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Oregon Residential Code Compliance Evaluation

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Executive Summary

Introduction

In 2023, the Northwest Energy Efficiency Alliance (NEEA) commissioned an evaluation of the residential new construction market's response to the 2021 Oregon Residential Specialty Code (2021 ORSC). NEEA selected a consulting team led by Industrial Economics, Inc. (IEC), with contributions from Resource Refocus LLC, Earth Advantage, Inc., and NMR Group, Inc., to conduct the evaluation. The main study objective was to assess statewide compliance with the 2021 ORSC. Additional objectives were to provide statewide findings regarding the proportion of homes with gas versus electric primary space heating, the proportion of homes with gas versus electric water heating, and the proportion of homes with above-code elements. This study also serves as an update to the Pacific Northwest National Laboratory (PNNL)'s 2020 *Oregon Residential Energy Code Field Study*.

Methodology

The study follows the sampling methodology specified in the U.S. Department of Energy (DOE)'s [Residential Building Energy Code Field Study: Data Collection & Analysis](#) with some modifications.

The study assesses statewide compliance levels for the following seven key measures in DOE's methodology:

1. Envelope tightness (air changes per hour (ACH) at 50 Pascals).
2. Windows (U-factor and solar heat gain coefficient (SHGC)).
3. Wall insulation (assembly U-factor).
4. Ceiling insulation (R-value).
5. Lighting (percent high efficacy).
6. Foundation insulation (including floor insulation, basement wall insulation, crawlspace wall insulation, and slab insulation R-values).
7. Duct tightness (expressed in cubic feet per minute (cfm) per 100 sq. ft. of conditioned floor area (CFA) at 25 Pascals).

The study also summarizes data on additional elements required by the 2021 ORSC:

- Duct location.
- Heating system location.
- Ventilation type.
- Selection of at least one Additional Measure (e.g., a high efficiency HVAC system) from Table N1101.1(2).

Using data collected on the seven individual code requirements, the study provides estimates of statewide energy code compliance based on the share of newly constructed homes that meet the minimum code requirements from an energy consumption perspective.

The analysis was split into three main components:

- **Statistical analysis** to assess compliance at the individual measure level.
- **Modeling analysis** to estimate the energy consumption of both an observed and code-compliant population of homes. The observed population is based on the data collected, while the code-compliant population assumes each home exactly meets the code requirements.
- **Savings analysis** to project the potential savings with improved energy code compliance relative to the 2021 ORSC. Savings are reported per home and statewide.

Throughout the report, the 2021 ORSC results are compared to the results of the PNNL's previous study of the 2017 ORSC.¹

Lastly, the team conducted interviews with five builders across Oregon to better understand the compliance process, barriers to meeting specific code requirements, and their perceptions about the building energy code.

Results

This study provides insight into 2021 ORSC compliance both at a measure and whole home level. Two climate zones are found in Oregon: climate zone 4C mixed marine (CZ4) and climate zone 5B cool dry (CZ5). On average, CZ5 has more heating degree days than CZ4, but the code requirements are the same statewide. More detailed information about the code requirements can be found in the Oregon Residential Code section in Chapter 1.

Key Statistical Observations

Heating, ventilation, and air conditioning (HVAC) and domestic hot water (DHW) fuel source:

There is a notable shift from natural gas to electricity for both space heating and DHW. For space heating, the share of natural gas furnaces has decreased from 81% (2017 ORSC) to 54% (2021 ORSC). The share of natural gas DHW systems has decreased from 70% (2017 ORSC) to 49.6% (2021 ORSC). In the current study of the 2021 ORSC, 46% of the HVAC systems and 40.7% of the DHW systems are electric heat pumps. In the previous study of the 2017 ORSC, both were 14%.

Insulation amount: 2021 ORSC compliance rates were high ($\geq 94\%$) for the amount of insulation in walls, CZ5 ceilings, and floors. About a quarter of the CZ4 ceiling insulation observations were not compliant. These results are similar to those found under the 2017 ORSC.

Insulation installation quality (IIQ): Statewide wall insulation U-factors increased from 43% compliant under the 2017 ORSC to 73% compliant under the 2021 ORSC. Statewide ceiling U-factor compliance decreased from 70% to 46%, while floor insulation U-factor compliance increased slightly from 51% to 59% statewide.

Lighting: Lighting compliance remained high, increasing slightly from 92% under the 2017 ORSC to 98% under the 2021 ORSC statewide.

Slabs: Slab foundation compliance (only observed in CZ5) increased from 33% (2017 ORSC) to 100% (2021 ORSC). However, there were six slab insulation observations in the previous study of the 2017 ORSC and only two in the current study.

Window U-factor: The window U-factor requirement is more stringent under the 2021 ORSC. While the average window U-factor was similar to the average under the 2017 ORSC, compliance decreased (87% down from 96% under the previous code) due to the stricter requirements.

Envelope tightness: Only 57% of the envelope tightness observations were compliant under the 2021 ORSC testing pathway statewide. However, the average envelope tightness improved from 4.1 ACH under the 2017 ORSC to 3.7 ACH under the 2021 ORSC. It is possible that a home could meet

¹ PNNL, 2020. Oregon Residential Energy Code Field Study.

https://www.energycodes.gov/sites/default/files/2020-08/Oregon_Residential_Field_Study_rev1.pdf

the requirements in the “Air Barrier Installation and Air Sealing Requirements” while not meeting the testing specification, so compliance may be underestimated when using the testing metric.

Duct location: Duct location is a new 2021 ORSC prescriptive requirement that was not included in the 2017 ORSC. There was 62% compliance for observations with quantitative values. However, when including the 26 responses from the homeowner surveys, compliance could be as low as 40%. It is unclear whether respondents were aware that ducts buried in R-19 insulation would also be compliant, even if in an unconditioned space like an attic. Since more than 50% of the compliant quantitative observations had buried ducts, it is difficult to provide a precise compliance estimate when including the survey responses.

Heating system location: Only 51% of the observed homes complied with the 2021 ORSC requirement that the HVAC system is inside the thermal envelope. This does not include any homes that would comply via the 5% duct system length exception per the 2021 ORSC errata. For the systems in unconditioned space that specified a location, about three quarters were in the garage and one quarter were in vented attics.

Additional Measure: The 2021 ORSC requires the selection of one Additional Measure. Over 90% of the homes selected Measure 1, a high-efficiency HVAC system. All of the gas furnaces exceeded the Measure 1 Annual Fuel Utilization Efficiency (AFUE) requirement. For the air source heat pumps, 100% of the systems met or exceeded the Seasonal Energy Efficiency Ratio (SEER) requirement, but only 73% of the systems met the Heating Seasonal Performance Factor (HSPF) requirement.

Ventilation type: Ninety-one percent of the observed homes complied with the ORSC 2021 requirement for a whole-house balanced ventilation system.

Table ES-1 summarizes the measure-level compliance rates for the previous study of the 2017 ORSC and the current results. Red text indicates a lower compliance rate under the 2021 ORSC, and green text indicates a higher compliance rate for the current study as compared to the previous study.

Table ES-1. Comparison of measure-level compliance rates under the 2017 and 2021 ORSC

	2017 ORSC (% compliant)			2021 ORSC (% compliant)		
	CZ 4	CZ 5	Statewide	CZ 4	CZ 5	Statewide
Envelope Tightness*	82%	100%	86%	63%	29%	57%
Window U-factor**	95%	100%	96%	85%	100%	87%
Wall Insulation R-value	100%	100%	100%	100%	100%	100%
Wall Insulation U-factor	46%	43%	45%	72%	80%	73%
Ceiling Insulation	78%	100%	83%	76%	100%	79%
Ceiling U-factor	66%	84%	70%	41%	78%	46%
Lighting	90%	100%	92%	98%	100%	98%
Floor insulation R-value	94%	100%	95%	98%	100%	98%
Floor insulation U-factor	59%	29%	51%	60%	56%	59%
Unvented Crawl R-value	---	---	---	100%	---	100%
Unvented Crawl U-factor	---	---	---	0%	---	0%
Slab R-value	33%	---	---	100%	---	100%
Duct tightness/duct location*	54%	63%	56%	71%	56%	68%

*2017 did not have a requirement. Previous study compared to less stringent baseline.

**2021 ORSC is more stringent than 2017 ORSC.

Table ES-2 provides an overall comparison of the efficiency levels under the 2017 ORSC and the 2021 ORSC.

Table ES-2. Summary of the 2017 ORSC and 2021 efficiency levels

Key measure	Statewide average efficiency		
	2017 ORSC	2021 ORSC	Units
Envelope leakage	4.1	3.7	ACH at 50 Pa
Window U-factor	0.28	0.27	Btu/h-ft ² -F
Wall insulation R-Value	22.1	22	h-ft ² -F/Btu
Wall insulation U-factor	0.063	0.061	Btu/h-ft ² -F
Ceiling insulation R-Value	49.6	47.8	h-ft ² -F/Btu
Ceiling Insulation U-factor	0.024	0.024	Btu/h-ft ² -F
Lighting	97.8%	99.8%	% high efficacy
Floor insulation R-value	32	33.6	h-ft ² -F/Btu
Floor insulation U-factor	0.033	0.034	Btu/h-ft ² -F
Unvented crawl wall R-value	---	21	h-ft ² -F/Btu
Unvented crawl U-factor	---	0.058	Btu/h-ft ² -F
Slab Edge R	13	15	h-ft ² -F/Btu
Duct locations	---	70.4	% ducts in conditioned space

Energy Analysis

The energy analysis results are provided in the histogram on the next page (**Figure ES-1**), which shows the weighted average regulated energy use intensity (EUI) of the observed data set compared to the expected weighted average regulated consumption based on homes that exactly met the prescriptive code requirements.²

The results estimate that the average new construction home in Oregon uses *more* energy than would be expected relative to a home built to the current minimum state code requirements. Based on the observed data set, the average regulated EUI is 24.0 kBtu/ft²-yr (dashed blue line). In comparison, homes exactly meeting minimum prescriptive energy code requirements have an average EUI of 22.4 kBtu/ft²-yr (solid blue line). A “typical” home in the state uses about 7% more regulated energy than a code compliant home.

Each of the models generated in the modeling analysis was compared to a minimally code-compliant model with the same heating and foundation type. In this comparison, the simulated population had an average compliance of 91.4%.³ This means that the analysis predicts 91.4%

² Regulated end uses include heating, cooling, lighting (interior and exterior), fans, and domestic hot water. The weights were defined by the frequency of field-observed heating system and foundation type combinations.

³ In this analysis, each individual model is compared to a code-compliant baseline model with the same foundation and heating type. If the individual model's energy use is less than or equal to the code-compliant

compliance and 8.6% non-compliance statewide. In comparison, NEEA reported 89% under the 2017 ORSC.

Note, the simulated population includes homes with above-code measures, which improves the average EUI statewide. This is why the average home uses 7% more energy than the code-compliant average, but there is still 8.6% non-compliance for the 2021 ORSC based on the individual models. Including above-code performance improves statewide compliance by about 1.6%.

There is a difference between the compliant and non-compliant home populations under the 2021 ORSC. When including above-code performance, on average the compliant population uses about 5.6% less energy than a code-compliant baseline while the non-compliant population uses about 12.4% more.

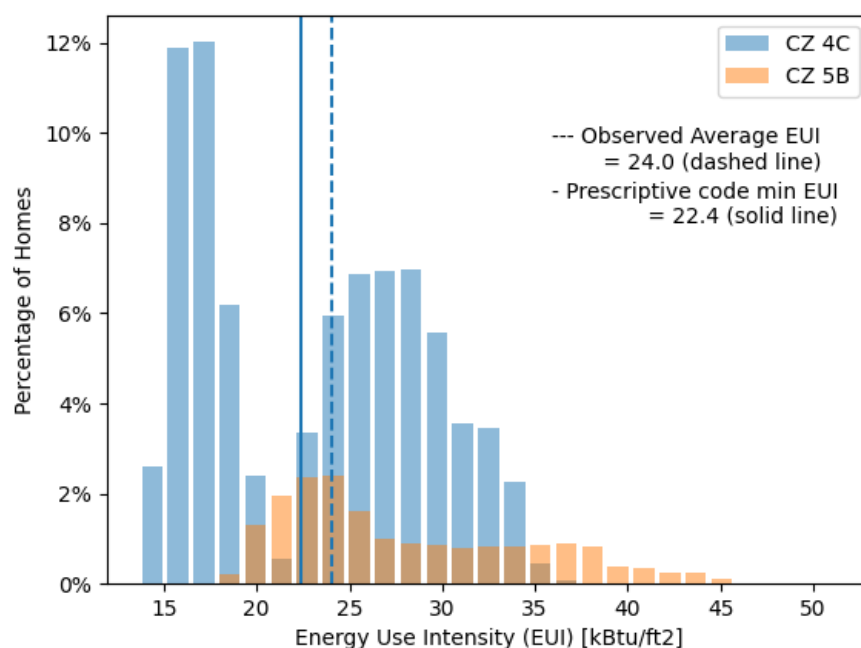


Figure ES-1. Statewide EUI analysis for Oregon

Savings Analysis

Table ES-3 summarizes the potential measure-level savings that could be the target for future education, training, and outreach activities. **Potential statewide annual energy savings are 26,728 MMBtu, which would result in \$613,725 in energy cost savings.** Over a 30-year period, this would save 12.4 million MMBtu and \$285 million.⁴

baseline, it is considered 100% compliant. If the individual model uses 5% more energy than the code-compliant baseline, it is considered 95% compliant. This methodology is used by NEEA for compliance reporting. It differs from the DOE *Residential Building Energy Code Field Study* methodology, which includes above-code performance in the average EUI.

⁴ Five-year, 10-year, and 30-year savings are included in the Savings Analysis Results section. Details on the energy cost assumptions are included in the Oregon Fuel Prices section in Appendix B.

Table ES-3. Annual statewide savings potential

Key Measure	Annual Savings	
	Energy (MMBtu)	Cost (\$)
Envelope Tightness (ACH50)	12,294	271,564
Window U-factor	421	8,443
Wall U-Factor	5,545	129,062
Ceiling U-Factor	4,085	91,189
Foundation Insulation	1,007	17,243
% Duct in Conditioned Space	3,375	96,223
TOTAL	26,728 MMBtu	\$613,725

Recommendations

Recommendations to improve code compliance and recommendations for future evaluation studies are summarized below. The main body of the report provides additional details for each recommendation.

Recommendations to Improve Code Compliance

NEEA and its partners should consider focusing education and outreach efforts on the variables with the highest potential energy savings. From highest to lowest, the majority of the potential savings are in envelope leakage, external wall insulation, ceiling insulation, and duct leakage. There is also room for improvement in foundation insulation and window U-factor compliance, but the potential savings are comparatively small.

Enhance envelope tightness, aiming for increased compliance and tighter envelopes.

Envelope tightness represents nearly half of the potential energy and cost savings. Under the 2021 ORSC, the statewide average envelope tightness is 3.7 ACH. In the previous study of the 2017 ORSC, the statewide average was 4.1 ACH, so the average ACH has improved. However, the maximum measured air leakage rate from this distribution (8.0 ACH) is essentially unchanged from that of the 2017 ORSC study (8.1). This indicates that while a portion of the industry is improving its air sealing practices, the leakiest buildings may not improve under the ORSC's current approach to envelope airtightness requirements.

Improve the quality of external wall insulation installation. The potential savings from improved compliance for external wall insulation represent 20% of the 2021 ORSC potential savings. Nearly all of the observations met or exceeded the R-21 insulation requirement, but about a third of the observations had Grade II or III IIQ, resulting in 73% compliance statewide. So, the amount of insulation is sufficient, but education and outreach efforts could focus on installation quality.

Improve both the quantity and quality of ceiling insulation, including compliance with increased R-value requirements. Ceiling insulation represents about 15% of the 2021 ORSC potential annual energy savings. All of the CZ5 observations met or exceeded the R-49 prescriptive requirement, while only 76% of the CZ4 observations did. Statewide, almost half of the IIQ observations were Grade II and III. So, education and outreach efforts could focus on IIQ statewide and the amount of insulation in CZ4.

Reduce duct leakage by relocating ducts to conditioned spaces or enhancing duct insulation in unconditioned spaces. Duct location is a new prescriptive requirement under the 2021 ORSC, requiring that 95% of the duct system (which includes the ductwork and heating system per the 2021 ORSC errata) is in the building's thermal envelope or that ducts are buried in R-19 insulation. Improved compliance with this measure represents about 13% of the potential savings statewide. Education and outreach efforts can focus on either moving ducts to conditioned spaces or improving duct insulation in unconditioned spaces. Notably, this requirement changed between the original 2021 ORSC and the 2021 ORSC errata, so there may be industry confusion on how to comply.⁵

Improve heating performance by relocating heating systems within the thermal envelope. Education and outreach efforts can focus on moving these systems to indoor closets or other spaces within the thermal envelope, rather than keeping them in garages or vented attics.

Consider developing accessible summaries of permitting and compliance requirements for builders along with more information about ORSC Additional Measure selection. During interviews, builders expressed frustration with what they described as “moving targets” in trying to achieve code requirements, especially across jurisdictions and code changes. They suggested that a streamlined summary of requirements for a given jurisdiction and highlighting the changes in the new code would help them meet requirements. Builders also tended to focus on costs when selecting an Additional Measure. Additional information and education about the benefits and best practices for installing specific measures might encourage the selection of Additional Measures beyond high performance heating equipment.

Recommendations for Future Studies

Future studies can focus on key areas to streamline and improve data collection.

Leverage multiple data sources to complete future studies in Oregon to limit the need for site visits. The IEC team was able to obtain most of the data used in this study through a combination of sources other than site visits, including AXIS/EPS data for above-code homes, permit data, plan sets, window and insulation contractor invoices, and homeowner survey data. Future studies in Oregon can leverage these sources to collect most data, although site visits will likely be required to collect IIQ observations and (for non-above-code homes) envelope tightness observations. Site visits may be the only reliable data source available in some jurisdictions, however, so future studies will need to use available data opportunistically and be flexible with sampling plans if attempting to reduce the need for site visits.⁶

Window and insulation contractor invoices and plan set reviews served as viable, cost-effective data sources for this study. There may be limitations and challenges associated with these approaches, however. This includes potential difficulty in getting contractors to provide data, a possible lack of representativeness in the data if only a small number of contractors share information or if plan sets are not available from a number of jurisdictions, and the possibility that data provided in invoices and plan sets will not reflect what measures are actually installed. To overcome these issues, future evaluators should attempt to collect data from a large pool of contractors and jurisdictions, which may require substantial outreach efforts and/or incentivizing

⁵ [Nov. 2021: BCD Technical Bulletin - 2021 ORSC](#) and [Feb. 2022: BCD Technical Bulletin - 2021 ORSC](#)

⁶ While these methods may be applicable in other states, this finding is specific to Oregon where the IEC team found greater success in using methods other than site visits than in similar studies in Montana and Idaho.

participation. Further, evaluators should conduct some verification visits to ensure invoices and plan sets are an accurate reflection of building practices.

