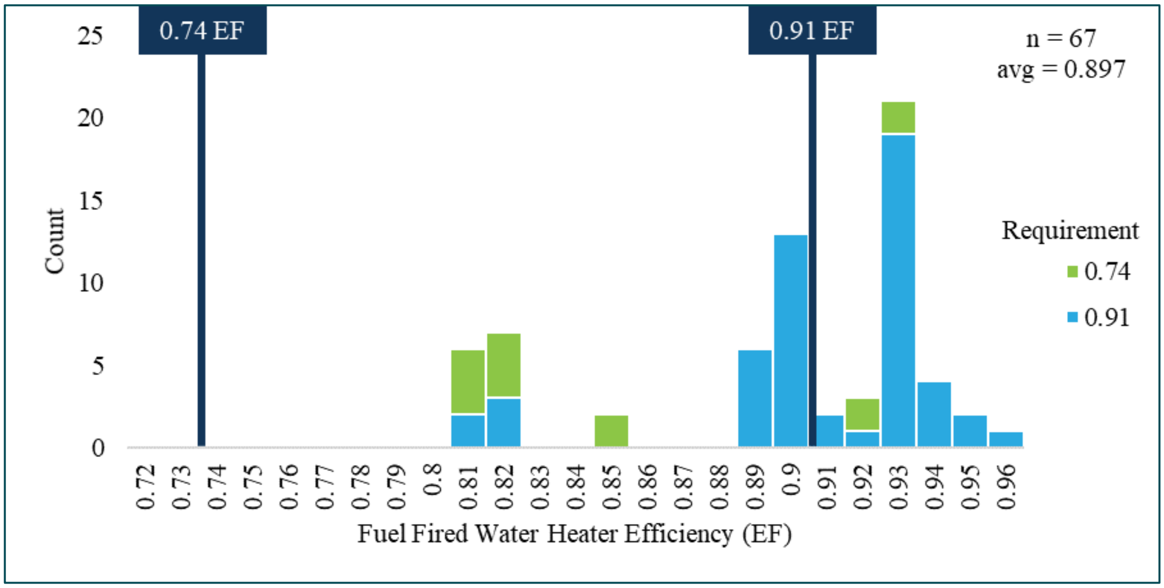
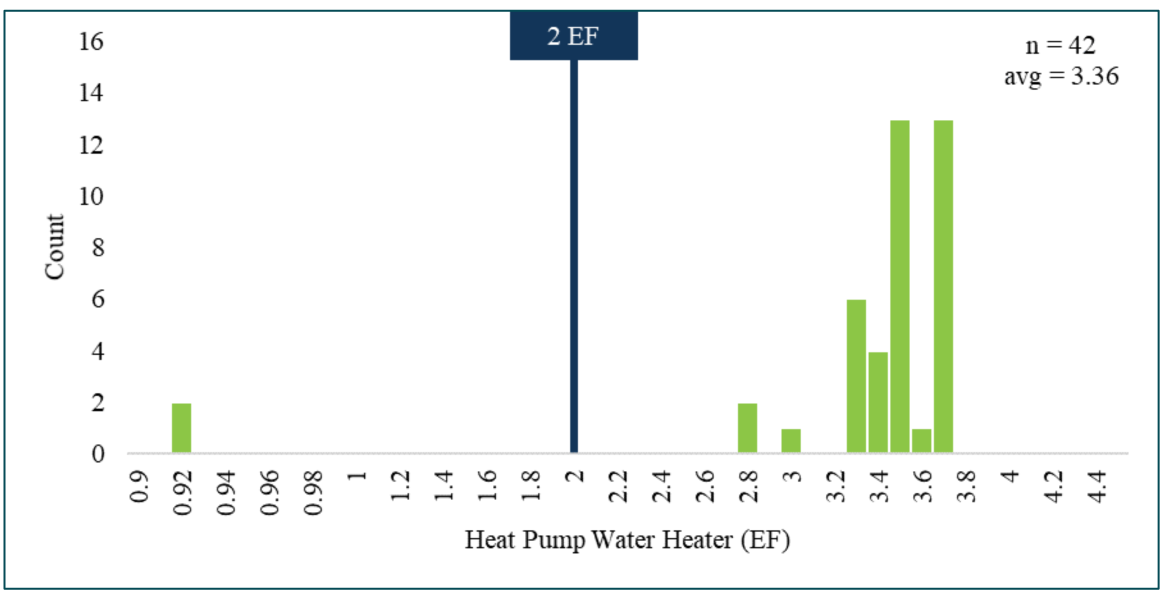


Figure 20 Heat Pump Water Heater Findings



Interpretation

Higher efficiency water heater compliance options were selected at 111 of 114 home with observable water heaters (97%). No drain water heat recover units were identified at houses.

45% of installations where Option 5c was selected, requiring a fuel-fired water heater with a 0.91 EF, did not meet the requirement. It is important to note that many of these non-compliant water heaters nearly met the requirement; 18 of those 23 non-compliant water heaters had energy factors of 0.89 – 0.90.

3.2.10 Duct Location

Only one option for high-efficiency HVAC distribution system is available for selection by builders from the Energy Credit Table:

Option 4: All heating and cooling system components installed in the conditioned space. A maximum of 10 linear feet of return ducts and 5 linear feet of supply ducts may be located outside the conditioned space. This option cannot be combined with Option 3d (ductless split systems).

Inspectors identified duct locations and approximated percentages of ducts in the attic, crawlspace, or conditioned space. As shown in Table 32, in four of 16 instances where Option 4 was identified in the plans, inspectors found the system to not meet the code requirement of having less than 10 linear feet of return ducts or 5 linear feet of supply ducts located outside the conditioned space. Two of those four houses had over 20% of supply ducts in the attic. The other two of those houses had a very small percentage, but over 5 linear feet, of supply ducts in the attic.

In all cases of ducts being fully installed in the conditioned space of the house, the inspectors also found the air handler to be installed inside the conditioned space of the house.

Table 32 Duct Location Option Findings

Description	Base	Option 4	Total
Attic	46	0	46
Attic and Conditioned	66	4	70
Attic and Crawlspace	15	0	15
Conditioned	12	12	24
Crawlspace	3	0	3
Crawlspace and Conditioned	3	0	3
Total	**145**	**16**	**161**

Table 33 Duct Location Option Findings

Description	Base	Opt 4	Total	Option Upgraded
Attic	29%	0%	29%	0%
Attic and Conditioned	41%	2%	43%	6%
Attic and Crawlspace	9%	0%	9%	0%
Conditioned	7%	7%	15%	50%
Crawlspace	2%	0%	2%	0%
Crawlspace and Conditioned	2%	0%	2%	0%
Total	**90%**	**10%**	**100%**	**10%**

Table 34 Duct Location Compliance Findings

Description	Opt 4	Overall[17]
Comply	12	157
Did Not Comply	4	4
Total	**16**	**161**
% Comply	75%	98%

Interpretation

The duct location data shows that duct location credits were applied at only 16 homes. Of those homes, 12 systems met the code requirements of Option 4 (75%). But the data also show 12 homes that meet the Option 4 credit requirements do not have that option selected to meet the code. These homes should see higher than expected savings because of the extra point they are choosing not to document.

3.2.11 Water Fixture Flow Rates

Washington energy code does not have a mandatory requirement for water fixture flow rates. Reduced water fixture flow rates in showerheads, kitchen sink faucets, and lavatory faucets is an option for additional energy credit through Option 5a: 1.75 GPM or less for all showerheads and kitchen sink faucets, and 1.0 GPM or less for lavatory faucets.

Flow rates for most showerheads and kitchen sink faucets were easily identifiable. Some flow rates were found at 1.8 GPM, which might be rounded up from 1.75 by manufacturers. For the compliance analysis below, 1.8 GPM is assumed to meet the 1.75 GPM flow rate requirement for kitchen faucets and showerheads.

Table 35 shows the number of homes observed in Phase 2 and recorded in Phase 1 with either a baseline selection or selection of Option 5a. In both Phase 1 and Phase 2, Option 5a is utilized in a high percent of homes. Table 36 shows compliance rates for homes where Option 5a was selected.

[17] Duct location is only a requirement of the code at homes where Option 4 is selected. In all other instances, the duct location complies with the code no matter where they are located.

Table 35 Water Fixture Flow Rate Findings

Option	Phase 2 Count	Phase 2 Percent	Phase 1 Count	Phase 1 Weighted Percent
Base	7	8%	41	15%
5a	82	92%	209	85%
Total	**89**		**250**	

Table 36 Water Fixture Compliance Findings by Flow Rate

Description	Shower 1.75 GPM	Kitchen 1.75 GPM	Bathroom 1 GPM
Comply	80	79	27
Did Not Comply	2	2	15
Total	**82**	**81**	**42**
% Comply	98%	98%	64%
Average	1.72	1.62	1.10

A breakout of finding by fixture type is shown in Table 37, and the total observed by fixture type shows the flow rates for many lavatory faucets were not identifiable. At homes where Option 5a was selected, all three components (showerhead, kitchen faucet, and bathroom faucet flow rates) complied at 32 of 48 homes.

Table 37 Water Fixture Compliance Findings by Room (Low-Flow and Baseline Combined)

Description	Shower	Kitchen	Bathroom	All Fixtures in all Rooms
Comply	87	86	33	32
Did Not Comply	2	2	15	16
Total	**89**	**88**	**48**	**48**
% Comply	98%	98%	69%	67%
Average	1.72	1.60	1.10	1.10

Figure 21 Shower Fixture Flow Rate Findings

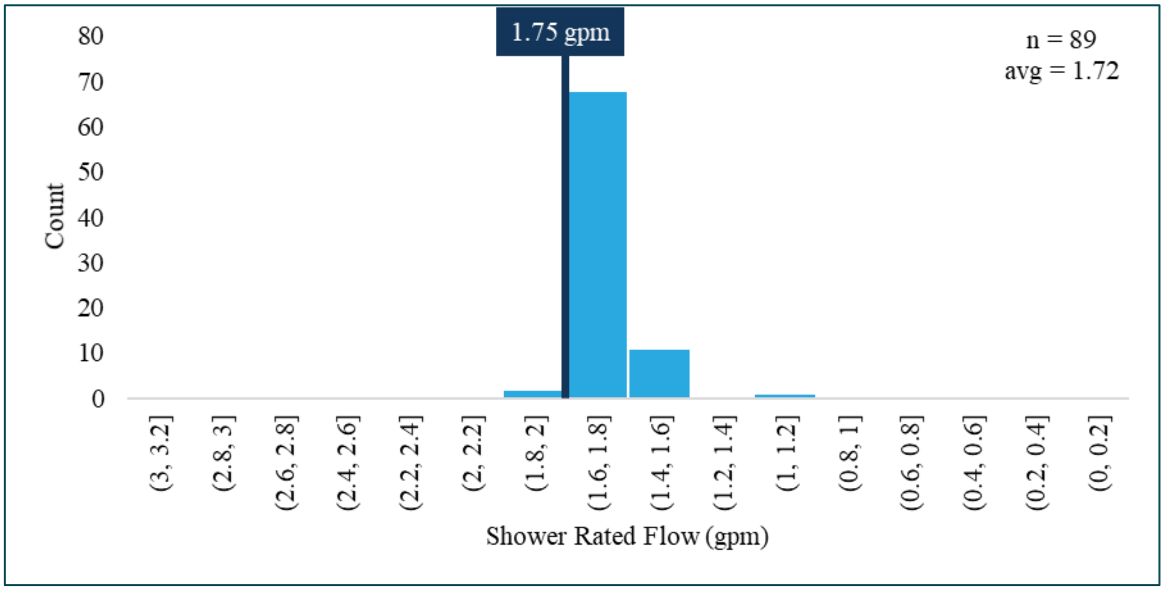


Figure 22 Kitchen Fixture Flow Rate Findings

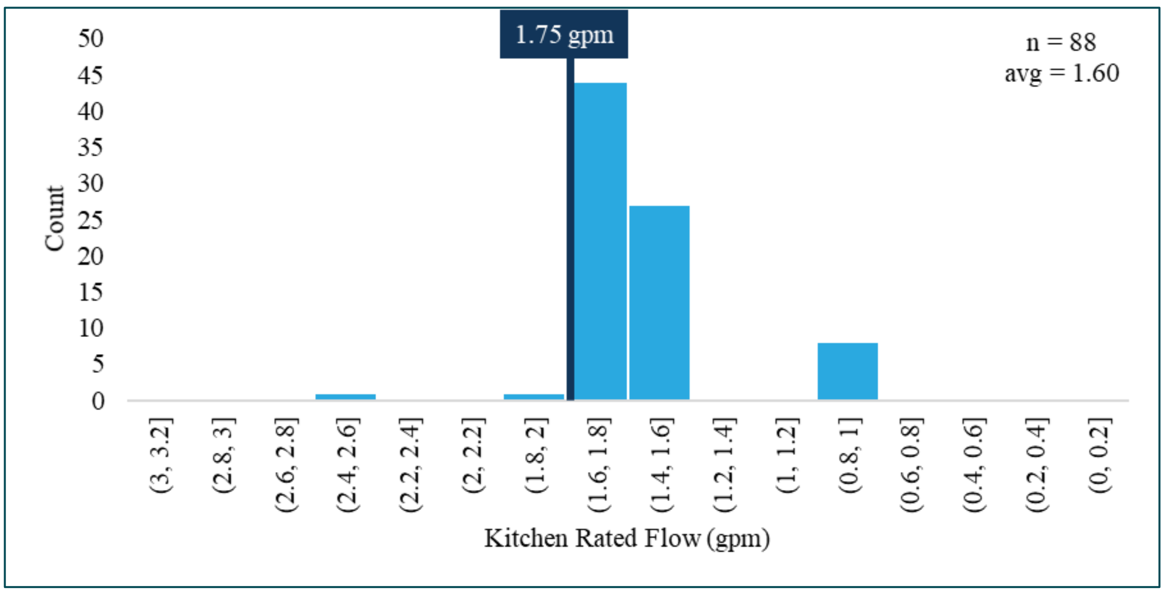
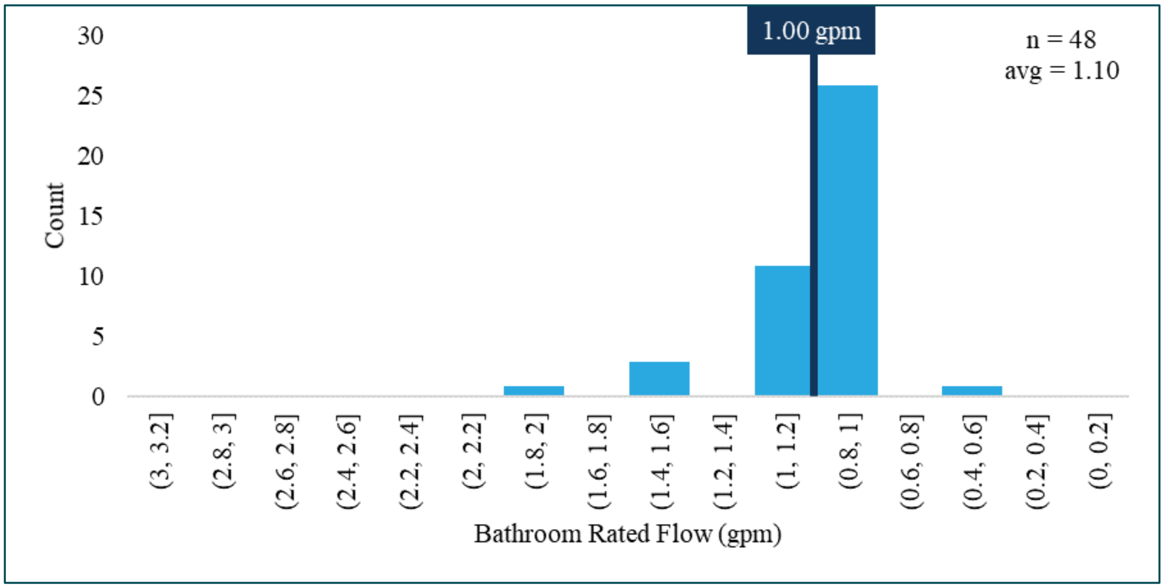


Figure 23 Bathroom Fixture Flow Rate Findings



Interpretation

Option 5a was selected at 92% of homes where fixtures were observed. Showerhead and kitchen faucet flow met Option 5a requirements at 98% of homes. Bathroom faucet flow rates met Option 5a requirements at 64% of homes where flow could be identified. Compliance rates were high in showers and kitchens, less so in bathrooms.