If NEEA conducts another homeowner survey, consider using additional data sources to identify new construction homes. Permitting data from ATTOM required extensive cleaning, and many of the permit descriptions did include key information, including whether the homes were single- versus multifamily or zoned as residential and/or the occupancy status.⁷ This made it difficult to identify suitable homes occupied with eligible prospective survey participants. As a result, some addresses in the mailing list may not have been within the scope of this study, which could have been avoided with more reliable data. Utilities, city building departments, and real estate websites (for example, Zillow) might have more specific information on home types and other characteristics, which would help narrow the scope of potential homes to survey and streamline the sampling plan.

⁷ ATTOM is a data service company that provides information on a number of metrics related to properties: <https://www.attomdata.com/>.

1 Introduction

Background and Study Objectives

Residential building energy codes have the potential to significantly affect energy consumption throughout the Northwest (Idaho, Montana, Oregon, and Washington). In collaboration with regional stakeholders, the Northwest Energy Efficiency Alliance (NEEA) identifies new potential energy code measures, participates in the public process by providing data and analysis, and works with state code bodies to support code implementation. To assess the extent to which the energy savings goals of these efforts are realized in the market, NEEA commissions evaluation studies measuring the market's response to updated building energy codes in the residential new construction sector in the Northwest.

In 2023, NEEA commissioned an evaluation of the residential new construction market's response to the 2021 Oregon Residential Specialty Code (2021 ORSC). NEEA selected a consulting team led by Industrial Economics, Inc. (IEC), with contributions from Resource Refocus LLC, Earth Advantage, Inc, and NMR Group, Inc.

The main study objective was to assess statewide compliance with the 2021 ORSC. The study generally follows the methodology specified in the U.S. Department of Energy (DOE)'s [Residential Building Energy Code Field Study: Data Collection & Analysis](#) with some modifications.⁸ Based on an analysis of data from newly constructed single-family homes across the state, the study assesses statewide compliance levels for the following seven key code elements:

1. Envelope tightness (air changes per hour (ACH) at 50 Pascals).
2. Windows (U-factor and solar heat gain coefficient (SHGC)).
3. Wall insulation (assembly U-factor).
4. Ceiling insulation (R-value).
5. Lighting (percent high efficacy).
6. Foundation insulation (including floor insulation, basement wall insulation, crawlspace wall insulation, and slab insulation R-values).
7. Duct tightness (expressed in cubic feet per minute (cfm) per 100 sq. ft. of conditioned floor area (CFA) at 25 Pascals).

The study also summarizes data on additional elements required by the 2021 ORSC:

- Duct location.
- Heating system location.
- Ventilation type.
- Selection of at least one Additional Measure from Table N1101.1(2).

In addition, this report provides statewide findings regarding:

⁸ DOE's methodology requires all data to be collected through site visits to newly constructed homes at either the rough-in or final stage. While the IEC team followed DOE's sampling methodology, a focus of this study was to explore alternative methods to collect data from newly constructed homes. The IEC team piloted the following methods during this study: 1) permit data, 2) data for above-code homes in the EPS/AXIS database, 3) plan sets and contractor invoices, 4) homeowner survey data, and 5) on-site data. Chapter 2 describes the viability of each data source and how the IEC team combined data from multiple sources to conduct the analysis. The EPS/AXIS database is maintained by Energy Trust and contains data on above-code residential new construction homes in Oregon. This dataset is publicly available and provides data that can be used to develop energy simulation models in REM/Rate™ or Ekotrope™. Additional information and the full dataset are available at: <https://insider.energytrust.org/eps-new-construction-data/>.

- Proportion of homes with gas versus electric primary space heating.
- Proportion of homes with gas versus electric water heating.
- Proportion of homes with above-code elements.

Using data collected on individual code elements, the study provides estimates of statewide energy code compliance based on the share of newly constructed homes that meet the minimum code requirements from an energy consumption perspective.

This report includes results from the:

- **Statistical analysis** to assess compliance at the individual measure level.
- **Modeling analysis** to estimate the energy consumption of both an observed and code-compliant population of homes. The observed population is based on the data collection, while the code-compliant population assumes each home exactly meets the code requirements.
- **Savings analysis** to project the potential savings with improved energy code compliance relative to the 2021 ORSC. Savings are reported per home and statewide.

Oregon Residential Code

This study assesses compliance for homes built under the 2021 ORSC, which took effect in April 2021. This study serves in part as an update to the Pacific Northwest National Laboratory (PNNL)'s 2020 *Oregon Residential Energy Code Field Study*, which summarized compliance under Oregon's previous code (2017 ORSC).

Oregon has two climate zones: climate zone 4C mixed marine (CZ4) and climate zone 5B cool dry (CZ5). On average, CZ5 has more heating degree days than CZ4, but the code requirements are the same statewide.

Table 1 summarizes the differences in prescriptive requirements between the 2017 ORSC and the 2021 ORSC. Under the 2021 ORSC, window U-factor became more stringent and new code provisions were introduced for envelope tightness, duct location, heating system location, and ventilation systems (as compared to 2017 ORSC).

Table 1. 2017 ORSC vs. 2021 ORSC prescriptive requirements

Component	2017 ORSC	2021 ORSC	Units
Envelope Tightness	Includes list of locations that must be sealed as approved by the code official	4 ACH50 or meet "Air Barrier Installation and Air Sealing Requirements"	ACH at 50 Pa
Fenestration U-factor	0.30	0.27	Btu/h-ft ² -F
Fenestration SHGC	NR		
Wood-framed R-value (U-factor)	R-21 int. (0.059)		h-ft ² -F/Btu (Btu/h-ft ² -F)
Ceiling R value (U-factor)	Flat: R-49 (0.021) Vaulted: R-30 (0.033)		h-ft ² -F/Btu (Btu/h-ft ² -F)
Lighting equipment	All but two fixtures must be high efficiency		% high efficacy
Floor R-value (U-factor)	30 (0.033)		h-ft ² -F/Btu (Btu/h-ft ² -F)
Basement wall R-value (U-factor)	15 ci or 21 cavity (0.063 C-factor)		h-ft ² -F/Btu (Btu/h-ft ² -F)
Slab R-value and depth	15, 2 ft (0.520)		h-ft ² -F/Btu
Crawlspace wall R-value (C-factor)	R-15 ci or R-21 cavity (0.063 C-factor)		h-ft ² -F/Btu (Btu/h-ft ² -F)
Duct location	N/A	95% of duct system in building thermal	

Component	2017 ORSC	2021 ORSC	Units
		envelope or ducts buried in R-19 insulation	
Heating system location	N/A	In thermal envelope (unless complying with 5% duct system length exception)	
Ventilation	N/A	Whole house balanced ventilation	

In addition to the prescriptive requirements outlined in the table above, the 2021 ORSC requires the selection of one Additional Measure. There are eight options, shown in **Table 2**. This is a change from the 2017 ORSC, which required the selection of one Envelope Enhancement Measure and one Conservation Measure. A summary of the 2017 ORSC Additional Measure options is in Appendix B.

Table 2. 2021 ORSC Additional Measures Table N1101.1(2)⁹

1	HIGH EFFICIENCY HVAC SYSTEM^a a. Gas-fired furnace or boiler AFUE 94 percent, or b. Air source heat pump HSPF 10.0/14.0 SEER cooling, or c. Ground source heat pump COP 3.5 or Energy Star rated
2	HIGH EFFICIENCY WATER HEATING SYSTEM a. Natural gas/propane water heater with minimum UEF 0.90, or b. Electric heat pump water heater with minimum 2.0 COP, or c. Natural gas/propane tankless/instantaneous heater with minimum 0.80 UEF and Drain Water Heat Recovery Unit installed on minimum of one shower/tub-shower
3	WALL INSULATION UPGRADE Exterior walls—U-0.045/R-21 conventional framing with R-5.0 continuous insulation
4	ADVANCED ENVELOPE Windows—U-0.21 (Area weighted average), and Flat ceiling ^b —U-0.017/R-60, and Framed floors—U-0.026/R-38 or slab edge insulation to F-0.48 or less (R-10 for 48"; R-15 for 36" or R-5 fully insulated slab)
5	DUCTLESS HEAT PUMP For dwelling units with all-electric heat provide: Ductless heat pump of minimum HSPF 10 in primary zone replaces zonal electric heat sources, and Programmable thermostat for all heaters in bedrooms
6	HIGH EFFICIENCY THERMAL ENVELOPE UA^c Proposed UA is 8 percent lower than the code UA
7	GLAZING AREA Glazing area, measured as the total of framed openings is less than 12 percent of conditioned floor area
8	3 ACH AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION Achieve a maximum of 3.0 ACH50 whole-house air leakage when third-party tested and provide a whole-house ventilation system including heat recovery with a minimum sensible heat recovery efficiency of not less than 66 percent.

For SI: 1 square foot = 0.093 m², 1 watt per square foot = 10.8 W/m².

- Appliances located within the building thermal envelope shall have sealed combustion air installed. Combustion air shall be ducted directly from the outdoors.
- The maximum vaulted ceiling surface area shall not be greater than 50 percent of the total heated space floor area unless vaulted area has a U-factor no greater than U-0.026.
- In accordance with Table N1104.1(1), the Proposed UA total of the Proposed Alternative Design shall be a minimum of 8 percent less than the Code UA total of the Standard Base Case.

⁹ This table is from the "[2021 Oregon Residential Specialty Code: Significant changes summary](#)."
Blue/Underlined = New Oregon amendment, Blue = Existing Oregon amendment

2 Methodology

Overview

As noted in Chapter 1, the methodology is generally based on the DOE's [Residential Building Energy Code Field Study: Data Collection & Analysis](#). However, DOE's methodology requires all data to be collected through site visits to newly constructed homes at either the rough-in or final stage. While the IEC team followed DOE's methods for designing and selecting a sampling plan, and for (most) key measure selection to support the modeling, a focus of this study was to try to collect data from newly constructed homes using methods other than site visits. This was intended both to reduce the level of effort and costs during data collection in this study, and to inform NEEA of the feasibility of using these less resource-intensive methods for future assessments. The IEC team explored the following data sources during this study, each of which was successful to a degree but had some limitations:

1. Permit data
2. AXIS/EPS data (above-code homes)¹⁰
3. Plan sets/invoices¹¹
4. Survey data
5. On-site data

This chapter describes the sample plan, the data collected from each data source listed above, and the feasibility of using each source in future code studies. This chapter also describes the IEC team's methodology for conducting in-depth interviews with five builders across the state, which supplemented the quantitative data with qualitative insights. The chapter concludes with a summary of the steps taken to complete the data analysis.

Data Collection for Modeling

Sample Design & Replacements

IEC and NEEA conducted the following steps to develop and select a representative final sample plan for collecting data to inform the energy modeling and analysis:

1. **Developed ten prospective plans:** IEC drew ten weighted random samples using a 3-year average (2021-2023) of the number of new single-family building permits issued across all permit issuing localities (cities, towns, and unincorporated county areas) included in the U.S. Census Bureau data.¹² Each plan included a total of 63 observations, the target number for representative statewide sampling, as specified in the DOE methodology.
2. **Selected a representative plan:** IEC coordinated with NEEA to select an option that both teams determined to be suitable for this study, ensuring building activity trends reflected statewide patterns and that eastern Oregon would be adequately represented.

¹⁰ The EPS/AXIS database is maintained by Energy Trust and contains data on above-code residential new construction homes in Oregon. This dataset is publicly available and provides data that can be used to develop energy simulation models in REM/Rate™ or Ekotrope™. Additional information and the full dataset are available at: <https://insider.energytrust.org/eps-new-construction-data/>.

¹¹ Earth Advantage obtained plan sets and invoices from four insulation and window contractors working across the state. Because these were large contractors, the data they provided covered a number of jurisdictions in the sample plan. Earth Advantage ensured that these data were only collected for non-above code homes to avoid overlap with data being obtained from the EPS/AXIS database.

¹² <https://www.census.gov/construction/bps/current.html>

Although the team attempted to collect data to align with the selected sample plan, data limitations made these targets difficult to achieve in some jurisdictions. As a result, the team worked with NEEA to identify areas with excess data available that could replace observations in similar jurisdictions (based on geographic and socioeconomic comparisons) where the team was unable to obtain information due to incomplete data sources or a limited number of newly constructed homes. **Table 3** shows the final list of counties that were included in the data collection, with these replacements included.¹³

The EPS/AXIS target column in **Table 3** represents the number of data points that the team extracted directly from Energy Trust of Oregon's ("Energy Trust") database of above-code homes. The team calculated this by comparing the number of homes in the AXIS database to the number of permits issued in the census data for corresponding years to determine the percentage of above-code homes in each jurisdiction. Because the team relied on AXIS data for all above-code home observations, all other data sources targeted only code-built homes.¹⁴

Table 3. Final sampling plan

County	Region ²	Target	IIQ/Envelope Tightness Target	AXIS Target
Lane	Eastern	10	7	1
Jackson	Eastern	8	5	2
Washington	Eastern	7	5	5
Multnomah	Eastern	6	4	3
Marion	Eastern	5	3	3
Benton	Eastern	5	3	2
Deschutes	Eastern	3	2	0
Clackamas	Eastern	3	2	2
Polk	Eastern	3	2	1
Union	Western	2	2	0
Morrow	Western	2	1	0
Jefferson	Western	2	1	0
Curry ¹	Eastern	0	0	0
Columbia	Eastern	2	1	0
Clatsop	Eastern	1	1	0
Yamhill	Eastern	1	1	0
Tillamook ¹	Eastern	0	0	0
Coos	Eastern	2	1	0
Crook	Western	1	1	1
Douglas ¹	Eastern	0	0	0
Linn ¹	Eastern	0	0	0
Total	--	63	42	20
- Although Tillamook, Curry, Douglas and Linn counties were not in the original sample plan, the team obtained some data from these locations and used them as replacements for similar areas with data shortfalls, following discussion with NEEA. - The east vs. west designations are based on Energy Trust's regions. The plan was developed to include a number of eastern Oregon observations outside of Deschutes County as the high level of building activity makes Deschutes unique from much of the rest of eastern Oregon.				

¹³ While the team initially targeted 63 total observations for all measures to achieve a 90/10 precision level across the state, the team reduced the target to 42 observations (80/20 precision) for IIQ and envelope tightness measures to reduce the total number of site visits needed, as IIQ data could only be collected through site visits and envelope tightness data were limited to site visits and the EPS/AXIS database.

¹⁴ The team was not able to determine the status (above-code or base) of all homes where IIQ visits were conducted. However, the team conducted these visits at random and determined with NEEA that IIQ grade may not differ across program and non-program homes.

Summary of Data Collection Methods

In total, the team collected data on at least one measure at 254 homes across all data sources to achieve the targets in the sample plan.¹⁵ Most of the data (69%) came from sources other than on-site inspections. All data sources provided substantial information on basic home characteristics (type of home, number of bedrooms, floor area, etc.) and water heater information.

Table 4 shows the data sources that were most reliable in providing the following information:

- **EPS/AXIS** provided quality data for all key measures and modifiers with the exception of IIQ grades, but only for above-code homes.
- **On-site data** provided information for all key measures and modifiers, including IIQ, although multiple visits are required to collect all key measures due to what can be observed at the rough-in versus final stages of construction.
- **Permits/Plan sets/Invoices** generally provided information on the ORSC Additional Measure, foundation type, windows, and insulation. Other data was occasionally available (mainly in permits), but not consistently. Information regarding envelope tightness, IIQ grades, and final measure installation (such as mechanical system information) are unlikely to be available from these sources.
- **Survey data:** Frequently provided information on duct location, lighting, and mechanical systems.¹⁶ The survey does not appear to be a reliable source of insulation, window, or envelope tightness information, as homeowners are often unaware of these characteristics.

Table 4. Measures collected by data source

Measure	EPS/AXIS	Field Form	Permit/Plan Ste/Invoice	Survey Data	Total
Water Heater Type	20	46	45	65	176
ORSC Additional Measure	--	26	37	--	63
Foundation Insulation	20	19	22	2	63
Foundation Type	20	18	22	3	63
Ceiling Insulation	20	21	20	2	63
Frame Wall insulation	20	1	38	4	63
Windows	20	1	39	3	63
Heating Type	20	34	2	6	62
Duct Tightness	20	16	1	25	62
Lighting	20	17	--	25	62
Foundation Insulation Quality	--	40	2	--	42
Envelope Tightness	13	25	1	--	39
Ceiling Insulation Quality	--	37	1	--	38
Wall Insulation Quality	--	36	--	--	36

The remainder of this section provides additional details on how the IEC team obtained data from each source to use in the evaluation, including a discussion of the feasibility of using each data source for future studies and the limitations with each method.

¹⁵ The team broke out homes by unique combinations of data source and collection method. Since some homes were included in multiple data sources, there were 25 duplicates within the 254 homes. This was constrained to homes that completed the survey and were included in a site visit as the team used survey participants to recruit as site visit locations.

¹⁶ While survey takers were generally unable to provide the ORSC additional measure present in their home, the information they provided on mechanical systems (model numbers) allows this and future studies to see if they own high efficiency HVAC equipment, the most frequently selected ORSC additional measure.

Permits

This evaluation was initially designed to rely primarily on the collection and analysis of permit data from newly constructed single-family homes across the state. However, at the outset of the study, the team anticipated the possibility that permit data may not consistently contain the energy code information needed to inform these research objectives. Following the development of the sample plan, the IEC team worked with NEEA to randomly select ten jurisdictions for a screening-level review of permit data availability.¹⁷ Ultimately, none of the ten jurisdictions were able to provide permit data with the fully usable energy code information required for this study.^{18,19} Despite these initial findings, Earth Advantage was later able to successfully collect some permit data that contained energy code measure values by physically visiting building department locations in several jurisdictions that do collect energy code information.

Plan Sets/Invoices

Earth Advantage contacted several major contractors across the state to see if these companies were willing to provide plan sets or insulation and/or window invoices from newly constructed homes. Upon obtaining the data, the team found that both plan sets and invoices consistently included information regarding insulation values, foundation types, window values, and the Additional Measure that was selected for a home. Because the contractor firms worked across multiple jurisdictions within the state, the team was able to utilize data from a limited number of contractors to fill the data requirements across multiple jurisdictions in the sample.

EPS/AXIS Database

The EPS/AXIS Database serves as a centralized data collection, storage, and sharing hub for above-code programs including Energy Trust's EPS program. EPS/AXIS contained highly relevant information for this study – values from verified on-site inspections for all key measures, with the exception of IIQ. In Oregon, the database is maintained by Energy Trust and NEEA, the former of which provided IEC with an address-specific version of the database. An anonymous public-facing version of the database is also available.²⁰

The team used the EPS/AXIS database to capture information on above-code homes (roughly one-third of the sample). As described above, the number of observations drawn from EPS/AXIS were reflective of the percentage of above-code homes in the sample plan jurisdictions. The team extracted the data from EPS/AXIS for inclusion in the study by randomly drawing homes from each jurisdiction until that jurisdiction's above-code target was met.²¹ EPS/AXIS data are high-quality, reliable, and have excellent coverage of all measures other than IIQ. We suggest NEEA continue to rely on this data source to fulfill the above-code datapoints for future studies in Oregon.

¹⁷ The initial sample included localities at the municipal level, in addition to counties. Following the initial permit outreach, the team switched to a county-only target approach, due to the difficulty in obtaining data at a more granular level.

¹⁸ Two jurisdictions reported that data were not available or were only available through the state ePermitting database, two had permits available that did not contain energy code information, two had only partial data available, and four did not respond to IEC's requests despite multiple follow-ups.