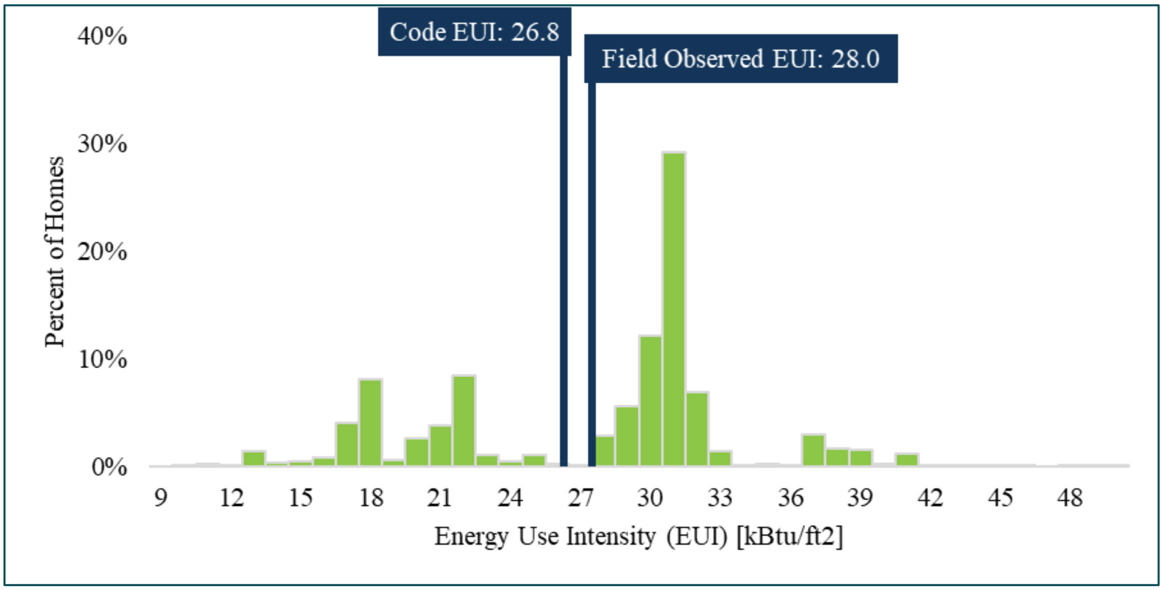
3.2.12 Statewide Energy Results – Consumption Implications

The research team analyzed how well builders are meeting the Washington state code and how this is estimated to affect energy consumption across the state. To conduct this analysis, we modeled home energy consumption based on data observed in the field and compared that to a baseline of modeled energy consumption in homes built to just meet state code. The analysis depicts the energy savings opportunity for all houses meeting the energy code[18].

Figure 24 depicts EUIs for homes modeled on observed data and those modeled to meet state code. The figure indicates that homes built-to-code have an estimated EUI of 26.8 compared to an EUI of 28.0 estimated for homes modeled on observed non-compliance data.

[18] Additional modeling information can be found in Appendix I

Figure 24 Average Modeled Distribution of Regulated EUI (kBtu/ft²/year) for Homes in Washington



3.2.13 Measure Energy Results – Savings Potential Analysis

The savings potential analysis which follows estimates the degree to which observed non-compliance in key items/measures negatively affect energy consumption. For the key item measure analysis, each home meeting or exceeding code is set to the code level and each unique non-complying value is unchanged. This creates the non-compliance savings analysis by measure. The table below represents impacts from measures not complying in at least 90% of homes.

SEEM runs were generated for each unique non-complying value (binned in some areas due to how many SEEM runs were generated—the bins used are in line with the histograms above). In total, 45,468 SEEM runs were used in the measure analysis; each level of a measure includes all the relevant climate, prototype, and base HVAC levels from the RTF. The cost of energy utilizes the latest EIA average rates for the state of Washington, $0.0947/kWh and $1.025/therm in December 2019. Non-compliance of each of the measures below are explained in the preceding sections.

Table 38 Statewide Annual Measure-Level Savings for Washington

Measure	Electricity Savings (kWh/home)	Natural Gas Savings (therms/home)	Total Savings (kBtu/home)	Number of Homes	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)
Wall Insulation	50	10	1,178	21792	25,672	328,142
Air Sealing	15	3	322	21792	7,019	91,558
Duct Tightness	9	3	285	21792	6,218	75,733
Low-Flow Fixtures	10	2	267	21792	5,816	73,124
DHW	20	1	168	21792	3,653	63,694
Ceiling Insulation	5	1	112	21792	2,438	31,202
Foundation Insulation	2	0	51	21792	1,116	14,028
Total	112	20	2,383		51,932	677,480

Table 39 5-Years, 10-Years, and 30-Years Cumulative Annual Statewide Savings for Washington

Measure	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)		
	5 Year	10 Year	30 Year	5 Year	10 Year	30 Year
Wall Insulation	385,086	1,411,983	11,937,671	4,922,132	18,047,817	152,586,090
Air Sealing	105,279	386,024	3,263,659	1,373,364	5,035,669	42,574,290
Duct Tightness	93,269	341,985	2,891,329	1,135,992	4,165,305	35,215,764
Low-Flow Fixtures	87,237	319,869	2,704,348	1,096,856	4,021,805	34,002,533
DHW	54,799	200,930	1,698,768	955,403	3,503,143	29,617,485
Ceiling Insulation	36,570	134,090	1,133,671	468,026	1,716,096	14,508,809
Foundation Insulation	16,733	61,356	518,738	210,425	771,557	6,523,162
Total	778,974	2,856,237	24,148,185	10,162,198	37,261,392	315,028,132

3.3 Anecdotal Stories from the Field

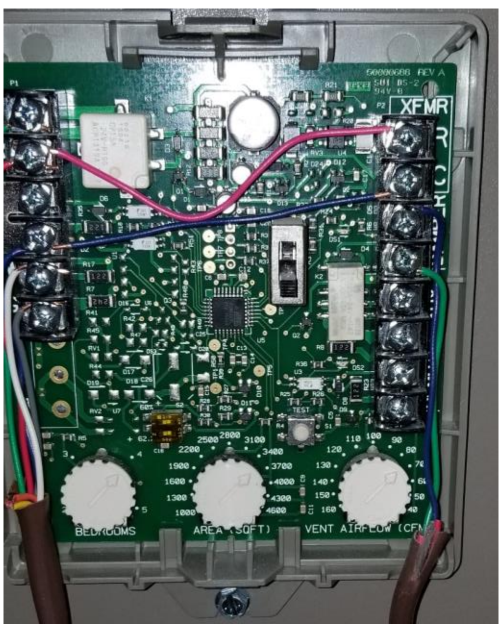
- Some builders reported that heat pump water heater settings are regularly switched by home buyers from "heat pump mode" or "hybrid mode" to "electric mode" after purchase following complaints of not having enough hot water, setting the system in the least efficient mode.