¹⁹ In addition to selecting the initial ten jurisdictions for outreach, the IEC team and NEEA met with staff at the Oregon Building Codes Division (BCD), which maintains the state's ePermitting database. BCD staff shared that although the database is beginning to add data regarding the Additional Measure used by homes to meet the 2021 ORSC, most energy code information is not maintained or available in the ePermitting database. At the time of this outreach ORSC Additional Measure data were only available for Deschutes County.

²⁰ <https://insider.energytrust.org/eps-new-construction-data/>

²¹ For each home selected, the team checked if the address was present from any other data collection method and dropped any that were duplicates across sources.

Homeowner Survey

NMR administered a survey of homeowners of newly constructed homes as a parallel effort to Earth Advantage's in-field data collection efforts. The survey sample plan was aligned with the overall sampling approach but varied slightly as it did not include the replacements made in the final plan. The study aimed to collect 70 survey responses across 17 counties, with sample targets based on the distribution of permits in the selected jurisdictions and their respective counties.²² Rural areas were oversampled to enhance representation in the final survey data, ensuring these areas were adequately covered. In total, NMR sent 7,382 postcards and achieved a sample of 93 respondents. See Appendix A on the next page for a full breakdown of results by jurisdiction.

Survey Recruitment

A random sample from the frame was contacted via physical postcards mailed to addresses associated with the ATTOM permit records. This recruitment method was chosen because the ATTOM data lacked email or phone contact information. The postcard included a description of the study goals and participation incentive,²³ a QR code and link to access the survey, and a unique access code for each home. The team initially mailed postcards to a portion of the sample frame, followed by four additional waves to additional addresses until the response targets were met.

Web Survey Development

To confirm that survey respondents were occupants of homes built under the 2021 ORSC, the survey included screening questions about home type, the date the home was built, and when the respondent first lived in the home. Qualified respondents were then asked to provide information about their home to assess statewide compliance with 2021 ORSC requirements and to provide other information of interest to NEEA and its stakeholders through answering questions with an option to submit photos for additional incentives.²⁴ The survey specifically focused on the following measures:

1. Envelope tightness (ACH at 50 Pascals)
2. Windows (U-factor & solar heat gain coefficient)
3. Wall insulation and R-value (assembly U-factor)
4. Ceiling insulation (R-value)
5. Lighting (percentage of high efficiency fixtures)
6. Foundation insulation and R-values (including floor, basement wall, crawlspace wall, and slab insulation)
7. Duct tightness (CFM per 100 ft² of conditioned floor area at 25 Pascals)

²² NMR developed the sample frame for the web survey using third-party building permit data purchased from ATTOM®. This data included all building permits issued in Oregon between October 2021 and March 2024. Since the dataset covered all permit types, NMR reviewed the data to identify likely single-family residential new construction (RNC) permits, finding 16,449 relevant records out of the original 839,769. For these likely RNC permits, the team used associated address data to build the sample frame for the selected counties. Of the 16,449 likely RNC records identified, 13,793 were in the selected counties. To further ensure that the sample frame included RNC permitted under the 2021 ORSC, only records dated between October 2021 and September 2023 were retained, resulting in a final sample frame of 10,985.

²³ Survey respondents were offered \$10 to complete the web survey and they could earn up to an additional \$40 in incentives by submitting photos of key energy consuming equipment or features of their home.

²⁴ Respondents who chose to submit photos were provided with additional instructions and example photos for each measure category included in the survey and common places to find equipment nameplates. Each self-audit submission requested two photos, one of the equipment or measure, and another of the nameplate which typically includes equipment model and serial numbers. This enabled on-site quality data to be collected via the survey effort, enabling the team to verify survey response choices and expand upon the data collected in the survey, such as gathering actual equipment capacities and efficiencies.

8. Duct location
9. Ventilation type
10. Mechanical equipment location
11. Heating equipment type and efficiency
12. Water heating equipment type and efficiency

Table 5 shows the distribution of survey respondents who completed the survey and submitted at least one photo of a relevant measure. After reviewing the final survey data, 39 duplicate respondents and 47 incomplete responses were removed, resulting in a total of 93 respondents who completed the core survey.²⁵ Of the 93 respondents who completed the core survey, 44 respondents participated in the optional self-audit portion of the survey. The research team excluded photo submissions that were not clear or did not cover the eligible equipment.²⁶ Differences in the number of photos provided by measure likely reveal which measures homeowners are more familiar with and/or can more easily access. Because self-reported data from homeowners is potentially unreliable, using the photos to verify the responses was an important step to increase accuracy.

Table 5. Count of photo submissions by measure

Measure	Count
Heating	16
Cooling	17
Heat Pumps	15
Water Heating	38
Ventilation	4
Windows	20
Above Grade Walls	5
Ceilings	7
Foundation Walls	4
Framed Floor	5
# of Respondents with Photos*	44
*Respondents who submitted photos as part of the self-audit survey but lacked sufficient clarity to validate the type of equipment or equipment specifications were excluded from these counts.	

On-Site Data Collection

Finally, the team conducted field visits to collect a number of data points. The on-site data collection followed DOE's [Residential Building Energy Code Field Study: Data Collection & Analysis](#). IEc worked with NEEA to modify the DOE field data collection form to ensure all key measures specific to Oregon were included. After planning ten initial visits to use as verification, the team expanded

²⁵ Duplicate survey responses include multiple entries from the same address. Typically, we believe this was due to a homeowner starting a survey on one device but then later restarting on a separate device (for example starting on a computer but switching to a phone once they realized the need to take pictures).

²⁶ NMR contacted survey respondents via email to request clarifying photos if initial photo submissions were unclear.

the scope of the on-site data collection due to lack of available data from other methods. Highlights of the DOE methodology for single-family residential buildings include:²⁷

- Results based on an energy metric and reported at the state level.
- A focus on individual energy efficiency measures within new single-family homes.
- Data confidentiality built into the experimental design – no identifiable data is shared.
- Sample designed around a single site visit prioritizing key items.
- Sample designed with statistically significant results in mind at the state-wide level.

The fieldwork prioritized the key code elements listed above, while collecting as much additional information as possible from each site. The decision to conduct a site visit most frequently occurred in jurisdictions to collect envelope tightness and IIQ observations, as these were the least available data through other methods.

Ultimately, the team completed a total of 78 site visits, collecting data at a mixture of the rough-in and final phases, to supplement the data collected through other methods. While NEEA could update many of the findings from this study using the methods described above, it would be difficult to collect information on envelope tightness and IIQ from other sources as the team found almost no information on these measures outside of field visits.²⁸

Interviews

To better understand homebuilders' compliance and experience with the 2021 ORSC, the team conducted interviews with five builders who construct single-family homes in Oregon. These interviews, which took place between October 2024 and January 2025, asked participating builders to base their responses on homes they were currently building or had built in the past two years. The interviews covered topics including: building standards, ORSC 2021 Additional Measures, envelope compliance challenges, preferences around which mechanical systems builders install, and compliance considerations for single-family versus multi-family homes.

Recruitment included reaching out to builders in Earth Advantage's network and recruiting builders to participate in an interview during field data collection. The builders who participated mostly work in the Portland area (four builders), as well as Central Oregon (two builders), and the Northern Coast (one builder).²⁹ Each reported building between five and 50 single-family homes annually, with an average of about 20 homes, though this varies year-to-year. Each interview took approximately 20 minutes to complete, and builders were provided with a \$175 incentive.

Data Analysis

Following the DOE methodology, data analysis was split into three phases, which are described in the following sections:

- **Statistical analysis** to assess compliance at the individual measure level.
- **Modeling analysis** to estimate the energy consumption of both an observed and code-compliant population of homes. The observed population is based on the data collection,

²⁷ Residential Building Energy Code Field Study: Data Collection & Analysis Methodology. September 2022. <https://www.energycodes.gov/sites/default/files/2022-09/bto-Res-Field-Study-Methodology--updated.pdf>

²⁸ The AXIS database contains data on envelope tightness, but the team did not find a data source that consistently had this information for non-above-code homes.

²⁹ Each of the five builders works in one or more areas, including: Portland, Gresham, Sandy, Estacada, Central Oregon, Beaverton, NW Metro Area, Washington County, Bend, and the Northern Oregon Coast.

while the code-compliant population assumes each home exactly meets the code requirements.

- **Savings analysis** to project the potential savings with improved energy code compliance relative to the 2021 ORSC. Savings are reported per home and statewide.

Statistical Analysis

The statistical analysis assessed compliance trends at the measure level based on the data collection. Observed distributions were plotted on histograms for each of the key measures in both climate zones. In addition, summary tables provide information on the range, average, and compliance rates for the key measures, at both the climate zone and statewide levels. The histograms and summary tables provide insight into the prevalence of installed measures and the range of below-code and above-code observations, which can help identify areas for improvement.

Energy Analysis

Following the DOE methodology, this study uses an energy metric to assess compliance. As described in DOE's 2022 *DOE Residential Building Energy Code Field Study: Data Collection & Analysis Methodology*, earlier studies only tracked whether a measure complied or not, which did not provide information on the level of noncompliance nor the resulting energy impact. An energy metric provides information on the energy saving potential by measure, which can inform more fine-tuned training and education efforts. As described in the methodology,

“An energy metric has the further benefit of allowing the results to be compared against different baseline and across geographic regions, which is of significant interest to utilities, government agencies, and others supporting energy-efficiency programs.... Ultimately, the results are used to identify household savings opportunities, develop more effective and targeted training programs, create and validate more accurate energy forecasts, inform industry consensus processes, and serve as a baseline for broader energy-efficiency programs and Research and Development (R&D) efforts.”

To complete the energy analysis, the measure distributions from the statistical analysis were used as inputs into a large-scale Monte Carlo energy modeling analysis. Monte Carlos are a general group of algorithms that all contain some stochastic element. They are often implemented with calculations where there is uncertainty in input variables, interactions between variables, and/or an interest in doing a sensitivity analysis. For this study, a Monte Carlo analysis was used to simulate a representative sample of potential measure combinations without having full sets of measure inputs from any given home.

The team developed a set of custom EnergyPlus models based on PNNL's 2021 residential prototype models for the foundations; heating, ventilation, and air conditioning (HVAC) types; and climate zones observed in Oregon. The team first developed a code-minimum set of models (exactly meeting minimum code requirements). Modeling details are included in the [EnergyPlus and OpenStudio](#) section in **Appendix B – Modeling Methodology**. These custom code-compliant models were then used as inputs for the OpenStudio Parametric Analysis Tool to simulate the as-built conditions observed for the key measures.³⁰ This resulted in upwards of 9,000 simulations within the state.³¹

³⁰ OpenStudio uses the EnergyPlus simulation engine and the EnergyPlus files generated can be extracted.

³¹ Simulations were only run for the prototypes that matched the heating and foundation type combinations observed in each climate zone. This resulted in six batches with 1,500 models each.

The output of this task was a histogram that compares the actual statewide average energy consumption to a 2021 ORSC-compliant baseline, which mirrors the previous Oregon field study. Specifically, a histogram shows the weighted average regulated energy use intensity (EUI) of the observed data set (from permit and on-site data) compared to the expected weighted average regulated consumption based on homes that exactly met the prescriptive code requirements.³²

Savings Analysis

The statistical analysis identified key measures that frequently did not meet code requirements. The savings analysis estimated the potential savings if these measures were brought to compliance. Potential savings were calculated for each of these measures individually. Another set of models was analyzed to compare the code-compliant EUI to that of a building where all measures are compliant except for the individual measure being studied. The difference in energy use represents the savings potential of increased compliance for that measure. The savings analysis reported the potential energy savings at the level of the individual home, climate zone, and state, as well as statewide energy cost savings if the measure was brought to compliance. Savings were weighted using construction starts in each climate zone to obtain the average statewide energy savings potential. In addition, Oregon-specific fuel prices were used to calculate the potential energy cost savings. Details on the energy cost assumptions are included in the [Oregon Fuel Prices](#) section in Appendix B.

Limitations

In general, the data collected for each individual home is an incomplete data set, so it is not possible to determine whether individual homes are compliant. As discussed above, this study relies on an energy compliance metric instead.

The prototype Monte Carlo modeling approach means that no individual homes were modeled. As a result, site-specific variables such as size, height, orientation, window area, and floor-to-ceiling height are not included in the analysis. Further, these variables are not a component of the Oregon code.

The savings analysis methodology does not account for interactive effects between measures. However, isolating the savings potential by measure will help stakeholders to prioritize where they should focus their efforts to increase compliance. As an illustrative example of interactive effects, high-efficacy lighting lowers the lighting energy use, but it can also result in higher heating and lower cooling demand. As noted in the *DOE Residential Building Energy Code Field Study*, “In a typical real building, the savings potential might be higher or lower; however, additional investigation indicated that the relative impact of such interactions is very small and could safely be ignored without changing the basic conclusions of the analysis.”

³² Regulated end uses include heating, cooling, lighting (interior and exterior), fans, and domestic hot water. The weights were defined by the frequency of field-observed heating system and foundation type combinations (which is how the PNNL prototype files are differentiated).

3 Compliance Results

Statistical Analysis Results

This section summarizes compliance results for homes built under the 2021 ORSC, which went into effect in April 2021. Throughout the analysis, the 2021 ORSC results are compared to the results of PNNL's previous study of the 2017 ORSC.

Table 6 summarizes the number of observations for each key item. More detailed results for each of these key measures are included in the sections below.

Table 6. Observation counts for key measures

Measure	Number of Observations		
	CZ 4	CZ 5	Statewide
Envelope Tightness	35	7	42
Window U-factor	53	10	63
Wall Insulation R-value	53	10	63
Wall Insulation U-factor	53	10	63
Ceiling Insulation	54	9	63
Ceiling U-factor	53	10	63
Lighting	53	10	63
Floor insulation R-value	50	9	59
Floor insulation U-factor	50	9	59
Unvented Crawl R-value	2	0	2
Unvented Crawl U-factor	2	0	2
Slab R-value	2	0	2
Duct Location	53	10	63

Foundation, Space Heating, and Domestic Hot Water Types

The foundation types observed in Oregon were floors over vented crawlspaces (93.7%), unvented crawlspaces (3.2%), and slabs (3.2%) as shown in **Table 7**. Unvented crawlspaces and slabs were only observed in CZ4. In the previous study of the 2017 ORSC, the foundation distribution was vented crawlspaces (87%), slabs (12%), and heated basements (1%).

Table 7. Oregon foundation types (n=63)

	Foundation Type		
	CZ4	CZ5	Statewide
Vented Crawlspac	77.8%	15.9%	93.7%
Unvented Crawlspac	3.2%	0.0%	3.2%
Slab	3.2%	0.0%	3.2%
Basement	0.0%	0.0%	0.0%

Fifty-four percent of the space heating systems were natural gas furnaces, while 46% were electric heat pumps, as shown in **Table 8**. In the previous study of the 2017 ORSC, the HVAC systems were

81% gas and 19% electric, with 14% electric heat pumps. This is a major shift from gas furnaces to electric heat pumps.

Table 8. Oregon space heating fuel source and type (n=63)

		Space Heating		
		CZ4	CZ5	Statewide
Type	Natural Gas Furnace	47.6%	6.3%	54.0%
	Electric Heat Pump	36.5%	9.5%	46.0%

For domestic hot water (DHW), 49.6% of the systems were natural gas, while 50.4% were electric, as shown in **Table 9**. Heat pump water heaters represent 40.7% of the systems statewide.

In the previous study of the 2017 ORSC, the DHW systems were 70% gas and 30% electric. Overall, there has been a shift from natural gas to electric DHW systems, and this is mostly due to a shift to heat pumps, which are about three times as prevalent. Under the 2017 ORSC, 16% of the DHW systems were electric resistance and 14% were electric heat pumps. Under the 2021 ORSC, these shares were 9.7% and 40.7%, respectively.

Table 9. Oregon domestic hot water fuel source and type (n=176)

		Domestic Hot Water		
		CZ4	CZ5	Statewide
Fuel Source	Natural Gas	39.7%	9.9%	49.6%
	Electric	45.3%	5.1%	50.4%
Type	Gas Tank	11.4%	4.3%	15.7%
	Gas Tankless	28.5%	5.6%	34.0%
	Electric Resistance	9.4%	0.3%	9.7%
	Electric Heat Pump	35.9%	4.8%	40.7%

Key Elements

The following sections include histograms and summary tables for the key measure observations. **Figure 1** shows the elements of an example histogram. The x-axis shows the value of key measure metric observed, while the y-axis shows the number of observations with that value. Observations in CZ4 are shown in blue and observations in CZ5 are shown in orange. The box in the upper right shows the total number of observations and the statewide distribution average. The vertical dotted lines show the code requirement. Some measures have different requirements in CZ4 and CZ5. Code requirements are noted in a summary table below each histogram.

For insulation observations, two sets of results are shown throughout the results section. The first is the wall R-value, and the second is the expected assembly U-factor, which also accounts for the insulation installation quality (IIQ) grades observed on-site. IIQ is discussed in more detail in [Impact of Insulation Installation Quality](#) section. The R-value results indicate whether the correct R-value insulation is installed. The U-factor results show whether the combination of the installed R-value and the IIQ grade meet the U-factor requirements. Non-compliance for insulation may result from the wrong amount of insulation, improper installation, or a combination of both.

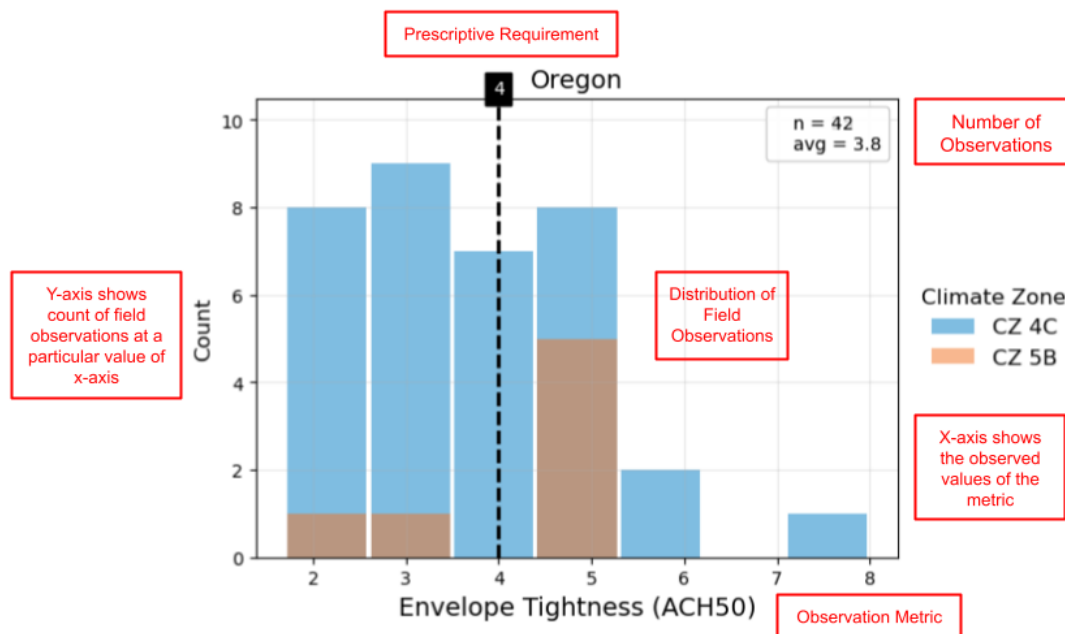


Figure 1. Example histogram

Envelope Tightness

Blower door testing for envelope tightness was not required in the 2017 ORSC. Instead, the 2017 ORSC required sealing around exterior joints and window and door air tightness labels. Under the 2021 ORSC, compliance can be met by either meeting the “Air Barrier Installation and Air Sealing Requirements” table or a blower door test less than or equal to 4ACH. The histogram below shows the distribution of blower door test results. It is possible that a home could meet the requirements in the “Air Barrier Installation and Air Sealing Requirements” while having an envelope leakage higher than 4ACH. So, basing compliance on blower door tests may underestimate compliance.

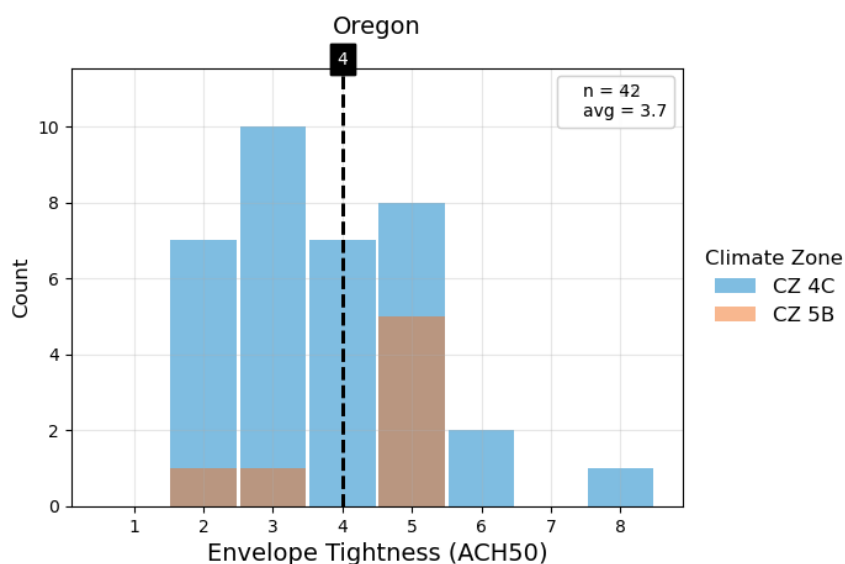


Figure 2. Envelope tightness (ACH50) by CZ

Table 10. Envelope tightness (ACH50) by CZ

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	35	7	42
<i>Range</i>	1.7 to 8.0	1.9 to 4.7	1.0 to 8.0
<i>Average</i>	3.7	4.0	3.7
<i>Requirement</i>	4	4	4
<i>Compliance Rate</i>	22 of 35 (63%)	2 of 7 (29%)	24 of 42 (57%)

Interpretations:

- Twenty-four of the 42 observations met or exceeded the prescriptive code option for envelope tightness (57%). There was 63% compliance in CZ4 and 29% compliance in CZ5.
- The distribution shows slightly lower air leakage (tighter envelope) than expected based on the blower door option with a statewide average of 3.7 ACH as compared to the 4ACH specified in the testing pathway.
- In the previous study of the 2017 ORSC, the statewide average was 4.1 ACH, with an average of 4.1 in CZ4 and 4.2 in CZ5, so the average ACH has improved in both climate zones.

However, the maximum measured air leakage rate from this distribution (8.0 ACH) is essentially unchanged from that of the 2017 ORSC study (8.1). This indicates that while a portion of the industry is improving its air sealing practices, the leakiest buildings may not improve under the ORSC's current approach to envelope airtightness requirements.

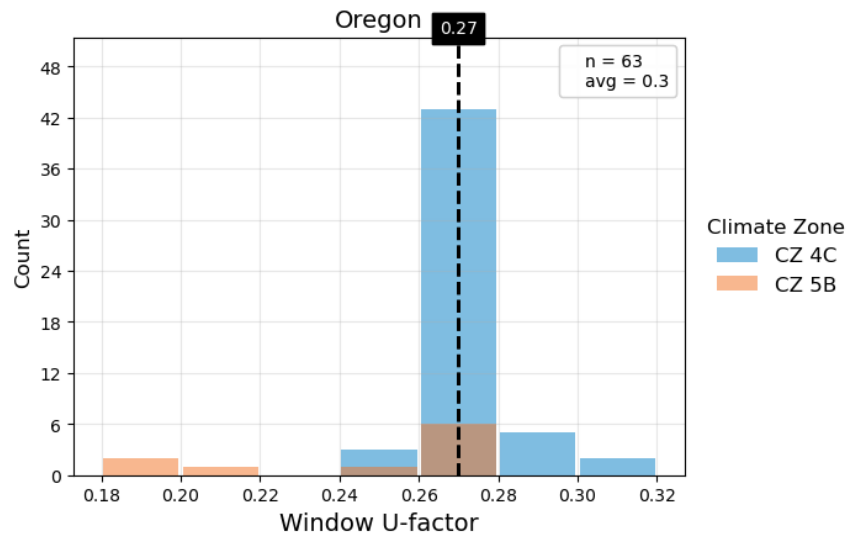
Windows***U-factor*****Figure 3. Window U-factor**

Table 11. Window U-factor

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	53	10	63
<i>Range</i>	0.24 to 0.30	0.19 to 0.27	0.19 to 0.30
<i>Average</i>	0.27	0.25	0.27
<i>Requirement</i>	0.27	0.27	0.27
<i>Compliance Rate</i>	45 of 53 (85%)	10 of 10 (100%)	55 of 63 (87%)

Interpretations:

- Fifty-five of the 63 observations met or exceeded the prescriptive code requirement (87%) for window U-factor, with an average of 0.27 statewide.
- Compared to the previous study of the 2017 ORSC, statewide compliance has decreased (96% under the 2017 ORSC, 87% under the 2021 ORSC). However, the average window U-factor has improved slightly from 0.28 to 0.27. The 2021 ORSC requirement for window U-factor is 0.27. This is more stringent than the 2017 ORSC's requirement of 0.30.
- Eighty-five percent of the observations in CZ4 complied, while 100% of those in CZ5 did, so window U-factor in CZ4 is a potential area for improvement.

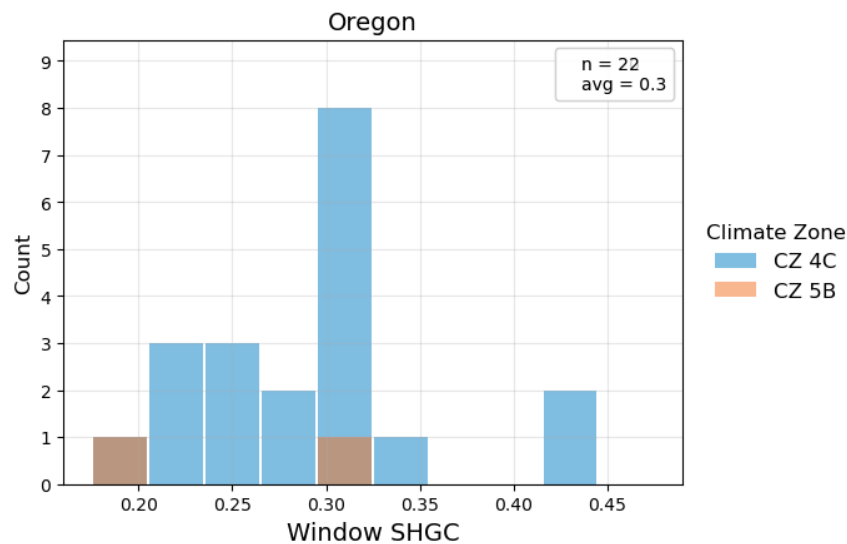
Solar Heat Gain Coefficient**Figure 4. Window SHGC**

Table 12. Window SHGC

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	20	2	22
<i>Range</i>	0.19 to 0.44	0.19 to 0.30	0.19 to 0.44
<i>Average</i>	0.29	0.24	0.29
<i>Requirement</i>	NR	NR	NR
<i>Compliance Rate</i>	NA	NA	NA

Interpretations:

- There is no SHGC requirement under the 2021 ORSC. The values ranged from 0.19 to 0.44 with a statewide average of 0.29.
- In comparison, the values ranged from 0.18 to 0.40 with a statewide average of 0.27 in the previous study of the 2017 ORSC.

Wall Insulation

For insulation observations throughout the results section, two charts are shown. The first is the wall R-value and the second is the expected assembly U-factor, which also accounts for the IIQ grades observed on-site.

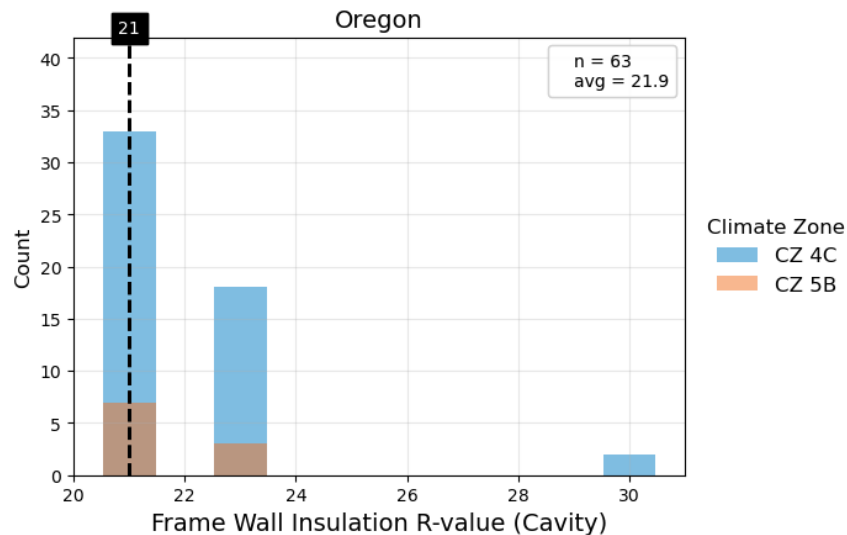


Figure 5. Wall R-values

Table 13. Wall R-values

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	53	10	63
<i>Range</i>	21 to 30	21 to 23	21 to 30
<i>Average</i>	22.0	21.6	22.0
<i>Requirement</i>	21	21	21
<i>Compliance Rate</i>	53 of 53 (100%)	10 of 10 (100%)	63 of 63 (100%)

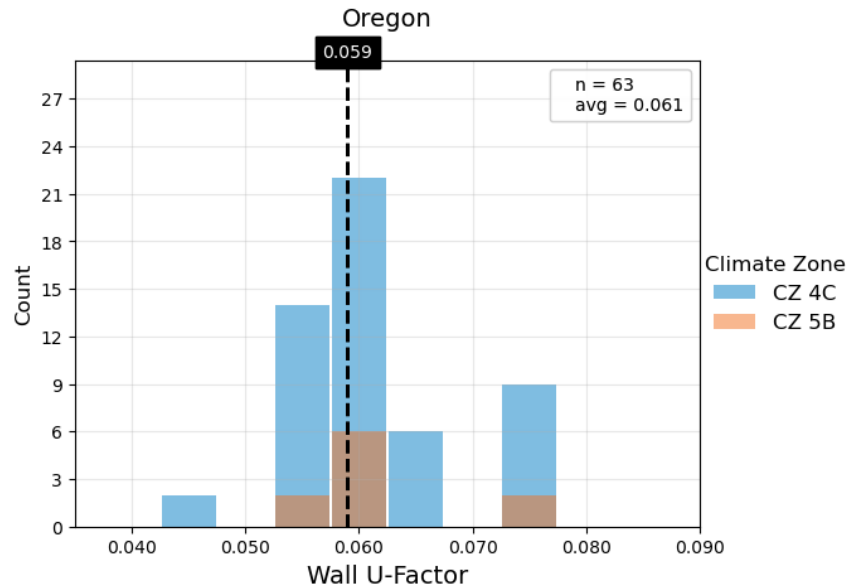


Figure 6. Wall U-factor

Table 14. Wall U-factor

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	53	10	63
<i>Range</i>	0.046 to 0.074	0.057 to 0.074	0.046 to 0.074
<i>Average</i>	0.061	0.061	0.061
<i>Assembly U-Factor (expected)</i>	0.059	0.059	0.059
<i>Compliance Rate</i>	38 of 53 (72%)	8 of 10 (80%)	46 of 63 (73%)

Interpretations:

- All of the observations met or exceeded the prescriptive code requirement for wall insulation R-value. Wall R-values ranged from R-21 to R-30, with a statewide average of R-22. This is slightly better than the R-21 code requirement.
- In the previous study of the 2017 ORSC, there was also 100% compliance for the wall R-values. The observations ranged from R-21 to R-30 with a statewide average of R-22.1.
- When accounting for IIQ, compliance drops to 73% statewide, 72% in CZ4, and 80% in CZ5. This is a noticeable improvement over the previous study of the 2017 ORSC, which showed 46% statewide, 43% in CZ4, and 45% in CZ5.
- Wall insulation installation quality statewide remains an area for improvement.

Ceiling Insulation

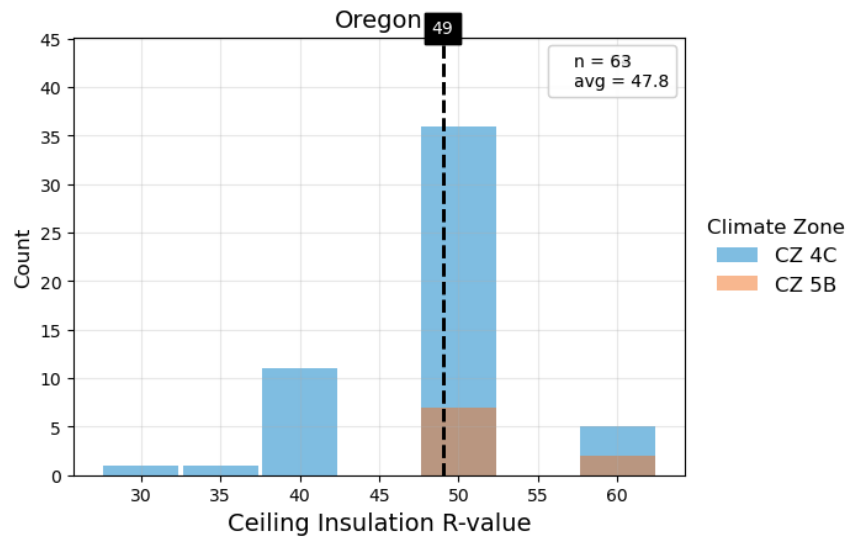


Figure 7. Ceiling R-value

Table 15. Ceiling R-value

Climate Zone	CZ4	CZ5	Statewide
Number	54	9	63
Range	30 to 60	49 to 60	30 to 60
Average	47.2	51.4	47.8
Requirement	49	49	49
Compliance Rate	41 of 54 (76%)	9 of 9 (100%)	50 of 63 (79%)

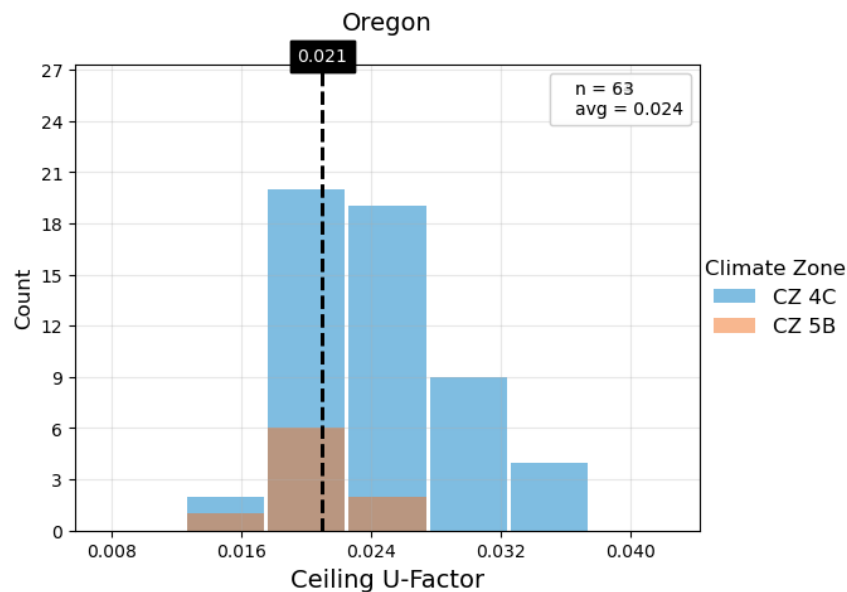


Figure 8. Ceiling U-factor

Table 16. Ceiling U-factor

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	54	9	63
<i>Range</i>	0.017 to 0.037	0.017 to 0.027	0.017 to 0.037
<i>Average</i>	0.025	0.022	0.024
<i>Assembly U-Factor (expected)</i>	0.021	0.021	0.021
<i>Compliance Rate</i>	22 of 54 (41%)	7 of 9 (78%)	29 of 63 (46%)

Interpretations:

- Fifty of the 63 observations met or exceeded the prescriptive code requirement (79%) for ceiling insulation R-value. All of the CZ5 observations met or exceeded the prescriptive requirement, while only 76% of the CZ4 observations did.
- This is similar to the previous study of the 2017 ORSC which found 83% compliance statewide, 78% in CZ4, and 100% in CZ5.
- When accounting for IIQ, only 46% of the observations were compliant, 41% in CZ4, and 78% in CZ5. This is a decrease in compliance as compared to the previous study of the 2017 ORSC, which was 70% compliant statewide (66% in CZ4 and 84% in CZ5). The current statewide average for ceiling U-factor is 0.024, which is worse than the previous average of 0.0234.
- Ceiling IIQ statewide and ceiling R-value in CZ4 continue to be an area for improvement.

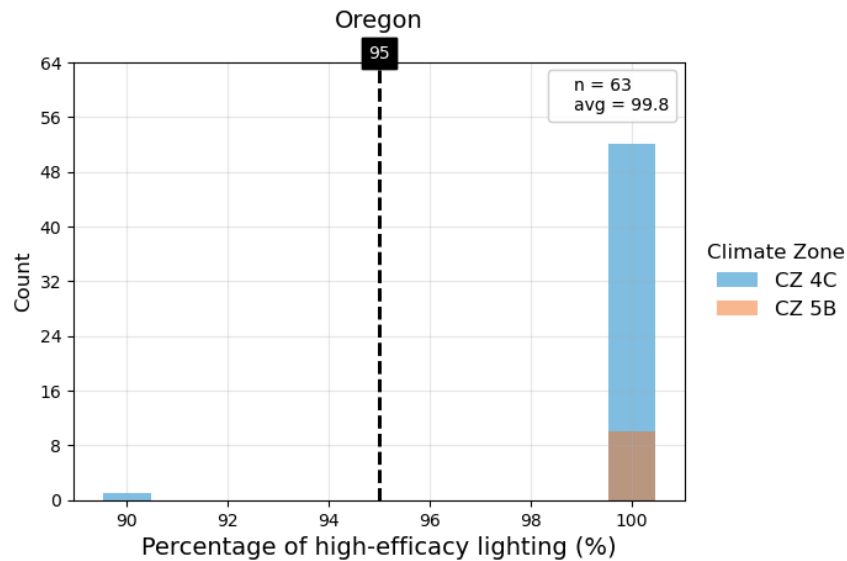
Lighting

Figure 9. High-efficiency lighting percentage

Table 17. High-efficacy lighting percentage

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	53	10	63
<i>Range</i>	90.0 to 100.0	100.0 to 100.0	90.0 to 100.0
<i>Average</i>	99.8	100.0	99.8
<i>Requirement</i>	95	95	95
<i>Compliance Rate</i>	52 of 53 (98%)	10 of 10 (100%)	62 of 63 (98%)

Interpretations:

- Both the 2017 and 2021 ORSC require all but two lighting fixtures to be high efficiency. This is estimated to be equivalent to 95% high-efficacy lighting.
- All but one observation had 100% high-efficacy lighting, exceeding the prescriptive code requirement (99.8% compliant). This is a small improvement over the previous study, which was 92% compliant statewide.