- Where insulation is placed between web-trusses below conditioned spaces above garages, the areas between the webs are potentially void of insulation.

- Some builders would prefer specific energy compliance pathways identified, instead of credit options so that they could be told specifically how to meet energy code requirements. The options were difficult for some of these builders to understand.

- Heat Recovery Ventilators (HRVs) are not being installed and tested correctly. Since HRVs are required more frequently under upcoming newer codes, more HRV training is needed.
- Ducts outside the envelope are more frequently in the attic rather than the crawl space which leads to more lost energy.

- When designers plan for ducts to be inside the envelope, the result is often a more efficient and shorter duct system.
- Code requires ECM blowers in air handlers with integrated whole house ventilation system. 23% of HVAC air handlers with integrated whole house ventilation have non-ECM blowers. Controllers for these systems were often not set to provide the appropriate amount of airflow for the house.



- Building inspectors have difficulty enforcing duct and air leakage testing.
- Building departments have difficulty confirming HVAC sizing calculations.
- Options that can be purchased (HVAC and water heating equipment efficiency) are easier for contractors to meet code requirements compared to options that require changes to building practices (duct location, continuous insulation).

4. Conclusions

The Washington New Residential Construction Code Study provides an understanding of how the 2015 Washington State Energy Code has impacted residential new construction building practice including which additional energy credit options are preferred by builders. The study also provides estimates of new home energy performance and where increased compliance with state energy code yields the potential for additional energy savings.

Table 40 Annual Statewide Savings Potential in Washington

Measure	Total Energy Savings (MMBtu/year)	Total Energy Cost Savings ($/year)
Wall Insulation	25,672	328,142
Air Sealing	7,019	91,558
Duct Tightness	6,218	75,733
Low-Flow Fixtures	5,816	73,124
DHW	3,653	63,694
Ceiling Insulation	2,438	31,202
Foundation Insulation	1,116	14,028
Total	51,932	677,480

Targeting wall insulation and air sealing will contribute to the highest energy savings and should be the focus of future educational outreach to builders, architects, code enforcement staff, and contractors. Selecting low-flow fixtures and water heater efficiency are also opportunities for large energy savings and should be easier items to comply with because they just involve purchasing decisions and not installation details.

5. References

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Washington Suggested Energy Credit Option Combinations. The complete presentation can be found at http://www.energy.wsu.edu/Documents/Codes_Option_pack_slides.pdf

Simplified Energy-Enthalpy Model (SEEM). https://rtf.nwcouncil.org/simplified-energy-enthalpy-model-seem

Appendix A State Sampling Plan

Sample Frame for Phase 1 and Phase 2. Phase 1 is a stratified random sample of jurisdictions within the Jurisdiction Size Categories. Phase 2 is a random sample of homes across the state from the average yearly count of homes built per jurisdiction.

Table 41 State Sampling Frame

County Place	2015 to 2017 average	Pct of Total	Cumul-ative Pct	Top 90th?	Cumul-ative ID	Sample Expected Value	Phase 2 Sample Value	Phase 1 Jurisdic-tion size
Pierce County Unincorporated Area (Pierce County, WA)	1,649	7.6%	7.6%	TRUE	1	5.3	4	3 - large
Snohomish County Unincorporated Area (Snohomish County, WA)	1,600	7.3%	14.9%	TRUE	1,650	5.1	3	3 - large
Clark County Unincorporated Area (Clark County, WA)	1,338	6.1%	21.0%	TRUE	3,250	4.3	7	3 - large
Spokane County Unincorporated Area (Spokane County, WA)	803	3.7%	24.7%	TRUE	4,588	2.6	1	3 - large
Seattle (King County, WA)	733	3.4%	28.1%	TRUE	5,390	2.4	3	3 - large
King County Unincorporated Area (King County, WA)	489	2.2%	30.3%	TRUE	6,124	1.6	1	3 - large
Kitsap County Unincorporated Area (Kitsap County, WA)	462	2.1%	32.5%	TRUE	6,613	1.5	3	3 - large
Thurston County Unincorporated Area (Thurston County, WA)	389	1.8%	34.2%	TRUE	7,075	1.3	2	3 - large
Pasco (Franklin County, WA)	387	1.8%	36.0%	TRUE	7,464	1.2	3	3 - large
Spokane (Spokane County, WA)	347	1.6%	37.6%	TRUE	7,851	1.1	2	2 - medium
Kirkland (King County, WA)	318	1.5%	39.1%	TRUE	8,198	1.0	0	2 - medium
Island County Unincorporated Area (Island County, WA)	295	1.4%	40.4%	TRUE	8,515	1.0	1	2 - medium
Bellevue (King County, WA)	288	1.3%	41.7%	TRUE	8,811	0.9	0	2 - medium
Vancouver (Clark County, WA)	287	1.3%	43.1%	TRUE	9,098	0.9	2	2 - medium
Sammamish (King County, WA)	283	1.3%	44.4%	TRUE	9,386	0.9	0	2 - medium
Whatcom County Unincorporated Area (Whatcom County, WA)	281	1.3%	45.7%	TRUE	9,668	0.9	2	2 - medium
Kennewick (Benton County, WA)	274	1.3%	46.9%	TRUE	9,949	0.9	0	2 - medium
Lacey (Thurston County, WA)	269	1.2%	48.1%	TRUE	10,223	0.9	0	2 - medium
Richland (Benton County, WA)	259	1.2%	49.3%	TRUE	10,492	0.8	1	2 - medium
Chelan County Unincorporated Area (Chelan County, WA)	248	1.1%	50.5%	TRUE	10,751	0.8	1	2 - medium
Lake Stevens (Snohomish County, WA)	243	1.1%	51.6%	TRUE	10,999	0.8	1	2 - medium
Kittitas County Unincorporated Area (Kittitas County, WA)	241	1.1%	52.7%	TRUE	11,242	0.8	0	2 - medium
Kent (King County, WA)	236	1.1%	53.8%	TRUE	11,483	0.8	1	2 - medium
Ridgefield (Clark County, WA)	231	1.1%	54.8%	TRUE	11,719	0.7	1	2 - medium
Camas (Clark County, WA)	231	1.1%	55.9%	TRUE	11,950	0.7	3	2 - medium
Benton County Unincorporated Area (Benton County, WA)	217	1.0%	56.9%	TRUE	12,181	0.7	2	2 - medium