Foundation Insulation

The three foundation types observed in Oregon were vented crawlspaces (93.6%), unvented crawlspaces (3.2%), and slabs (3.2%).

Insulation in Floors Over Unconditioned Spaces

Following DOE's methodology, insulation in floors over unconditioned spaces includes both vented crawlspaces and unheated basements. There were no unheated basements observed, so the results below are from homes with vented crawlspaces, which were the most common foundation type.

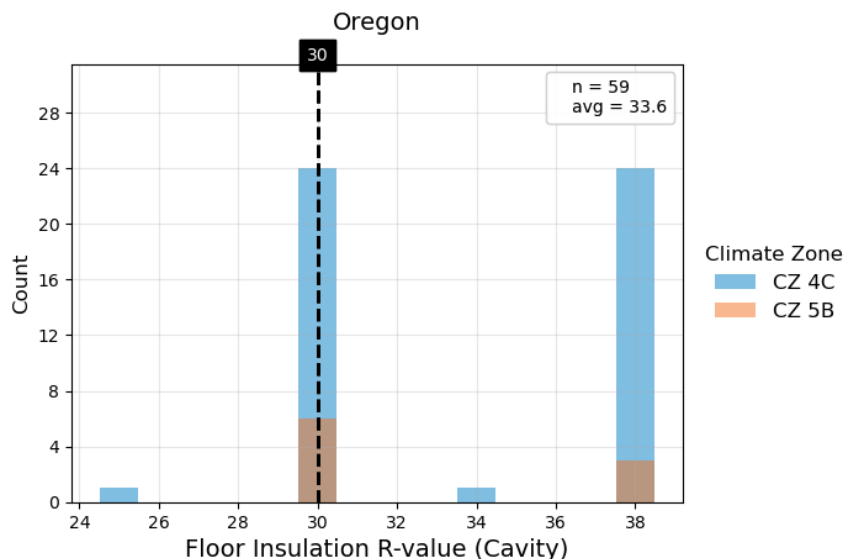
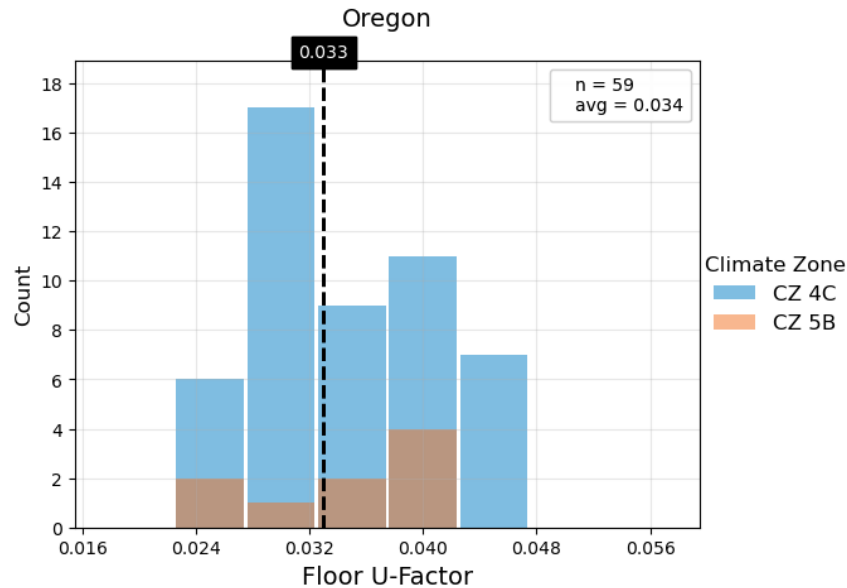
**Figure 10. Floor R-value**

Table 18. Floor R-value

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	50	9	59
<i>Range</i>	25.0 to 38.0	30.0 to 38.0	25.0 to 38.0
<i>Average</i>	33.8	32.7	33.6
<i>Requirement</i>	30	30	30
<i>Compliance Rate</i>	49 of 50 (98%)	9 of 9 (100%)	58 of 59 (98%)


Figure 11. Floor U-factor
Table 19. Floor U-factor

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	50	9	59
<i>Range</i>	0.026 to 0.045	0.026 to 0.038	0.026 to 0.045
<i>Average</i>	0.034	0.033	0.034
<i>Assembly U-Factor (expected)</i>	0.033	0.033	0.033
<i>Compliance Rate</i>	30 of 50 (60%)	5 of 9 (56%)	35 of 59 (59%)

Interpretations:

- Fifty-eight of the 59 floor R-value observations met or exceeded the prescriptive code requirement (98%).
- Observations range from R-25 to R-38 with a statewide average of R-33.6, which exceeded the R-30 code requirement. Nearly all of the observations were R-30 (30 observations) or R-38 (27 observations).
- These results are similar to the previous study of the 2017 ORSC. In that study, observations ranged from R-25 to R-38 with a statewide average of R-32. Again, nearly all of the

observations were R-30 or R-38; however, R-30 was about twice as common as R-38, so the share of R-38 floors has increased.

- When IIQ is considered, compliance drops to 59% statewide, 60% in CZ4, and 56% in CZ5. The previous study of the 2017 ORSC was 51% compliant statewide, 59% in CZ4, and 29% in CZ5. So, compliance is similar in CZ4 but improved in CZ5.
- The amount of floor insulation generally met or exceeded the prescriptive code requirement, but IIQ continues to be an area for improvement.

Slab Edge R-value

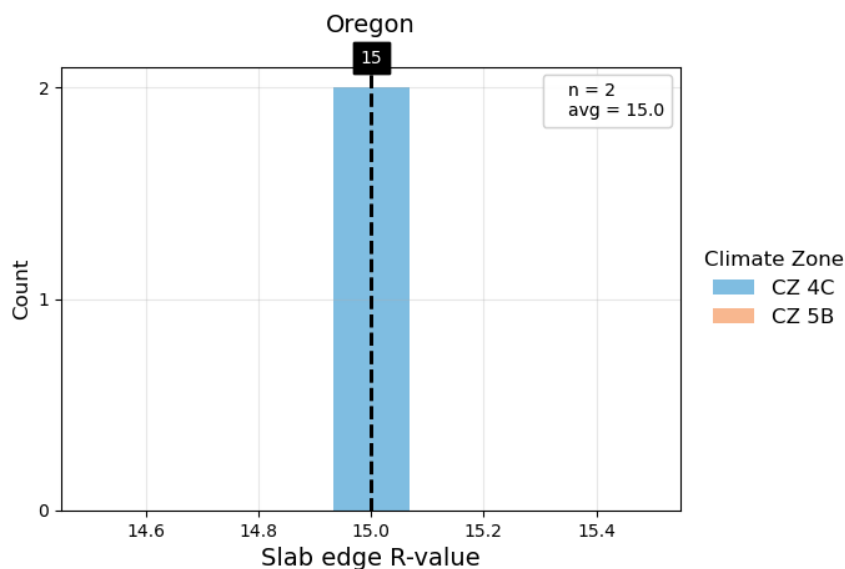


Figure 12. Slab edge R-value

Table 20. Slab edge R-value

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	2	0	2
<i>Range</i>	15 to 15	NA	15.0 to 15.0
<i>Average</i>	15.0	NA	15.0
<i>Requirement</i>	15	15	15
<i>Compliance Rate</i>	2 of 2 (100%)	NA	2 of 2 (100%)

Interpretations:

- Both of the slab edge R-value observations exactly met the R-15 code requirement.
- The previous study found that only 33% of the observations met or exceeded the slab edge R-value requirement, with a statewide average of R-13. However, there were only two slab observations in the current study and six in the previous study.

Unvented Crawlspace Wall Insulation

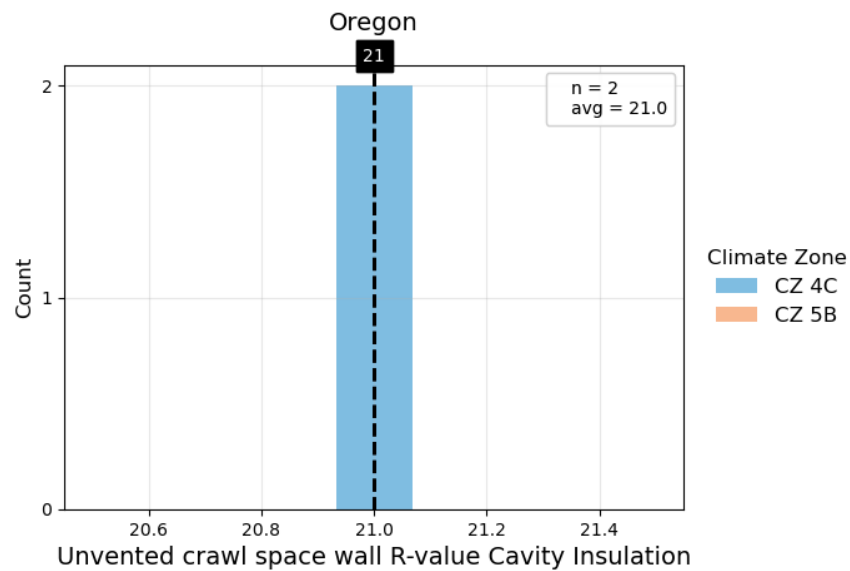


Figure 13. Unvented crawlspace wall R-value

Table 21. Unvented crawlspace wall R-value

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	2	0	2
<i>Range</i>	21 to 21	NA	21 to 21
<i>Average</i>	21.0	NA	21.0
<i>Requirement</i>	21	21	21
<i>Compliance Rate</i>	2 of 2 (100%)	NA	2 of 2 (100%)

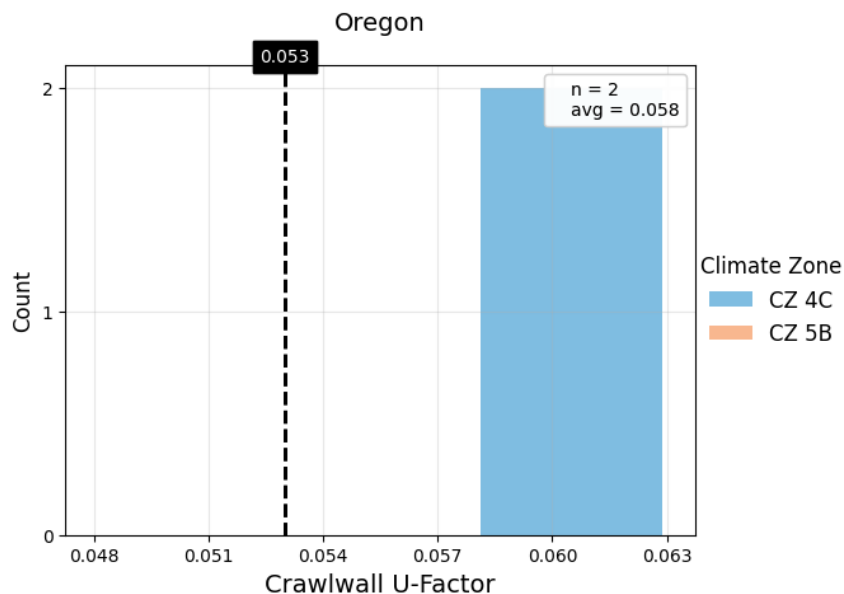


Figure 14. Unvented crawlspace wall U-factor

Table 22. Unvented crawlspace wall U-factor

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	2	0	2
<i>Range</i>	0.058 to 0.058	NA	0.058 to 0.058
<i>Average</i>	0.058	NA	0.058
<i>Assembly U-Factor (expected)</i>	0.053	0.053	0.053
<i>Compliance Rate</i>	0 of 2 (0%)	NA	0 of 2 (0%)

Interpretations:

- Both of the unvented crawlspace wall insulation R-values exactly met the R-21 requirement. However, when accounting for IIQ, neither of these observations met the U-factor requirement.
- This foundation type was not observed in the previous study of the 2017 ORSC.
- While there is room for improvement in the crawlspace wall IIQ, this type of foundation only represented 3.2% of the observations statewide.

Ducts

The 2021 ORSC requires that 95% of the duct system (which includes the ductwork and the heating system per the 2021 ORSC errata) is in the building's thermal envelope or that the ducts are buried in R-19 insulation. This is a new prescriptive requirement that was not included in the 2017 ORSC.

The histogram below shows the results for the 37 observations that provided a numerical value. There were 26 additional observations from the survey data that entered "yes" or "no" to "Ducts in building thermal envelope?" Of these, only five entered "yes."

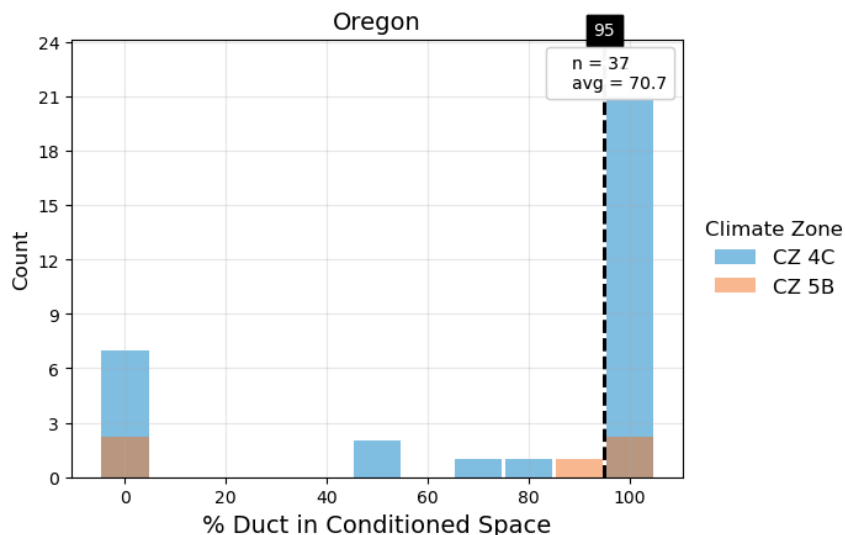


Figure 15. Percentage of ducts in conditioned space

Table 23. Percentage of ducts in conditioned space

Climate Zone	CZ4	CZ5	Statewide
Number	32	5	37
Range	0.0 to 100.0	0.0 to 100.0	0.0 to 100.0
Average	73.0	57.4	70.7
Requirement	95	95	95
Compliance Rate	21 of 32 (66%)	2 of 5 (40%)	23 of 37 (62%)

Interpretations:

- Only 62% of the statewide quantitative observations had ducts in conditioned spaces, 66% in CZ4 and 33% in CZ5.
- Notably, all 21 of the above-code homes in the AXIS database met this requirement. Twenty of these met the requirement through buried insulation in the attic. In comparison, only 2 of the 16 (12.5%) quantitative site observations were compliant.
- It should be noted that only including the quantitative responses likely overestimates statewide compliance. If it is assumed that all five "yes" survey responses are compliant and all 22 "no" responses are non-compliant, then statewide compliance drops to 45%. If the five "yes" responses are also non-compliant (meaning some ducts are in conditioned space, but less than 95%), then the statewide compliance could be as low as 40%.
- However, it is unclear whether respondents were aware that ducts buried in R-19 insulation would also be compliant, even if in an unconditioned space like an attic. Since more than 50% of the compliant quantitative observations had buried ducts, it is difficult to provide a precise compliance estimate when including the survey responses.
- Duct location or duct insulation are likely targets for education and outreach efforts to improve compliance.

Additional ORSC Elements

Additional Measure Selection

The 2021 ORSC requires the selection of one Additional Measure. The detailed requirements for the Additional Measures are included above in **Table 2**.

The eight Additional Measures options are:

1. High efficiency HVAC system.
2. High efficiency water heating system.
3. Wall insulation upgrade.
4. Advanced envelope.
5. Ductless heat pump.
6. High efficiency thermal envelope UA.
7. Glazing area.
8. 3 ACH air leakage control and efficient ventilation.

Measure 1 was by far the most commonly selected option. Of the 63 observations, 59 selected Measure 1 High efficiency HVAC system, three selected Measure 4 Advanced envelope, and one selected Measure 8 ACH air leakage control and efficient ventilation.

The Measure 1 compliance options are:

1. Gas-fired furnace or boiler Annual Fuel Utilization Efficiency (AFUE) 94%, or
2. Air source heat pump Heating Seasonal Performance Factor (HSPF) 10.0/14.0 Seasonal Energy Efficiency Ratio (SEER) cooling, or
3. Ground source heat pump COP 3.5 or ENERGY STAR® rated.