County Place	2015 to 2017 average	Pct of Total	Cumul-ative Pct	Top 90th?	Cumul-ative ID	Sample Expected Value	Phase 2 Sample Value	Phase 1 Jurisdic-tion size
Everett (Snohomish County, WA)	202	0.9%	57.8%	TRUE	12,397	0.7	0	2 - medium
Auburn (King County, WA)	198	0.9%	58.7%	TRUE	12,599	0.6	1	2 - medium
Skagit County Unincorporated Area (Skagit County, WA)	185	0.8%	59.6%	TRUE	12,798	0.6	2	2 - medium
Bellingham (Whatcom County, WA)	184	0.8%	60.4%	TRUE	12,983	0.6	1	2 - medium
Gig Harbor (Pierce County, WA)	182	0.8%	61.2%	TRUE	13,167	0.6	0	2 - medium
Renton (King County, WA)	180	0.8%	62.1%	TRUE	13,348	0.6	0	2 - medium
Cowlitz County Unincorporated Area (Cowlitz County, WA)	162	0.7%	62.8%	TRUE	13,528	0.5	0	1 - small
Redmond (King County, WA)	160	0.7%	63.6%	TRUE	13,690	0.5	1	1 - small
Issaquah (King County, WA)	159	0.7%	64.3%	TRUE	13,850	0.5	1	1 - small
Spokane Valley (Spokane County, WA)	157	0.7%	65.0%	TRUE	14,009	0.5	2	1 - small
Tacoma (Pierce County, WA)	157	0.7%	65.7%	TRUE	14,166	0.5	1	1 - small
Yakima County Unincorporated Area (Yakima County, WA)	155	0.7%	66.4%	TRUE	14,323	0.5	0	1 - small
Mason County Unincorporated Area (Mason County, WA)	152	0.7%	67.1%	TRUE	14,478	0.5	0	1 - small
Clallam County Unincorporated Area (Clallam County, WA)	146	0.7%	67.8%	TRUE	14,630	0.5	1	1 - small
Mount Vernon (Skagit County, WA)	145	0.7%	68.5%	TRUE	14,776	0.5	0	1 - small
Bothell (King County, WA)	140	0.6%	69.1%	TRUE	14,921	0.5	0	1 - small
Liberty Lake (Spokane County, WA)	140	0.6%	69.8%	TRUE	15,061	0.5	0	1 - small
Puyallup (Pierce County, WA)	138	0.6%	70.4%	TRUE	15,202	0.4	1	1 - small
Douglas County Unincorporated Area (Douglas County, WA)	136	0.6%	71.0%	TRUE	15,339	0.4	0	1 - small
Olympia (Thurston County, WA)	134	0.6%	71.6%	TRUE	15,475	0.4	0	1 - small
Yakima (Yakima County, WA)	132	0.6%	72.2%	TRUE	15,610	0.4	0	1 - small
Lewis County Unincorporated Area (Lewis County, WA)	131	0.6%	72.8%	TRUE	15,742	0.4	0	1 - small
Jefferson County Unincorporated Area (Jefferson County, WA)	130	0.6%	73.4%	TRUE	15,873	0.4	0	1 - small
Poulsbo (Kitsap County, WA)	122	0.6%	74.0%	TRUE	16,002	0.4	1	1 - small
Grant County Unincorporated Area (Grant County, WA)	122	0.6%	74.5%	TRUE	16,124	0.4	0	1 - small
Battle Ground (Clark County, WA)	114	0.5%	75.1%	TRUE	16,246	0.4	1	1 - small
Bainbridge Island (Kitsap County, WA)	109	0.5%	75.6%	TRUE	16,360	0.4	0	1 - small
Okanogan County Unincorporated Area (Okanogan County, WA)	108	0.5%	76.1%	TRUE	16,469	0.3	0	1 - small
Monroe (Snohomish County, WA)	107	0.5%	76.6%	TRUE	16,577	0.3	0	1 - small

County Place	2015 to 2017 average	Pct of Total	Cumul-ative Pct	Top 90th?	Cumul-ative ID	Sample Expected Value	Phase 2 Sample Value	Phase 1 Jurisdic-tion size
Marysville (Snohomish County, WA)	105	0.5%	77.0%	TRUE	16,684	0.3	1	1 - small
Franklin County Unincorporated Area (Franklin County, WA)	104	0.5%	77.5%	TRUE	16,789	0.3	0	1 - small
West Richland (Benton County, WA)	103	0.5%	78.0%	TRUE	16,892	0.3	0	1 - small
San Juan County Unincorporated Area (San Juan County, WA)	102	0.5%	78.5%	TRUE	16,995	0.3	0	1 - small
Bremerton (Kitsap County, WA)	99	0.5%	78.9%	TRUE	17,097	0.3	0	1 - small
Woodland (Cowlitz County, WA)	96	0.4%	79.3%	TRUE	17,196	0.3	0	1 - small
Tumwater (Thurston County, WA)	94	0.4%	79.8%	TRUE	17,292	0.3	0	1 - small
Stevens County Unincorporated Area (Stevens County, WA)	94	0.4%	80.2%	TRUE	17,387	0.3	0	1 - small
Orting (Pierce County, WA)	94	0.4%	80.6%	TRUE	17,481	0.3	0	1 - small
Ferndale (Whatcom County, WA)	94	0.4%	81.1%	TRUE	17,575	0.3	0	1 - small
Klickitat County Unincorporated Area (Klickitat County, WA)	92	0.4%	81.5%	TRUE	17,669	0.3	0	1 - small
Ocean Shores (Grays Harbor County, WA)	92	0.4%	81.9%	TRUE	17,761	0.3	0	1 - small
Kenmore (King County, WA)	91	0.4%	82.3%	TRUE	17,853	0.3	0	1 - small
Grays Harbor County Unincorporated Area (Grays Harbor County, WA)	87	0.4%	82.7%	TRUE	17,944	0.3	0	1 - small
Moses Lake (Grant County, WA)	87	0.4%	83.1%	TRUE	18,031	0.3	0	1 - small
Washougal (Clark County, WA)	85	0.4%	83.5%	TRUE	18,118	0.3	0	1 - small
Edgewood (Pierce County, WA)	85	0.4%	83.9%	TRUE	18,203	0.3	0	1 - small
Anacortes (Skagit County, WA)	78	0.4%	84.3%	TRUE	18,288	0.3	0	1 - small
Port Orchard (Kitsap County, WA)	78	0.4%	84.6%	TRUE	18,367	0.2	1	1 - small
Mercer Island (King County, WA)	75	0.3%	85.0%	TRUE	18,444	0.2	0	1 - small
Lynden (Whatcom County, WA)	72	0.3%	85.3%	TRUE	18,519	0.2	0	1 - small
Shoreline (King County, WA)	71	0.3%	85.6%	TRUE	18,591	0.2	0	1 - small
Newcastle (King County, WA)	69	0.3%	86.0%	TRUE	18,662	0.2	0	1 - small
Sequim (Clallam County, WA)	69	0.3%	86.3%	TRUE	18,732	0.2	1	1 - small
Pacific County Unincorporated Area (Pacific County, WA)	67	0.3%	86.6%	TRUE	18,801	0.2	1	1 - small
Maple Valley (King County, WA)	67	0.3%	86.9%	TRUE	18,868	0.2	0	1 - small
Wenatchee (Chelan County, WA)	67	0.3%	87.2%	TRUE	18,935	0.2	0	1 - small
Burien (King County, WA)	67	0.3%	87.5%	TRUE	19,002	0.2	0	1 - small
Walla Walla (Walla Walla County, WA)	66	0.3%	87.8%	TRUE	19,069	0.2	0	1 - small
Ellensburg (Kittitas County, WA)	66	0.3%	88.1%	TRUE	19,135	0.2	0	1 - small
Snoqualmie (King County, WA)	66	0.3%	88.4%	TRUE	19,201	0.2	0	1 - small
Yelm (Thurston County, WA)	65	0.3%	88.7%	TRUE	19,267	0.2	0	1 - small

County Place	2015 to 2017 average	Pct of Total	Cumul-ative Pct	Top 90th?	Cumul-ative ID	Sample Expected Value	Phase 2 Sample Value	Phase 1 Jurisdic-tion size
Bonney Lake (Pierce County, WA)	65	0.3%	89.0%	TRUE	19,332	0.2	1	1 - small
University Place (Pierce County, WA)	63	0.3%	89.3%	TRUE	19,397	0.2	1	1 - small
North Bend (King County, WA)	59	0.3%	89.6%	TRUE	19,460	0.2	0	1 - small
Port Townsend (Jefferson County, WA)	57	0.3%	89.8%	TRUE	19,519	0.2	0	1 - small

Appendix B Substitutions

City of Poulsbo was replaced with City of Bremerton. One sample set was required. Outreach to builders and the building department was conducted without gaining access to homes. Outreach staff was informed that a large subdivision had recently completed, and construction had slowed down. Bremerton was selected as a substitute because of its location near Poulsbo, within the same county, and had the most similar size and number of project starts compared to Poulsbo compared to other local cities.

Skagit County Unincorporated Area was substituted with City of Mount Vernon. Two sample sets were required. Outreach to builders and the building department was conducted was without gaining access to homes. The building department suggested reaching out to the regional home builders' association. The home builders' association suggested that minimal homes were being built due to restrictions placed on accessing county water sources. City of Mount Vernon was selected as a substitute because of its location within Skagit County and we were informed that builders in the county also build in Mount Vernon.