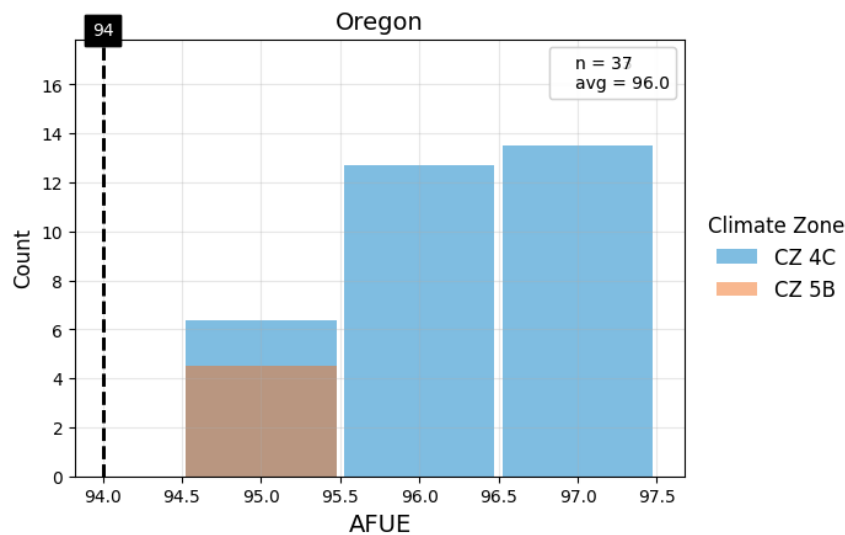
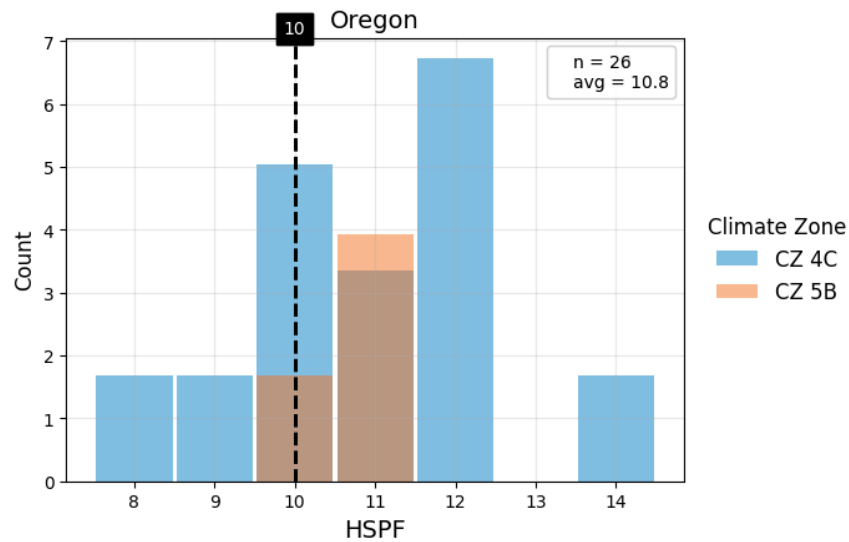


Figure 16. AFUE

Table 24. AFUE

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	33	4	37
<i>Range</i>	95.0 to 97.0	95.0 to 95.0	95.0 to 97.0
<i>Average</i>	96.1	95.0	96.0
<i>Requirement</i>	94	94	94
<i>Compliance Rate</i>	33 of 33 (100%)	4 of 4 (100%)	37 of 37 (100%)


Figure 17. HSPF
Table 25. HSPF

Climate Zone	CZ4	CZ5	Statewide
<i>Number</i>	20	6	26
<i>Range</i>	8.2 to 13.6	9.5 to 10.9	8.0 to 14.0
<i>Average</i>	10.9	10.5	10.8
<i>Requirement</i>	10	10	10
<i>Compliance Rate</i>	15 of 20 (75%)	4 of 6 (67%)	19 of 26 (73%)

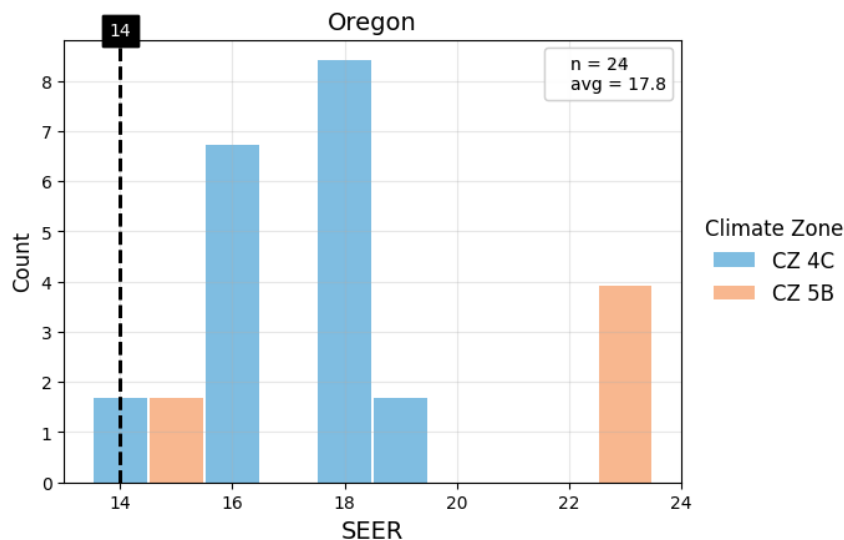


Figure 18. SEER

Table 26. SEER

Climate Zone	CZ4	CZ5	Statewide
Number	18	6	24
Range	14.0 to 19.0	15.0 to 22.8	14.0 to 23.0
Average	17.0	20.5	17.8
Requirement	14	14	14
Compliance Rate	18 of 18 (100%)	6 of 6 (100%)	24 of 24 (100%)

Interpretations:

- All 37 gas furnaces exceeded the AFUE requirement. The statewide average AFUE was 96%, while the Measure 1 requirement is 94%.
- For the air source heat pumps, 100% of the systems met or exceeded the SEER requirement, but only 73% of the systems met the HSPF requirement.³³
- Air source heat pump HSPF is an area for improvement.

Ventilation type

2021 The ORSC requires a whole-house balanced ventilation system. The ventilation type was identified in 58 homes. Of these, 70.7% were balanced (41), 20.7% were standalone ERV/HRV (12), and 8.6% were exhaust fans only systems (5). Since both balanced and ERV/HRV systems meet this requirement, 91.4% of the observed homes were compliant for ventilation.

While whole-house balanced ventilation was not a prescriptive requirement under the 2017 ORSC, it was included in the envelope enhancement Measure #5 “air sealing home and ducts.” Under the 2017 ORSC, Measure #5 was tied with Measure #2 “upgraded features.” Both were selected in a third of the homes observed (n=34).

³³ For air source heat pumps, 26 observations included HSPF, but two of these did not list SEER, so there were only 24 SEER observations.

Heating system location

The 2021 ORSC requires that the HVAC system be in the thermal envelope (unless satisfying an exception). Only 51% of the observations met this requirement. This does not include any homes that would comply via the 5% duct system length exception per the 2021 ORSC errata. For the systems in unconditioned space that specified a location, about three quarters were in the garage and a quarter were in vented attics. One observation was in a vented crawlspace. For the HVAC systems within the thermal envelope that specified a location, about three quarters listed “closet” and a quarter listed “living space.”

Impact of Insulation Installation Quality

The DOE *Residential Building Energy Code Field Study: Data Collection & Analysis Methodology* states that:

At the start of the project, IIQ was noted as a particular concern among project teams and stakeholders as it plays an important role in the energy performance of envelope assemblies. However, insulation installation is not a requirement in the model energy codes and is not a key item by itself. Data on cavity IIQ was collected in the field and used in the analyses to modify the energy contribution from ceiling, wall, and foundation insulation.

Table 27 shows the IIQ for the observed envelope assemblies under both the 2017 ORSC and the 2021 ORSC. On average, the 2021 ORSC IIQ observations are worse than the 2017 ORSC ones. The total share of Grade II observations was similar, but there was a shift from Grade I to Grade III.

While there is quantitative guidance on each grade, translating this in the field is subjective and may vary between raters. So, it is unclear whether there has been an overall decrease in IIQ or if the raters in this study are generally stricter. Either way, IIQ is a concern and a likely target for training and education for all assembly types.

Table 27. Insulation installation quality

IIQ Values 2017 ORSC (n=226)					IIQ Values 2021 ORSC (n=123)				
Assembly	Grade			TOTAL	Assembly	Grade			TOTAL
	I	II	III			I	II	III	
Roof/Ceiling	65	11	1	77	Roof/Ceiling	20	8	10	38
Frame wall	30	29	5	64	Frame wall	23	5	8	36
Foundation	34	49	2	85	Foundation	12	30	7	49
TOTAL	129	89	8	226	TOTAL	55	43	25	123

Assembly	Grade		
	I	II	III
Roof/Ceiling	84%	14%	1%
Frame wall	47%	45%	8%
Foundation	40%	58%	2%
TOTAL	57%	39%	4%

Assembly	Grade		
	I	II	III
Roof/Ceiling	53%	21%	26%
Frame wall	64%	14%	22%
Foundation	24%	61%	14%
TOTAL	45%	35%	20%

Energy Analysis Results

The results of the statistical analysis were used as inputs into a large-scale Monte Carlo energy modeling analysis. This task compared the weighted average regulated energy consumption of the observed data set to the expected weighted average regulated consumption based on homes that exactly met the prescriptive code requirements. From the modeling results, regulated end uses include heating, cooling, lighting (interior and exterior), fans, and domestic hot water.

The results are shown in the histogram below, which estimates that the average home in Oregon uses *more* energy than would be expected relative to a home built to the current minimum state code requirements. Based on the observed data set, the average regulated EUI is 24.0 kBtu/ft²-yr (dashed blue line). In comparison, homes exactly meeting minimum prescriptive energy code requirements have an average EUI of 22.4 kBtu/ft²-yr (solid blue line). The EUI for a “typical” home in the state uses about 7% more regulated energy than a code compliant home.

Each of the models generated in the modeling analysis was compared to a minimally code-compliant model with the same heating and foundation type. In this comparison, 91.4% of the simulated population had a regulated EUI less than or equal to the 2021 ORSC compliant model. This means that the analysis predicts 91.4% compliance and 8.6% non-compliance statewide.

Note, the simulated population includes homes with above-code measures, which improves the average performance statewide. This is why the average home underperforms the code-compliant average by 7%, but there is still 8.6% non-compliance for the 2021 ORSC based on the individual models. Including above-code performance improves statewide compliance by about 1.6%.

There is a difference between the compliant and non-compliant home populations under the 2021 ORSC. When including above-code performance, on average the compliant population uses about 5.6% less energy than a code-compliant baseline while the non-compliant population uses about 12.4% more.

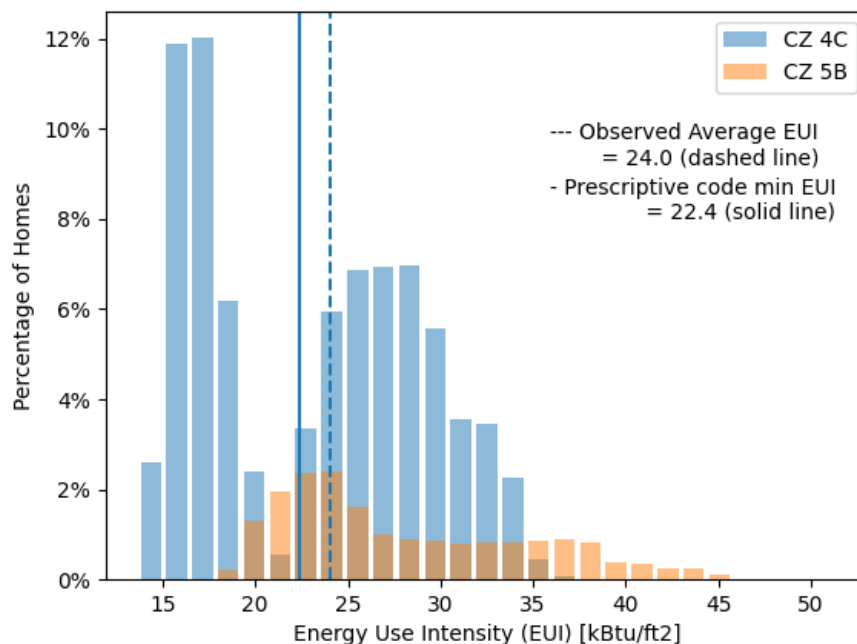


Figure 19. Statewide EUI analysis for Oregon

Savings Analysis Results

The following section summarizes the potential energy, energy cost, and emissions savings for key measures with below-code observations. Potential savings were calculated for the following key measures:³⁴

Table 28. Key measures with savings potential

	2021 ORSC (% compliant)		
	CZ4	CZ5	Statewide
Envelope Tightness	63%	29%	57%
Window U-factor	85%	100%	87%
Wall Insulation U-factor	72%	80%	73%
Ceiling U-factor	41%	78%	46%
Unvented Crawl U-factor	0%	---	0%
Floor insulation U-factor	60%	56%	59%
Duct location	66%	40%	62%

The estimated savings are shown in **Table 29**. Energy savings are shown both per home and statewide, while energy cost and emissions savings are statewide. The foundation insulation savings include both floor insulation over vented crawlspaces and wall insulation in unvented crawlspaces. **Table 30** shows the savings breakdown by foundation type. **Table 31** shows the total statewide savings that would accumulate over five, 10, and 30 years of construction.

³⁴ Savings potential was calculated for key measures with more than 5% of observations not meeting the prescriptive code requirement in either a climate zone or statewide. For insulated assemblies, the U-factor observations are used.

Table 29. Statewide annual measure-level savings for Oregon

Measure	Climate Zone	Electricity Savings (kWh/home)	Natural Gas Savings (Therms/home)	Energy Savings (kBtu/home)	Number of Homes	Total Energy Savings (MMBtu)	Total Energy Cost Savings (\$)
Envelope Tightness (ACH50)	4C	68	8	1074	7,626	8,190	162,397
	5B	301	13	2,297	1,787	4,104	109,167
	State Total	112	9	1,306	9,413	12,294	271,564
Window U-factor	4C	4	0.4	55	7,626	421	8,443
	State Total	4	0.4	55	7,626	421	8,443
Wall U-Factor	4C	49	4	567	7,626	4,325	95,672
	5B	95	4	683	1,787	1,221	33,390
	State Total	58	4	589	9,413	5,545	129,062
Ceiling U-Factor	4C	39	3	472	7,626	3,600	78,199
	5B	36	1	272	1,787	486	12,990
	State Total	38	3	434	9,413	4,085	91,189
Foundation Insulation	4C	2	1	107	7,343	789	11,981
	5B	13	1	122	1,787	217	5,262
	State Total	4	1	110	9,131	1,007	17,243
% Duct in Conditioned Space	4C	44	2	313	7,626	2,387	65,490
	5B	97	2	553	1,787	988	30,733
	State Total	54	2	358	9,413	3,375	96,223
TOTAL		268	19	2839	9,413	26,728	613,725

Notes: See Table 30 below for annual measure-level savings results by foundation type.

Table 30. Statewide annual measure-level savings by foundation type for Oregon

Measure	Climate Zone	Electricity Savings (kWh/home)	Natural Gas Savings (Therms/home)	Energy Savings (kBtu/home)	Number of Homes	Total Energy Savings (MMBtu)	Total Energy Cost Savings (\$)
Crawlwall U-Factor	4C	-0.001	0.01	1	282	0	3
	State Total	-0.001	0.01	1	282	0	3
Floor U-Factor	4C	2	1	112	7,061	789	11,978
	5B	13	1	122	1,787	217	5,262
	State Total	4	1	114	8,848	1,006	17,240
TOTAL		4	1.0	110	9,131	1,007	17,243

Notes: Negative values mean that savings or reductions decrease if the measure is brought to code. Increased insulation can result in lower natural gas usage in the winter but higher electricity usage in the summer. For foundation measures, the total number of homes is multiplied by the foundation share for each foundation type and is therefore smaller than the total number of homes shown for other measures.

Table 31. Five-, ten-, and thirty-year cumulative annual statewide savings for Oregon

Measure	Total Energy Savings (MMBtu)			Total Energy Cost Savings (\$)		
	5yr	10yr	30yr	5yr	10yr	30yr
Envelope Tightness (ACH50)	184,417	676,197	5,716,941	4,073,463	14,936,032	126,277,360
Window U-factor	6,322	23,180	195,980	126,649	464,379	3,926,111
Wall U-Factor	83,179	304,991	2,578,561	1,935,933	7,098,420	60,013,916
Ceiling U-Factor	61,282	224,699	1,899,731	1,367,831	5,015,381	42,402,766
Foundation Insulation	15,099	55,365	468,083	258,647	948,371	8,018,049
% Duct in Conditioned Space	50,618	185,600	1,569,164	1,443,349	5,292,279	44,743,812
Total	400,918	1,470,033	12,428,460	9,205,871	33,754,862	285,382,013

Above-Code Observations

Overall, about a third of the individual observations exceeded the prescriptive code requirements. **Table 32** summarizes the percentage of above-code observations for each key measure. Of particular note, 98% of the lighting and 57% of the envelope tightness observations exceeded the prescriptive code requirements statewide.

Table 32. Summary of above-code observations

	% of above-code observations		
	CZ 4	CZ 5	Statewide
Envelope Tightness	63%	29%	57%
Window U-factor	21%	40%	24%
Wall Insulation R-value	38%	30%	37%
Wall Insulation U-factor	30%	20%	29%
Ceiling Insulation	9%	22%	11%
Ceiling U-factor	7%	22%	10%
Lighting	98%	100%	98%
Floor insulation R-value	50%	33%	47%
Floor insulation U-factor	46%	33%	44%
Unvented Crawl R-value	0%	---	0%
Unvented Crawl U-factor	0%	---	0%
Slab R-value	0%	---	0%

Comparison to the 2017 ORSC

The results of the current study of the 2021 ORSC are compared to the previous study of the 2017 ORSC to track how compliance rates have changed since the last code cycle. **Table 33** summarizes the measure-level compliance rates for the previous study and the current results. Red text indicates a lower compliance rate, and green text indicates a higher compliance rate for the current study as compared to the previous study. Under the 2021 ORSC, window U-factor became more stringent and new code requirements were introduced for envelope tightness and ducts (as compared to 2017 ORSC).

Table 34 provides an overall comparison of the efficiency levels under the 2017 ORSC and the 2021 ORSC.

Key observations:

Analyses indicated the following for measures with the same requirements under the 2017 ORSC and the 2021 ORSC,

- **Insulation amount:** Compliance rates remained high ($\geq 94\%$) for the amount of insulation in walls, CZ5 ceilings, and floors. However, about a quarter of the CZ4 observations were non-compliant under both the 2017 ORSC and 2021 ORSC.
- **Insulation installation quality:** When accounting for IIQ, insulation compliance rates are lower. Floor insulation U-factors increased from 43% compliant under the 2017 ORSC to 73% compliant under the 2021 ORSC statewide. Statewide ceiling U-factor compliance decreased from 70% to 46%, while floor insulation u-factor increased slightly from 51% to 59% statewide.
- **Lighting:** Lighting compliance remained high and increased slightly from 92% to 98% statewide.
- **Slabs:** Slab foundation compliance (only observed in CZ5) increased from 33% to 100%. However, there were six slab insulation observations in the previous study of the 2017 ORSC and only two in the current study.

Window U-factor: The window U-factor requirement is more stringent under the 2021 ORSC. While the average window U-factor was similar, compliance decreased due to the stricter requirements.

Envelope tightness: While only 57% of the observations were compliant under the 2021 ORSC testing pathway statewide, the average envelope tightness improved from 4.1ACH under the 2017 ORSC to 3.7ACH under the 2021 ORSC. As noted above, it is possible that a home could meet the requirements in the “Air Barrier Installation and Air Sealing Requirements” while not meeting the testing limits, so compliance may be underestimated.

Duct location: Duct location is a new 2021 ORSC prescriptive requirement that was not included in the 2017 ORSC. There was 62% compliance for the observations with quantitative values. However, when including the 26 additional “yes/no” responses from the surveys, compliance could be as low as 40%. It is unclear whether respondents were aware that ducts buried in R-19 insulation would also be compliant, even if in an unconditioned space like an attic. Since more than 50% of the compliant quantitative observations had buried ducts, it is difficult to provide a precise compliance estimate when including the survey responses.

Table 33. Comparison of measure-level compliance rates under the 2017 and 2021 ORSC

	2017 ORSC (% compliant)			2021 ORSC (% compliant)		
	CZ 4	CZ 5	Statewide	CZ 4	CZ 5	Statewide
Envelope Tightness*	82%	100%	86%	63%	29%	57%
Window U-factor**	95%	100%	96%	85%	100%	87%
Wall Insulation R-value	100%	100%	100%	100%	100%	100%
Wall Insulation U-factor	46%	43%	45%	72%	80%	73%
Ceiling Insulation	78%	100%	83%	76%	100%	79%
Ceiling U-factor	66%	84%	70%	41%	78%	46%
Lighting	90%	100%	92%	98%	100%	98%
Floor insulation R-value	94%	100%	95%	98%	100%	98%
Floor insulation U-factor	59%	29%	51%	60%	56%	59%
Unvented Crawl R-value	---	---	---	100%	---	100%
Unvented Crawl U-factor	---	---	---	0%	---	0%
Slab R-value	33%	---	---	100%	---	100%
Duct tightness/duct location*	54%	63%	56%	71%	56%	68%

*2017 did not have a requirement. Previous study compared to less stringent baseline.

**2021 ORSC is more stringent than 2017 ORSC.

Table 34. Summary of the 2017 ORSC and 2021 efficiency levels

Key measure	Statewide average efficiency		
	2017 ORSC	2021 ORSC	Units
Envelope leakage	4.1	3.7	ACH at 50 Pa
Window U-factor	0.28	0.27	Btu/h-ft ² -F
Wall insulation R-Value	22.1	22	h-ft ² -F/Btu
Wall insulation U-factor	0.063	0.061	Btu/h-ft ² -F
Ceiling insulation R-Value	49.6	47.8	h-ft ² -F/Btu
Ceiling Insulation U-factor	0.024	0.024	Btu/h-ft ² -F
Lighting	97.8%	99.8%	% high efficacy
Floor insulation R-value	32	33.6	h-ft ² -F/Btu
Floor insulation U-factor	0.033	0.034	Btu/h-ft ² -F
Unvented crawl wall R-value	---	21	h-ft ² -F/Btu
Unvented crawl U-factor	---	0.058	Btu/h-ft ² -F
Slab Edge R	13	15	h-ft ² -F/Btu
Duct locations	---	70.4	% ducts in conditioned space

The EUI for a “typical” home in the state uses about 7% more regulated energy than a code-compliant home. In comparison, the previous study found that typical homes used about 0.3% more regulated energy than a code-compliant home. When above-code performance is excluded, compliance is about 91.4% under the 2021 ORSC and 89% under the 2017 ORSC.

In the current study of the 2021 ORSC, potential statewide annual energy savings are 26,728 MMBtu, resulting in \$613,725 in energy cost savings. In the previous study, the potential annual energy savings were 43,998 MMBtu, resulting in \$611,195 in energy cost savings.

The potential energy savings of the 2021 ORSC are less than half of the 2017 ORSC while the cost savings are nearly the same. While this may seem counterintuitive, this is due to a few factors.

Compared to the previous study of the 2017 ORSC, the current study of the 2021 ORSC had higher electricity savings (about 50% more) and lower gas savings (about half). This is the expected result because there is a higher proportion of electric HVAC and DHW systems in the current study. Because electricity is more expensive than gas for the same unit of energy, relatively lower energy savings still result in similar cost savings. Also of note, the estimated increase in electricity price is higher than the estimated increase in gas price. The previous study of the 2017 ORSC assumed about \$0.1071/kWh and \$1.0630/therm.³⁵ This study assumed \$0.1462/kWh (37% increase) and \$1.329/therm (27% increase).³⁶

However, it is important to note that heat pumps are more efficient than traditional gas HVAC and DHW systems on a site energy basis. So, while electricity is more expensive than gas per unit of energy, heat pumps also use less energy than gas furnaces to deliver the same amount of heat, so they can cost less to operate.

³⁵ The previous report of the 2017 ORSC did not list the gas and electricity prices used. These values are derived from the savings tables in the report.

³⁶ “Oregon State Energy Profile.” US EIA. 2025. <https://www.eia.gov/state/print.php?sid=OR>

4 Interview Results

This section provides the key interview findings from the five builder interviews, broken out by topic area. Topics included questions about what standards builders target during construction (base code or above code), ORSC Additional Measure selection, envelope compliance, mechanical system choices, compliance challenges due to code changes, differences across home types (single versus multi-family) and jurisdictions, and additional feedback.

Building Standard/Pathway Selection

When asked about the building standards to which they build their homes (**Table 35**), three builders reported that they build to [ENERGY STAR Requirements](#) and [EPS New Construction Program Requirements](#), while two builders said they build to base code. Generally, builders stressed the importance of balancing building costs with measures to increase energy efficiency. One builder who solely builds to base code said they do this to save money, but that the code minimum is already “very efficient.” Conversely, one builder who chooses both ENERGY STAR Requirements and EPS New Construction Program Requirements said that there is some marketing value to the programs, and EPS has helped cover the costs of more energy-efficient building. While most builders said they build to the same standard for all homes, one builder said they change their approach based on the home price and buyer preferences. In addition, one builder said they build to ENERGY STAR requirements to take advantage of incentives and tax credits.

Table 35. Building standards targeted for residential homes

Which of the following describes the standard to which you typically build new residential homes?	# of Builders
Higher than base code (ENERGY STAR and/or EPS)	3
Base code + higher than base code	1
Base code only	1

Interviewers also asked builders whether they are aware of the Energy Trust and the resources it provides. Three builders were aware of Energy Trust and have utilized resources it provides, including the EPS Best Practices Field Guide.

None of the builders noted significant changes in the annual number of single-family new construction homes they have built over the past decade, but multiple builders said they have been building more multi-family and cottage cluster housing since Oregon’s middle housing statutes took effect in 2019.³⁷ Four out of the five builders said they typically follow the prescriptive path for energy code compliance, while one builder said they are building far above the code. Builders who follow the prescriptive path cited ease and budget as the primary reasons for this choice.

Additional Measure Selection

Interviewers asked builders which Additional Measure options from the 2021 ORSC they typically choose (most builders selected multiple options). Four builders typically choose High Efficiency HVAC Systems, with one builder commenting that they prefer this measure for its cost effectiveness. Three builders typically choose High Efficiency Water Heating Systems, and two builders each selected the following measures: Wall Insulation Upgrade, Ductless Heat Pump, and 3 ACH Air Leakage Control and Efficient Ventilation. Typically, above-code builders seemed more likely to select ACH and efficient ventilation, while those building to the base code focused more on

³⁷ See House Bill 2001 (2019), <https://gov.oregonlive.com/bill/2019/hb2001/>.

high efficiency mechanicals. Only one of the builders said that customers have input in the selection of the Additional Measure. None of the builders said there are ORSC Additional Measures that they would *never* consider incorporating, but multiple builders noted that cost is an important factor and reported that cost was the greatest driver when selecting an Additional Measure. One builder said that they would not incorporate any measures that they believe would detract from the durability, safety, or usability of the unit.

Envelope Compliance

Four out of the five builders said they use U-factor and R-value tables when planning out construction.³⁸ Most commented that they use U-factors for windows and R-values for insulation and other components, with two builders citing “convention” as the reason they use these ratings. When asked what kind of insulation they use in the walls and attic, two builders prefer batts in walls and crawlspaces and blown-in insulation for the attic. One of these builders said they have also tried using blown-in insulation in walls, but it is hard to justify the additional cost. The other two builders use blown-in insulation whenever possible, with one of them citing blown-in fiberglass’s reliability (fewer settling concerns, fewer moisture concerns, and less volatility) as their reason for this preference. All of the builders provided strategies they use to minimize air leakage when constructing homes (**Table 36**).

Table 36. Strategies to minimize air leakage

Do you have any strategies to minimize air leakage when constructing the building?
• Sealing drywall to top plates on second floors • Insulators do air-sealing package • Caulk/glue in wood joints • Careful framing and roughs • Tyvek system • AeroBarrier® • Self-adhered WRBs • Mid-construction blower door tests • Sealing under wall plates and around windows, can lights, and exterior plugs

Mechanical Systems

Each builder described the mechanical systems they install in the homes they build (**Table 37**). Three builders typically install furnaces, while two builders tend to install heat pumps. For water heating, two builders install gas tankless heaters, and the three remaining builders install either electric tank heaters, instantaneous heaters, or heat pumps. For ventilation, four builders install HRV/ERV and one installs exhaust ventilation. Two builders typically install central ducted heating and cooling, while three builders said that their choice between ducted or ductless heating and cooling depends on the building.

³⁸ One builder did not respond to this question.

Table 37. Mechanical systems that builders typically install

Furnace vs heat pump	# of Builders (n=5)
Furnace	3
Heat pump	2
Water Heater	
Gas Tankless	2
Electric tank	1
Instantaneous	1
Heat Pump	1
Exhaust Ventilation vs. HRV/ERV	
Exhaust ventilation	1
HRV/ERV	4
Ductless vs. Central Ducted Heating/Cooling	
Ductless	0
Central ducted heating/cooling	2
Depends on building	3

The team also discussed the presence of air conditioning in gas-heated homes. In their experience, many homes with gas furnaces do not have central air conditioning, especially in marine climates.³⁹ However, these homes may be marketed as “AC ready.” For example, the contractor might wire a thermostat to be ready for future air conditioning systems and leave a sticker with more information on the furnace.

In the total set of observed homes,⁴⁰ 90 had a gas furnace, 79 in CZ 4C and 11 in CZ 5B. Statewide, about half of the homes with gas furnaces noted a central AC system, 50.6% of the CZ 4C observations and 54.5% of the CZ 5B observations.

Code Changes

Builders generally did not report difficulties in complying with the 2021 ORSC compared with the 2017 code. One builder commented on challenges they have had with getting HVAC and ducts inside conditioned spaces. Another builder felt that the two codes are similar in that some measures are “pretty attainable” while others are cost prohibitive or overly complex.

Multi-Family Construction

Interviewers asked builders a series of questions about whether code compliance is easier or more challenging for single-family versus multi-family construction. Two builders did not provide input since they only build single-family homes.

Interviewees discussed how their equipment choices differ for multi-family versus single-family buildings. One builder said that mini-splits are an effective method for heating and cooling when there is not space for a furnace, but they do not always work well in larger units, and it can be challenging to run the line sets through the walls of multi-family buildings. To avoid this issue, another builder uses packaged terminal heat pumps (PTHPs). For water heating systems, one builder commented they prefer to install a central heating plant versus individual water heaters in each unit.

³⁹ As noted above, two climate zones are found in Oregon: climate zone 4C mixed marine (CZ4) and climate zone 5B cool dry (CZ5). On average, CZ5 has more heating degree days than CZ4.

⁴⁰ The total set of observed homes may overrepresent counties where observations were collected beyond the required statistical sample.

Builders also differed in their approaches to ventilation systems in multi-family construction. While one builder installs HRV in both single-family and multi-family homes, two builders said their choices are limited by costs or space in multi-family homes. One builder said that ERVs are too expensive for them to include in their builds, and another said that they are limited in their ventilation system choices due to space constraints.

Builders did not note many differences between single- and multi-family construction for selection of Additional Measures or air tightness. One builder mentioned that it is difficult to adequately seal individual units in multi-family construction.

Permitting/Compliance Across Different Jurisdictions

Builders also discussed differences in permitting and compliance depending on what permit-issuing jurisdiction they are building in. All five builders said that permitting varies by jurisdiction, with some being more difficult than others. For example, one builder who builds in Milwaukie, Happy Valley, and Portland said that Portland is “definitely the most difficult.” Another builder echoed this sentiment, saying that “Portland is unpredictable, and permit costs can be difficult to understand.” Two builders noted that each place they build in enforces code to different degrees, which creates challenges for builders.

Experience with Oregon Permitting/Compliance Process

Three builders provided additional comments on the Oregon permitting and compliance process. All three of these builders offered recommendations for addressing some of the challenges they have experienced while building homes in Oregon. One builder said that it would be a “great benefit” to have accessible summaries of permitting and compliance requirements for single and multifamily homes. Another builder discussed how Oregon’s code standards seem disproportionate to Oregon’s climate zone. This builder felt that standards for the Portland area are similar to standards for much colder climates, and that this has increased project costs. The final builder expressed frustration at the lack of energy code inspections for many homes. This builder said that plans examiners often create challenges and “permitting hoops” for builders to overcome, but that field inspectors often “drive by and sign off on things.”

5 Conclusions

This study provides insight into code compliance both at a measure and whole-home level under 2021 ORSC. From a whole-home EUI perspective, the weighted modeling results predict 91.4% compliance statewide (compared with an estimated 89% under the previous code, ORSC 2017). Statewide, the average home uses about 7% more energy than a baseline home that exactly meets code requirements.

Note, the simulated population includes homes with above-code measures, which improves the average performance statewide. This is why the average home underperforms the code-compliant average by 7%, but there is still 8.6% non-compliance for the 2021 ORSC based on the individual models. Including above-code performance improves statewide compliance by about 1.6%. There is a difference between the compliant and non-compliant home populations under the 2021 ORSC. When including above-code performance, on average the compliant population uses about 5.6% less energy than a code-compliant baseline while the non-compliant population uses about 12.4% more.

Table 38 below summarizes the potential measure-level savings that could be the target for future education, training, and outreach activities. Potential statewide annual energy savings are 26,728 MMBtu, which would result in \$613,725 in energy cost savings. Over a 30-year period, this would save 12.4 million MMBtu and \$285 million.⁴¹

The highest potential savings are in envelope leakage, representing about 46% of the potential savings. Improved insulation assemblies in floors, walls, and ceilings represent about 40% of the potential savings. While the amount of insulation is generally sufficient, there is room for improvement in insulation installation quality. Improved duct leakage represents about 13% of the potential savings.

Table 38. Annual statewide savings potential

Key Measure	Annual Savings	
	Energy (MMBtu)	Cost (\$)
Envelope Tightness (ACH50)	12,294	271,564
Window U-factor	421	8,443
Wall U-Factor	5,545	129,062
Ceiling U-Factor	4,085	91,189
Foundation Insulation	1,007	17,243
% Duct in Conditioned Space	3,375	96,223
TOTAL	26,728 MMBtu	\$613,725

There is a notable shift from natural gas to electricity for both space heating and DHW. For space heating, the share of natural gas furnaces has decreased from 81% (2017 ORSC) to 54% (2021 ORSC), while the share of natural gas DHW systems has decreased from 70% (2017 ORSC) to 49.6% (2021 ORSC). In the current study of the 2021 ORSC, 46% of the HVAC systems and 40.7% of the DHW systems are electric heat pumps; these were both only 14% in the previous study of the 2017 ORSC.

⁴¹ 5-year, 10-year, and 30-year savings are included in the Savings Analysis Results section. These calculations followed the methodology specified in *DOE's Residential Building Energy Code Field Study: Data Collection & Analysis*. Details on the energy cost assumptions are included in the Oregon Fuel Prices section in Appendix B.

6 Recommendations

Recommendations to improve code compliance and recommendations for future studies are provided below.

Recommendations to Improve Code Compliance

NEEA and its partners should consider focusing education and outreach efforts on the variables with the highest potential energy savings. From highest to lowest, the majority of the potential savings are in envelope leakage, external wall insulation, ceiling insulation, and duct leakage. There is also room for improvement in foundation insulation and window U-factor compliance, but the potential savings are comparatively small.

Enhance envelope tightness, aiming for increased compliance and tighter average envelopes.

Envelope tightness represents nearly half of the potential energy and cost savings. Under the 2021 ORSC, the statewide average envelope tightness is 3.7 ACH. In the previous study of the 2017 ORSC, the statewide average was 4.1 ACH, so the average ACH has improved. However, the maximum measured air leakage rate from this distribution (8.0 ACH) is essentially unchanged from that of the 2017 ORSC study (8.1). This indicates that while a portion of the industry is improving its air sealing practices, the leakiest buildings may not improve under the ORSC's current approach to envelope airtightness requirements.

Improve the quality of external wall insulation installation. Improved compliance for external wall insulation represents 20% of the 2021 ORSC potential savings. Nearly all of the observations met or exceeded the R-21 insulation requirement, but about a third of the observations had Grade II or III IIQ, resulting in 73% compliance statewide. So, the amount of insulation is sufficient, but education and outreach efforts could focus on installation quality.

Improve both the quantity and quality of ceiling insulation, including compliance with increased R-value requirements. Ceiling insulation represents about 15% of the 2021 ORSC potential annual energy savings. All of the CZ5 observations met or exceeded the R-49 prescriptive requirement, while only 76% of the CZ4 observations did. Statewide, almost half of the IIQ observations were Grade II and III. So, education and outreach efforts could focus on IIQ statewide and the amount of insulation in CZ4.

Reduce duct leakage by relocating ducts to conditioned spaces or enhancing duct insulation in unconditioned spaces. Duct location is a new prescriptive requirement under the 2021 ORSC, requiring that 95% of the duct system (which includes the ductwork and heating system per the 2021 ORSC errata) is in the building's thermal envelope or that ducts are buried in R-19 insulation. Improved compliance with this measure represents about 13% of the potential savings statewide. Education and outreach efforts can focus on either moving ducts to conditioned spaces or improving duct insulation in unconditioned spaces. Notably, this requirement changed between the original 2021 ORSC and the 2021 ORSC errata, so there may be industry confusion on how to comply.⁴²

⁴² The [original 2021 ORSC N1105.3 Exception 2](#) ("Up to 5 percent of the length of an HVAC system ductwork shall be permitted to be located outside of the thermal envelope") was modified by an [2021 ORSC erratum](#) that struck "ductwork" from said phrase and applied the 2021 ORSC definition for *HVAC system* ("Refers to the equipment, distribution network, and terminals [...]"). Building Codes Division Technical Bulletins on this topic issued [Nov. 2021](#) and [Feb. 2022](#) likewise provided differing representations of compliant options.

Improve heating performance by relocating heating systems within the thermal envelope. Education and outreach efforts can focus on moving these systems to indoor closets or other spaces within the thermal envelope, rather than keeping them in garages or vented attics.

Consider developing accessible summaries of permitting and compliance requirements for builders and more information about ORSC Additional Measure selection. During interviews, builders expressed frustration with what they described as “moving targets” in trying to achieve code requirements, especially across jurisdictions and code changes. They suggested that a streamlined summary of requirements for a given jurisdiction and highlighting the changes in the new code would help them meet requirements. Builders also tended to focus on costs when selecting an Additional Measure. Additional information and education about the benefits and best practices for installing specific measures might encourage the selection of Additional Measures beyond high performance heating equipment.

Recommendations for Future Studies

Leverage multiple data sources to complete future studies with limited need for site visits.

The IEc team was able to obtain most of the data used in this study through a combination of sources other than site visits, including AXIS/EPS data for above-code homes, permit data, plan sets, window and insulation contractor invoices, and homeowner survey data. Future studies in Oregon can leverage these sources to collect most data, although site visits will likely be required to collect IIQ observations and (for non-above-code homes) envelope tightness observations. Site visits may be the only reliable data source available in some jurisdictions, however, so future studies will need to use available data opportunistically and be flexible with sampling plans if attempting to reduce the need for site visits.⁴³

Window and insulation contractor invoices and plan set reviews served as viable cost-effective data sources for this study. There may be limitations and challenges associated with this approach, however, including difficulty in getting contractors to provide data, lack of representativeness in the data if only a small number of contractors share information or if plan sets are not available from a number of jurisdictions, and the possibility that data provided in invoices and plan sets will not reflect what measures are actually installed. To overcome these issues, evaluators should attempt to collect data from a large pool of contractors and jurisdictions, which may require substantial outreach efforts and/or incentivizing participation. Further, evaluators should conduct verification visits to ensure invoices and plan sets are an accurate reflection of building practices.