Appendix C Heat Pump Sizing and Controls

Due to the undersized heat pumps requiring additional strip heat at low temperatures, heat pump sizes were analyzed. Oversized heat pumps might cause the system to frequently cycle during cooling, potentially increasing energy consumption and affecting dehumidification. Construction details were used to calculate expected heating capacity.

Table 42 Heat Pump Capacity Findings

Expected Heat Pump Capacity per Sizing Calculations (btu/h)	Installed Heat Pump Capacity (btu/h)	Comments
39,316	36,000	Undersized
36,000	48,000	
24,000	28,000	
24,750	30,000	
19,412	24,000	
25,750	46,000	
20,250	30,000	
24,000	24,000	
19,412	24,000	

Use of auxiliary electric resistance heat increases electricity use in homes heated with heat pumps. Locking out the use of auxiliary heat through controls (usually set in the thermostat) reduces the use of auxiliary heat. Washington energy code requires controls to be installed on heat pump systems with supplementary electric heaters to be set at final inspection to lock out auxiliary heat when outdoor temperature is 35°F or more. Air source heat pumps were installed at 12 houses inspected at final. Controls were inspected at 9 of those houses. Auxiliary heat lockout settings did not meet the code requirement and were not set at 35°F or less at 7 of 9 houses.

Appendix D Table R406.2 Energy Credits (2015 Code)

The below is an abbreviated version of Table 406.2. The complete table can be found at www.energy.wsu.edu/Documents/2015WSEC_R_final.pdf

Table 43 Summary of Additional Energy Credit Requirements

Option	Description	Credits
1a: EFFICIENT BUILDING ENVELOPE	Vertical fenestration U = 0.28 Floor R-38 Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab	0.5
1b: EFFICIENT BUILDING ENVELOPE	Vertical fenestration U = 0.25 Wall R-21 plus R-4 Floor R-38 Basement wall R-21 int plus R-5 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab	1.0
1c: EFFICIENT BUILDING ENVELOPE	Vertical fenestration U = 0.22 Ceiling and single-rafter or joist-vaulted R-49 advanced Wood frame wall R-21 int plus R-12 ci Floor R-38 Basement wall R-21 int plus R-12 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab	2.0
1d: EFFICIENT BUILDING ENVELOPE	Vertical fenestration U = 0.24	0.5
2a: AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION	Reduce the tested air leakage to 3.0 air changes per hour maximum and All whole house ventilation requirements as determined by Section M1507.3 of the International Residential Code shall be met with a high efficiency fan (maximum 0.35 watts/cfm), not interlocked with the furnace fan. Ventilation systems using a furnace including an ECM motor are allowed, provided that they are controlled to operate at low speed in ventilation only mode.	0.5
2b: AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION	Reduce the tested air leakage to 2.0 air changes per hour maximum and All whole house ventilation requirements as determined by Section M1507.3 of the International Residential Code shall be met with a heat recovery ventilation system with minimum sensible heat recovery efficiency of 0.70.	1.0

Option	Description	Credits
2c: AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION	Reduce the tested air leakage to 1.5 air changes per hour maximum and All whole house ventilation requirements as determined by Section M1507.3 of the International Residential Code shall be met with a heat recovery ventilation system with minimum sensible heat recovery efficiency of 0.85.	1.5
3a: HIGH EFFICIENCY HVAC EQUIPMENT	Gas, propane or oil-fired furnace with minimum AFUE of 94%, or Gas, propane or oiled-fired boiler with minimum AFUE of 92%	1.0
3b: HIGH EFFICIENCY HVAC EQUIPMENT	Air-source heat pump with minimum HSPF of 9.0	1.0
3c: HIGH EFFICIENCY HVAC EQUIPMENT	Closed-loop ground source heat pump; with a minimum COP of 3.3 or Open loop water source heat pump with a maximum pumping hydraulic head of 150 feet and minimum COP of 3.6	1.5
3d: HIGH EFFICIENCY HVAC EQUIPMENT	Ductless Split System Heat Pumps, Zonal Control: In homes where the primary space heating system is zonal electric heating, a ductless heat pump system shall be installed and provide heating to the largest zone of the housing unit.	1.0
4: HIGH EFFICIENCY HVAC DISTRIBUTION SYSTEM	All heating and cooling system components installed inside the conditioned space. This includes all equipment and distribution system components such as forced air ducts, hydronic piping, hydronic floor heating loop, convectors and radiators. All combustion equipment shall be direct vent or sealed combustion. Electric resistance heat and ductless heat pumps are not permitted under this option. Direct combustion heating equipment with AFUE less than 80% is not permitted under this option.	1.0
5a: EFFICIENT WATER HEATING	All showerhead and kitchen sink faucets installed in the house shall be rated at 1.75 GPM or less. All other lavatory faucets shall be rated at 1.0 GPM or less.	0.5
5b: EFFICIENT WATER HEATING	Water heating system shall include one of the following: Gas, propane or oil water heater with a minimum EF of 0.74 or Water heater heated by ground source heat pump meeting the requirements of Option 3c.	1.0

Option	Description	Credits
5c: EFFICIENT WATER HEATING	Water heating system shall include one of the following: Gas, propane or oil water heater with a minimum EF of 0.91 or Solar water heating supplementing a minimum standard water heater. Solar water heating will provide a rated minimum savings of 85 therms or 2000 kWh based on the Solar Rating and Certification Corporation (SRCC) Annual Performance of OG-300 Certified Solar Water Heating Systems or Electric heat pump water heater with a minimum EF of 2.0 and meeting the standards of NEEA's Northern Climate Specifications for Heat Pump Water Heaters	1.5
5d: EFFICIENT WATER HEATING	A drain water heat recovery unit(s) shall be installed, which captures waste water heat from all the showers, and has a minimum efficiency of 40% if installed for equal flow or a minimum efficiency of 52% if installed for unequal flow. Such units shall be rated in accordance CSA B55.1 and be so labeled.	0.5
6: RENEWABLE ELECTRIC ENERGY	For each 1200 kWh of electrical generation per each housing unit provided annually by on-site wind or solar equipment a 0.5 credit shall be allowed, up to 3 credits.	0.5

Appendix E Suggested Energy Credit Option Combinations

The below is an abbreviated version of Washington's suggested energy credit option combinations. The combinations below allow the builder to utilize available equipment and minor envelope upgrades and is an available resource on the WSU Energy Program Building Efficiency website. The complete presentation can be found at http://www.energy.wsu.edu/Documents/Codes_Option_pack_slides.pdf

Opt	Description	Pts
3a or **3b**	94 AFUE Gas Furnace or 9.0 HSPF heat pump	1.0
4	All ducts and furnace located inside the conditioned space	1.0
5a	Kitchen sink and showerheads ≤ 1.75 GPM, lavatory faucets ≤ 1.0 GPM	0.5
5b	Gas water heater ≥ 0.74 EF	1.0
	Total	**3.5**

Opt	Description	Pts
1a	R-38 Floors and U-0.28 Windows	0.5
3a or **3b**	94 AFUE Gas Furnace or 9.0 HSPF heat pump	1.0
5a	Kitchen sink and showerheads ≤ 1.75 GPM, lavatory faucets ≤ 1.0 GPM	0.5
5c	Gas water heater ≥ 0.91 EF or Electric water heater ≥ 2.0 EF	1.5
	Total	**3.5**

Opt	Description	Pts
1a	R-38 Floors and U-0.28 Windows	0.5
2a	Air leakage ≤ 3.0 ACH @ 50pa	0.5
3a **or** **3b**	94 AFUE Gas Furnace or 9.0 HSPF heat pump	1.0
5a	Kitchen sink and showerheads ≤ 1.75 GPM, lavatory faucets ≤ 1.0 GPM	0.5
5b	Gas water heater ≥ 0.74 EF	1.0
	Total	**3.5**

Opt	Description	Pts
2a	Air leakage ≤ 3.0 ACH @ 50pa	0.5
3a or 3b	94 AFUE Gas Furnace or 9.0 HSPF heat pump	1.0
5a	Kitchen sink and showerheads ≤ 1.75 GPM, lavatory faucets ≤ 1.0 GPM	0.5
5c	Gas water heater ≥ 0.91 EF or Electric water heater ≥ 2.0 EF	1.5
	Total	**3.5**

Opt	Description	Pts
1a	R-38 Floors and U-0.28 Windows	0.5
3d	Ductless Heat Pump	1.0
5a	Kitchen sink and showerheads ≤ 1.75 GPM, lavatory faucets ≤ 1.0 GPM	0.5
5c	Electric water heater ≥ 2.0 EF	1.5
	Total	**3.5**

Opt	Description	Pts
3a	92 AFUE Gas Boiler	1.0
4	All heating and cooling system components installed within the conditioned space. Electric resistance and ductless heat pumps not permitted under this option.	1.0
5c	Gas water heater ≥ 0.91 EF	1.5
	Total	**3.5**

Appendix F Additional Data Items

The information below provides a summary of additional observations of residential construction practices in the state. Except where indicated, data are from on-site inspections of homes.

Average Conditioned Floor Area

- Phase 1 (n=321) 2575 sq. ft weighted[19] (data from plans or permits obtained during Document Review – Phase 1)
- Phase 2 (n=184) 2268 sq. ft (data from plans or permits obtained during Site Visits – Phase 2)

Number of Stories Above Grade (n=184)

- 38% 1 Story
- 53% 2 Story
- 9% 3 Story

Foundation Type (n=184)

- 7% Heated Basement
- 11% Slab on Grade
- 82% Vented Crawlspace

Insulation

Under-Floor Insulation

- R-Value
    - R-38 (n=76)
    - R-30 (n=47)
- Floor Joist Depth Greater than Insulation Thickness[20]
    - 1% of joists with R-30 are deeper than 10”
    - 9% of joists with R-38 are deeper than 12”
- Attics
    - Over 90% of homes have primarily flat ceilings with R49 blown-in fiberglass insulation

Ducts

Total Duct Leakage (CFM per 100 sq. ft of conditioned floor area at 25 Pa)

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[19] Weighting description in Section 2.2 Document Review – Phase 1
[20] Assume 10” thick batt for R-30 and 12” for R-38
https://res.cloudinary.com/knauf-insulation/image/upload/v1582746731/Knauf%20Insulation/Batt%20Insulation/EcoBatt/Standard/Literature/knauf-ecobatt-data-sheet.pdf
https://dcpd6wotaa0mb.cloudfront.net/mdms/dms/Residential%20Insulation/10013811/10013811-EcoTouch-PINK-FIBERGLAS-Insulation-Product-Data-Sheet.pdf?v=1575807602000
https://www.certainteed.com/resources/30-29-179.pdf

- 4.6 CFM25/100 sq. ft Measured (n=61) Tested at Post-Construction
- 2.6 CFM25/100 sq. ft Reported (n=41) Tested at Rough In

House Leakage at Final (ACH50)

- Average 3.8 ACH50 Measured[21] (n=107)
- Average 3.3 ACH50 Reported[22] (n=36)

Heating

Fuel Source (n=178)

- 79% Gas
- 20% Electricity
- 1% Propane

Primary Heating System Type (n=178)

- 80% Furnace
- 8% Central Heat Pump
- 12% Ductless Heat Pump

Equipment Efficiency

- Average 95.6% AFUE Gas Furnace (n=135)
- Average 8.9 HSPF Central Air Source Heat Pump (n=12)
- Average 10.9 HSPF Ductless Heat Pump (n=12)

ECM (n =145)

- 62% Yes
- 38% No

Cooling

Primary Cooling System Type (n=82)

- 56% Central Air Conditioner
- 18% Central Heat Pump
- 26% Ductless Heat Pump

Equipment Efficiency

- 13.4 SEER Central Air Conditioner
- 14.8 SEER Central Heat Pump
- 20.9 SEER Ductless Heat Pump

Water Heating

Fuel Source (n=114)

[21] Measured values are results from tests performed by program staff during the study

[22] Reported values are documented results from tests performed for the builder and found in builder records or the energy compliance certificate

- 61% Natural Gas
- 37% Electric
- 2% Propane

System Type (n=114)

- 40% Storage
  - 34% Heat Pump Water Heater
  - 2% Electric Conventional
  - 3% Gas Conventional
  - 1% Ground Source Heat Pump
- 60% Tankless
  - 58% Natural Gas
  - 2% Propane

Storage System Capacity (n=45)

- Average 58 Gallons
  - Electric Conventional Average 50 Gallons
  - Gas Conventional Average 50 Gallons
  - Heat Pump Water Heater Average 58 Gallons

Equipment Efficiency (n=112)

- Average 0.89 UEF Natural Gas
  - Average 0.58 Conventional
  - Average 0.90 Natural Gas Tankless
- Average 3.38 UEF Electric
  - Average 0.92 Electric Conventional
  - Average 3.39 UEF Heat Pump Water Heater

Whole House Ventilation

System Type (n=136)

- 57% Exhaust Only
- 37% Supply Ventilation Integrated with Whole-House Air Handler
  - 77% ECM[23]
  - 23% No ECM
- 2% HRV Integrated with Whole-House Air Handler
- 4% HRV Not Integrated with Whole-House Air Handler

Measured Exhaust Flow (n=51)

- Average 64 CFM

[23] ECM is required for supply ventilation integrated with whole-house air handler

Appendix G Simplified Energy-Enthalpy Model (SEEM)

The following description of SEEM is adapted from the RTF SEEM website.[24]

SEEM, written at Ecotope, was developed by and for the Northwest Power and Conservation Council and NEEA. SEEM is used extensively in the Northwest to estimate conservation measure savings for regional energy utility policy planners. It is the simulation engine used to provide heating and cooling energy savings estimates for the residential sector in the Council's Power Plan, for the Performance Tested Comfort System (PTCS) incentive program, the Northwest EnergyStar for Homes program, as well as numerous other utility program offerings. SEEM is also used to support state building energy code revisions including the Washington, Oregon, Idaho and Montana state energy codes.

The SEEM program is designed to model small scale residential building energy use. The program consists of an hourly thermal simulation and an hourly moisture (humidity) simulation that interacts with duct specifications, equipment, and weather parameters to calculate the annual heating and cooling energy requirements of the home. It is based on algorithms consistent with current American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), American Heating and Refrigeration Institute (AHRI), and International Organization for Standards (ISO) calculation standards.

For the SEEM model to be used in RTF measure assessments, it must be calibrated to baseline and efficient-case consumption. Calibration for single family, multi-family, and manufactured homes are separate endeavors that utilize metered data from a sample of homes in the NW to estimate energy consumption. The most recent SEEM calibration files can be found below, along with supporting documentation necessary to run the SEEM model.

To create a simulation, SEEM takes a number of input parameters including those for occupancy, equipment, ducts, envelope, foundation, and infiltration. The input structure makes the program flexible and allows it to model a diverse set of building construction types such as split-level, heated basements, slab-on-grade, and cantilevered floors. SEEM generates a number of outputs including building UA, heating load, heating equipment input requirements, cooling load, and cooling equipment input requirements.

SEEM offers a number of advantages over other simulation programs. The step-by-step hourly calculations accurately model both air temperature and mean radiant temperature using a state-of-the-art algorithm. Next, heat pumps and air-conditioners are modeled on real performance data from manufactures' catalogues. SEEM also provides the capability to use multiple control strategies and thermostat setups for the equipment. Further, SEEM closely tracks duct losses to user specified zones (inside, outside, crawl, attic) and accurately models their impacts. Additionally, SEEM contains a comprehensive below-grade heat loss algorithm to model building ground contact through slabs, crawl spaces, and basements. Lastly, weather data for the simulation comes from the widely used Typical Meteorological Year (TMY) datasets.

[24] https://rtf.nwcouncil.org/simplified-energy-enthalpy-model-seem

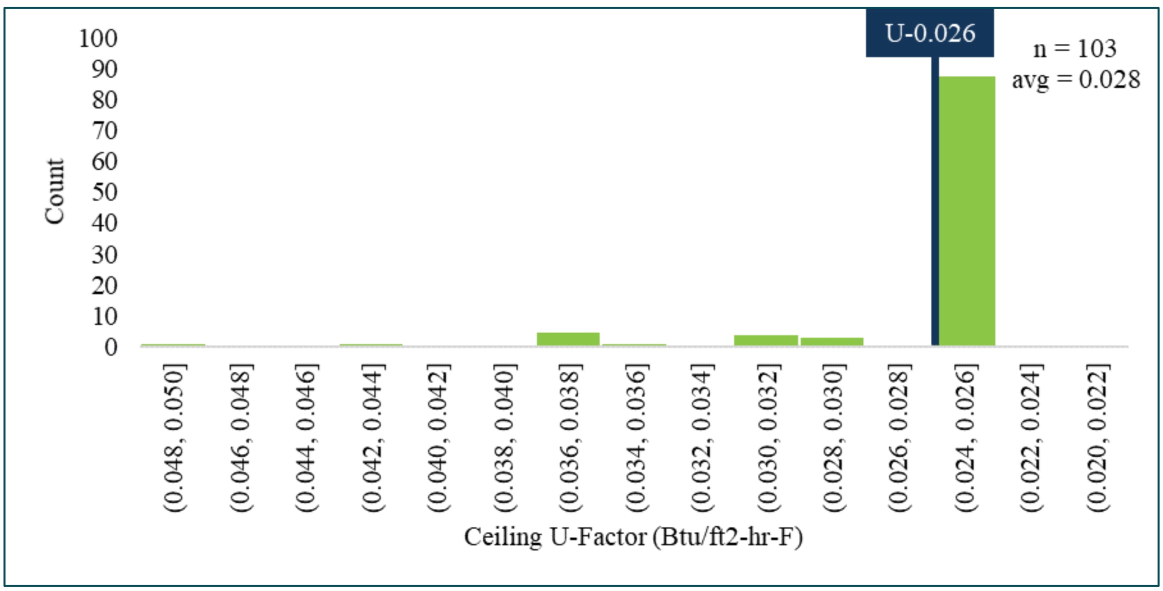
Appendix H Ceiling and Floor Insulation U-Factor Findings

Insulation grades of ceilings and floors were not identified during inspections. Therefore, U-factor compliance for ceilings and floors aligns with R-Value findings. The required U-factor of 0.026 is identified in Washington energy code for ceilings with R-49 insulation (without full insulation above exterior walls) and is also deemed equivalent to ceilings with R-38 insulation (with full insulation above exterior walls.) U-factors were calculated for ceilings with less than the required R-49 insulation.

Table 44 Ceiling Insulation U-Factor Compliance Findings

Description	0.026
Comply	88
Did Not Comply	15
Total	**103**
% Comply	85%
Average	0.028

Figure 25 Ceiling Insulation U-Factor Findings

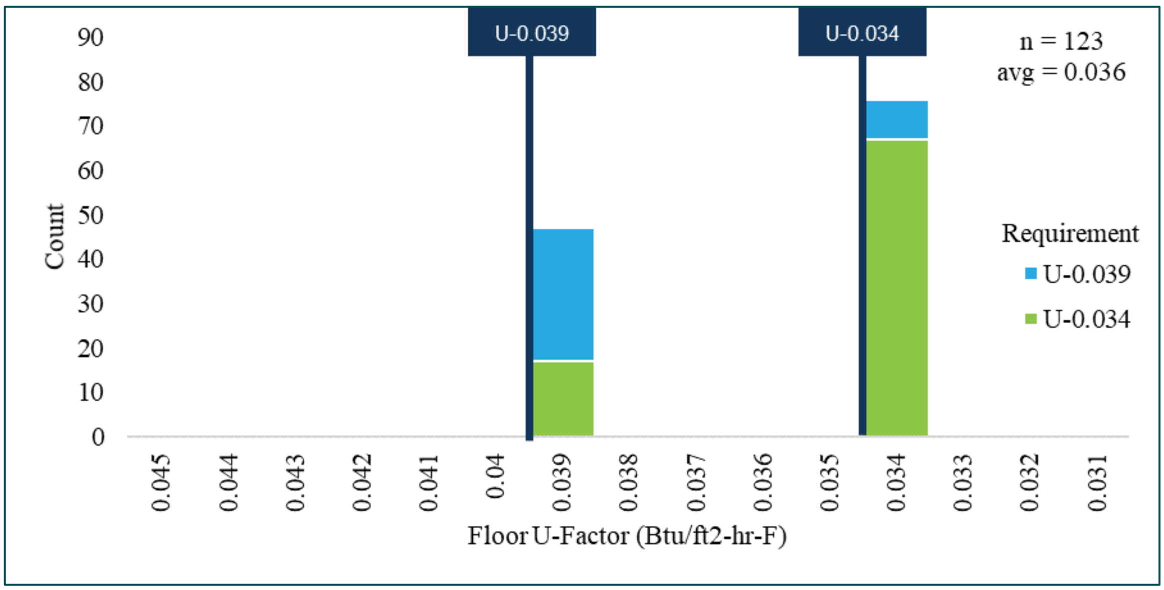


Framed-floor cavity depth was measured and compared to the standard thickness of the fiberglass insulation. U-factors shown below are not degraded for compression or if insulation was not in contact with the subfloor. The required U-factors in Table 45 align with values provided in Washington energy code.

Table 45 Floor Insulation U-Factor Compliance Findings

Description	Required U-0.039	Required U-0.034	Total
Comply	39	67	106
Did Not Comply	0	17	17
Total	**39**	**84**	**123**
% Comply	100%	80%	86%
Average	0.038	0.035	0.036

Figure 26 Floor Insulation U-Factor Findings



Appendix I Statewide Energy Analysis Description

In the statewide analysis there are two sets of models: the baseline and observed. The baseline model is weighted prototype analysis using the code requirements as inputs. The observed model uses the findings from the field data collection to estimate the implemented energy use of homes by factoring in the non-compliance findings and not allowing the above-code findings to offset those deficiencies. If a key item was found to only comply 75% of the time, then the individual model runs to build up the observed model will have an expected compliance of 75% as well.

The process for creating each prototype model run for the observed category is through random number generation applied to the distribution of field study findings. Each key item has a random number generated for each prototype model run, and the random number is used as a lookup value for the input. For instance, if a measure has a 50% probability of level A, 30% of level B, and 20% of level C, and a home is assigned a random number of 34.28592% for this measure, the home is assigned to level A because 34.28592% falls in the first interval of 0%-50%, while not falling in 50%-80% or 80%-100%, utilizing a cumulative probability.

The prototype models use the RTF methodology of building sizes, HVAC types, and RTF climates in addition to the most common pathways used to meet the code. These combinations create the baseline model. For the observed model, each of the key items that did not comply more than 90% of the time have a set of observed observations and a percent associated with how often each of those observations were found. Thus, the observed model has many more individual models used to build up the statewide results. In total there were 3,241 SEEM models used for this statewide analysis.

Using this methodology to build up a random sample of homes across the state using the probability findings of the individual measures yields the results shown in Figure 24. The bars represent the findings from the observed model and the two reference lines are the mean EUI from the baseline model (Code EUI) and the mean EUI from the observed model (Field Observed EUI). The non-compliance represents about a 6% increase in energy use over the baseline model.