If NEEA conducts another homeowner survey, consider using additional data sources to identify new construction homes. Permitting data from ATTOM required extensive cleaning, and many of the permit descriptions did not indicate the home type and other key information, including whether the homes were single or multifamily, zoned as residential, and/or the occupancy status.⁴⁴ This made it difficult to identify suitable homes occupied with eligible prospective survey participants. As a result, some addresses in the mailing list may not have been within the scope of this study, which could have been avoided with more reliable data. Utilities, city building departments, and real estate websites (for example, Zillow) might have more specific information on home types and other characteristics, which would help narrow the scope of potential homes to survey and streamline the sampling plan.

⁴³ While these methods may be applicable in other states, this finding is specific to Oregon where the IEc team found greater success in using methods other than site visits than in similar studies in Montana and Idaho.

⁴⁴ ATTOM is a data service company that provides information on a number of metrics related to properties: <https://www.attomdata.com/>.

Appendix A – State Sampling Plan

Table 39 shows the final sample plan that the team used to conduct the data collection. As described in Section 2, this plan was selected by NEEA from ten options developed by the IEC team following DOE/PNNL methodology. The team was able to generally follow the sample plan, although the team worked with NEEA to make replacements based on population size, building activity, climate zone, and geographic location in some places where full data were not available. Notably, Tillamook, Curry, Douglas, and Linn Counties were not in the original sample plan, but served as replacements for data shortfalls in Clatsop, Coos, Jackson, and Benton Counties, respectively.

Table 39. On-site inspection sample plan

Location	Number of Measures
Lane County	10
Jackson County	8
Washington County	7
Multnomah County	6
Marion County	5
Benton County	5
Deschutes County	3
Clackamas County	3
Polk County	3
Union County	2
Morrow County	2
Jefferson County	2
Curry County	2
Columbia County	2
Clatsop County	1
Yamhill County	1
Crook County	1

Table 40 shows the number of homes with data collected on at least one measure, broken down by county and data source.

Table 40. Total homes collected by data source

County	AXIS	On-Site	Permits/Plan Sets/Invoice	Survey Data	Total
Lane	1	21	8	11	41
Washington	5	8	7	20	40
Clackamas	2	10	4	16	32
Jackson	2	8	8	8	26
Multnomah	3	7	7	5	22
Marion	3	3	7	5	18
Deschutes	--	3	4	10	17
Coos	--	6	3		9
Yamhill	--	2	2	5	9
Polk	1	1	3	2	7
Benton	2	2	--	2	6
Crook	1	--	1	2	4
Linn	--	2	--	2	4
Morrow	--	2	2	--	4
Union	--	1	1	2	4
Columbia	--	1	1	1	3
Clatsop	--	--	1	1	2
Jefferson	--	--	2	--	2
Tillamook	--	--	2	--	2
Curry	--	--	--	1	1
Douglas	--	1	--	--	1
Grand Total	20	78	63	93	254

Table 41 summarizes survey sample targets and outreach results for each county.

Table 41. Survey outreach results

Jurisdiction	Total Sample	Sample Targets	Postcards Sent	Sample Achieved	Survey Response Rate
Benton	412	1	201	3	1.5%
Clackamas	1,315	9	1,130	15	1.3%
Clatsop	229	1	75	1	1.3%
Columbia	169	1	76	1	1.3%
Crook	435	2	151	2	1.3%
Curry	157	1	75	1	1.3%
Deschutes	2,329	11	1,429	9	0.6%
Jackson	767	6	587	8	1.4%
Jefferson	176	1	125	1	0.8%
Lane	901	7	520	11	2.1%
Marion	1,061	6	761	6	0.8%
Morrow	13	1	13	0	0.0%
Multnomah	501	6	501	6	1.2%
Polk	500	2	250	2	0.8%
Union	74	1	74	2	2.7%
Washington	1,017	11	1,011	20	2.0%
Yamhill	929	3	403	5	1.2%
Total	10,985	70	7,382	93	1.3%

Appendix B – Modeling Methodology

Additional Measure Selection

The 2021 ORSC requires one Additional Measure, as shown in the table below. So, in addition to modeling the prescriptive requirements, the team needed to decide which Additional Measure to include in the code-compliant baseline. In PNNL's previous study of the 2017 ORSC, they used the most commonly selected option, so this study used the same approach.

As noted in the body of the report, Measure 1 was by far the most commonly selected option. Of the 63 observations, 59 selected Measure 1 High efficiency HVAC system, three selected Measure 4 Advanced envelope, and one selected Measure 8 ACH air leakage control and efficient ventilation. Therefore, the Measure 1 HVAC specifications were incorporated into the code-compliant baseline models.

Table 42. 2021 ORSC Additional Measures Table N1101.1(2)⁴⁵

1	HIGH EFFICIENCY HVAC SYSTEM^a a. Gas-fired furnace or boiler AFUE 94 percent, or b. Air source heat pump HSPF 10.0/14.0 SEER cooling, or c. Ground source heat pump COP 3.5 or Energy Star rated
2	HIGH EFFICIENCY WATER HEATING SYSTEM a. Natural gas/propane water heater with minimum UEF 0.90, or b. Electric heat pump water heater with minimum 2.0 COP, or c. Natural gas/propane tankless/instantaneous heater with minimum 0.80 UEF and Drain Water Heat Recovery Unit installed on minimum of one shower/tub-shower
3	WALL INSULATION UPGRADE Exterior walls—U-0.045/R-21 conventional framing with R-5.0 continuous insulation
4	ADVANCED ENVELOPE Windows—U-0.21 (Area weighted average), and Flat ceiling ^b —U-0.017/R-60, and Framed floors—U-0.026/R-38 or slab edge insulation to F-0.48 or less (R-10 for 48"; R-15 for 36" or R-5 fully insulated slab)
5	DUCTLESS HEAT PUMP For dwelling units with all-electric heat provide: Ductless heat pump of minimum HSPF 10 in primary zone replaces zonal electric heat sources, and Programmable thermostat for all heaters in bedrooms
6	HIGH EFFICIENCY THERMAL ENVELOPE UA^c Proposed UA is 8 percent lower than the code UA
7	GLAZING AREA Glazing area, measured as the total of framed openings is less than 12 percent of conditioned floor area
8	3 ACH AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION Achieve a maximum of 3.0 ACH50 whole-house air leakage when third-party tested and provide a whole-house ventilation system including heat recovery with a minimum sensible heat recovery efficiency of not less than 66 percent.

For SI: 1 square foot = 0.093 m², 1 watt per square foot = 10.8 W/m².

- a. Appliances located within the building thermal envelope shall have sealed combustion air installed. Combustion air shall be ducted directly from the outdoors.
- b. The maximum vaulted ceiling surface area shall not be greater than 50 percent of the total heated space floor area unless vaulted area has a U-factor no greater than U-0.026.
- c. In accordance with Table N1104.1(1), the Proposed UA total of the Proposed Alternative Design shall be a minimum of 8 percent less than the Code UA total of the Standard Base Case.

⁴⁵ This table is from the "[2021 Oregon Residential Specialty Code: Significant changes summary.](#)"
Blue/Underlined = New Oregon amendment, Blue = Existing Oregon amendment

For reference, a summary of the 2017 ORSC Additional Measures is included below. The 2017 ORSC required the selection of one Envelope Enhancement Measure and one Conservation Measure. In the previous study of the 2017 ORSC, Envelope Enhancement Measures 2 and 5 were tied for the most common, while the high efficiency HVAC was the most common Conservation Measure, as shown below in **Table 43**.

Table 43. 2017 ORSC Additional Measures

**TABLE N1101.1(2)
ADDITIONAL MEASURES**

Envelope Enhancement Measures (Select One)	1	High efficiency walls Exterior walls—U-0.045/R-21 cavity insulation + R-5 continuous
	2	Upgraded features Exterior walls—U-0.057/R-23 intermediate or R-21 advanced, Framed floors—U-0.026/R-38, and Windows—U-0.28 (average UA)
	3	Upgraded features Exterior walls—U-0.055/R-23 intermediate or R-21 advanced, Flat ceiling—U-0.017/R-60, and Framed floors—U-0.026/R-38
	4	Super Insulated Windows and Attic OR Framed Floors Windows—U-0.22 (Triple Pane Low-e), and Flat ceiling—U-0.017/R-60 or Framed floors—U-0.026/R-38
	5	Air sealing home and ducts Mandatory air sealing of all wall coverings at top plate and air sealing checklist ^f , and Mechanical whole-building ventilation system with rates meeting M1507.3 or ASHRAE 62.2, and All ducts and air handlers contained within building envelope ^d or All ducts sealed with mastic ^b
	6	High efficiency thermal envelope UA^g Proposed UA is 8% lower than the code UA
Conservation Measure (Select One)	A	High efficiency HVAC system^a Gas-fired furnace or boiler AFUE 94%, or Air source heat pump HSPF 9.5/15.0 SEER cooling, or Ground source heat pump COP 3.5 or Energy Star rated
	B	Ducted HVAC systems within conditioned space All ducts and air handlers contained within building envelope ^d <i>Cannot be combined with Measure 5</i>
	C	Ductless heat pump Ductless heat pump HSPF 10.0 in primary zone of dwelling
	D	High efficiency water heater^c Natural gas/propane water heater with UEF 0.85 OR Electric heat pump water heater Tier 1 Northern Climate Specification Product

For SI: 1 square foot = 0.093 m², 1 watt per square foot = 10.8 W/m².

Table 44. Additional Measure selection in the previous study of the 2017 ORSC**Table 3.20.** Observations for Combinations of Envelope Enhancement and Conservation Measures

Conservation Measure Options to the Right, Envelope Enhancement Measures Below	Option A - High Eff HVAC System	Option B - Ducted HVAC in Conditioned Space	Option C - Ductless Heat Pump	Option D - High Efficiency Water Heater	Total
Measure 1 - High Efficiency Walls	0	1	0	0	1
Measure 2 - Upgraded Features 1	9	1	1	0	11
Measure 3 - Upgraded Features 2	2	0	0	0	2
Measure 4 - Super Insulated Windows and Attic or Framed Floors	0	0	0	0	0
Measure 5 - Air Sealing Home and Ducts	10	0	0	1	11
Measure 6 - High Efficiency Thermal Envelope UA	7	0	0	0	7
Measure - Blank	0	0	0	2	2
Total	28	2	1	3	34

EnergyPlus and OpenStudio

For the energy modeling tasks, the study used the PNNL Single Family Residential Prototype building models based on the 2018 version of the IECC for climate zones 4C and 5B.

Note that since the previous field study, updates were made to the single family EnergyPlus prototype model files to directly use the airflow network for duct leakage modeling rather than relying on post processing.

The following modifications to the models were made to comply with 2021 ORSC:

- Window U-factor
 - Climate zone: 4C and 5B
 - 0.3 --> 0.27 Btu/h-ft²-F
- Envelope tightness
 - Climate zones: 4C and 5B
 - 3 ACH50 --> 4 ACH50
- High Efficiency lighting:
 - Climate zones: 4C and 5B
 - 90% --> 95% (assumed)
 - ORSC 2021 specifies all but two fixtures must be high efficiency, which is assumed to be approximately 95% High Efficiency Lighting
- Foundation:
 - Basement Wall R-value
 - Climate zones: 4C and 5B
 - R-19 → R-21 cavity insulation
 - Slab R-value and Depth

- Climate zones: 4C and 5B
 - R-10, 2ft → R-15, 2ft
- HVAC Heating Efficiency
 - Gas Furnace
 - Climate zones: 4C and 5B
 - 0.8 → 0.94 AFUE
 - Heat pump
 - Climate zones: 4C and 5B
 - 3.8 → 4.2 COP

Additionally, a model was created for an unvented crawlspace foundation. The existing PNNL crawlspace foundation assumes a vented crawlspace with foundation insulation placed in the floor. The newly created model for an unvented crawlspace assumes:

- Insulation is placed along the exterior crawlspace wall
 - R-21 cavity insulation
- Crawlspace ventilation matches the indoor ventilation:
 - 4 ACH50

Oregon Fuel Prices

The fuel prices used for calculating potential energy cost savings from improved compliance are derived from the U.S. Energy Information Administration's (EIA) Oregon State Energy Profile, which shows a state average residential electricity price of \$0.1462/kWh and residential gas price of \$13.8/Mcf, which is equal to \$1.349/therm assuming a natural gas heat content of 1,023 Btu/cf.^{46,47}

⁴⁶ "Oregon State Energy Profile." US EIA. 2024. <https://www.eia.gov/state/print.php?sid=OR>

⁴⁷ "Heat Content of Natural Gas Consumed. US EIA. 2024. https://www.eia.gov/dnav/ng/ng_cons_heat_a_EPG0_VGTH_btucf_a.htm

Appendix C – Interview Guide

NEEA Residential Energy Code Compliance Study Draft Interview Guide – Builders

[POPULATE THE FOLLOWING FIELDS PRIOR TO CONDUCTING THE INTERVIEW.]

Date of Interview: _____
Interviewer Name: _____
Interviewer Email: _____
Respondent Name: _____
Respondent Organization Name: _____
Respondent Phone: _____
Respondent Email: _____

Introduction

[INTERVIEWER READ] Thank you for your participation in the Northwest Energy Efficiency Alliance (NEEA) Residential Code Evaluation Study. Interviews with homebuilders like you are an important part of the study. I will be asking you some questions about your experience with new single-family home construction projects in Oregon. When you answer these questions, please consider homes that you are building now and homes that you built within the last two years. Please note that this study pertains specifically to the 2021 ORSC, although many questions will be relevant under the current code (2023 ORSC) as well. All responses will remain confidential, and no personal information will be shared. The interview should take no longer than 30 minutes to complete. May I begin?

1. Please briefly describe your background and your company. How many years have you been building homes in Oregon? What part(s) of the State do you mostly work in and what types of homes (i.e., custom versus prescriptive) do you typically build?
- 2A. In a typical year, how many single-family new construction homes does your company build in Oregon?
- 2B. Has the number of single-family new construction homes that your company builds in a typical year in Oregon changed over the past decade? If so, please describe how this has changed.
3. When you build a new home, do you typically follow the prescriptive path, or the Part II, Alternative Systems Analysis (Energy Rating Index) requirements for achieving compliance with the energy code? Please explain why you typically follow this path.
- 4A. Which of the following describes the standard to which you typically build new residential homes? (Select all that apply):
 - a. Base code
 - b. Reach code (Please specify the reach code)
 - c. Energy Star Requirements
 - d. EPS New Construction program requirements
 - e. Based on EPS rating?
- 4B. Please explain why you choose to build to this level of code and/or to participate in the program(s).

5A. I will now read the list of additional measure options in the 2021 ORSC. Which additional measure(s) do you typically choose, and why? Examples of reasons for choosing an additional measure could include, but are not limited to: lowest cost, easy to acquire, comfort of home, anticipated energy savings, homeowner preference, etc.

Measure [Select all that apply]	Reason for selecting [Only populate if selected]
High Efficiency HVAC System	
High Efficiency Water Heating System	
Wall Insulation Upgrade	
Advanced Envelope	
Ductless Heat Pump	
High Efficiency Thermal Envelope UA	
Glazing Area	
3 ACH Air Leakage Control and Efficient Ventilation	

5B. Does your selection of the additional measure vary across different parts of the State? If yes, please explain.

5C. Does your selection of the additional measure vary depending on the customer? If yes, please explain.

6. Are there any additional measures that you would NEVER consider incorporating into a new home? If yes, please explain why (e.g., cost, difficulty/lack of skilled expertise to install, etc.).

7A. I'm now going to ask a few questions about envelope compliance. Do you typically use the U-factor or R-value table when planning out construction, and why?

7B. What type of insulation do you use in the walls and attic/ceiling (batt, blown-in, etc.), and why?

7C. Do you have any strategies to minimize air leakage when constructing the building, or do you typically wait for the blower door test to see if you need to make improvements?

8A. Do any particular types of mechanical systems make it easier to build to code? (Examples: boiler vs. furnace vs. HP; gas storage WH vs. instantaneous WH vs. HPWH; exhaust ventilation vs. HRV/ERV; ductless vs. central ducted heating/cooling, etc.)

8B. Do you choose a mechanical system because it is easiest to build to code, or do you choose the system for other reasons (e.g., cost, availability, familiarity, ease of installation, etc.)? **[Interviewer please record responses to both parts of the question, i.e., if different systems are easier to build to code and/or other factor(s) that builders consider when installing these systems]**

9. Has the difficulty in complying with code requirements changed in a noticeable way with the shift from the 2021 Oregon Residential Specialty Code to the current 2023 code? If yes, what changes have been the most challenging, and why?

10A. NEEA's current study focuses on new single-family home construction, but NEEA is interested in understanding whether the study findings can shed light on new multi-family construction. Please explain any areas where you think compliance may be easier or more challenging for single-family vs. multi-family requirements.

10B. How do these differences affect the compliance level and energy efficiency of these homes?

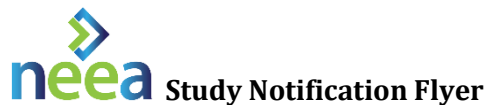
10C. Do you think that statewide energy code compliance estimates for new-construction single-family homes would be applicable to new multi-family homes? Why or why not?

11. Have you built homes in multiple permit-issuing jurisdictions (i.e., have you had to apply for permits with multiple cities, towns, and/or counties) within the State? If yes, please briefly describe how permitting/compliance differs across these jurisdictions.

12. Are you aware of the Energy Trust of Oregon ("Energy Trust") and the resources they provide? If yes, have you utilized any of their resources? (e.g., trainings, trained/knowledgeable trade ally subcontractors, verifiers, design assistance, EPS rating, incentives)

13. Are there any other thoughts you would like to share on the permitting/compliance process within the State of Oregon?

Appendix D – Study Notification Flyer



Residential Energy Code Compliance Study

The Northwest Energy Efficiency Alliance, Inc. (“NEEA”), part of an alliance with Northwest utilities, and its contractors are conducting a Residential Energy Code Compliance Study by collecting and analyzing data to better understand how energy codes are being implemented in Oregon (the “Study”). Using protocols established by the Department of Energy, NEEA is collecting the following data points from a group of randomly selected residences: envelope tightness, window heat gain, window Ufactor, wall insulation, ceiling insulation, floor and foundation insulation, lighting efficacy, and duct leakage. Not all data points will be collected from each residence.

This residence has been randomly selected to contribute to this Study. By allowing the collection of data, you agree to participate in the Study and also understand and agree to the following terms:

- NEEA and its contractors take your privacy seriously and will not disclose any information in a manner that could identify you or the location of the residence.
- NEEA and its contractors are not providing advice, recommendations, or certification related to residential energy code compliance. Any advice, guidance, or services provided by NEEA and its contractors is provided “as is”. NEEA DISCLAIMS ALL REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, ADVICE AND WARRANTIES, EXPRESS OR IMPLIED, REGARDING THE STUDY INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEEA AND ITS CONTRACTORS MAKE NO REPRESENTATION OR WARRANTY OF ANY KIND, AND ASSUME NO LIABILITY WITH RESPECT TO QUALITY, SAFETY, PERFORMANCE, OR ANY OTHER ASPECT OF ANY DESIGN, OF EQUIPMENT OR STRUCTURES INSPECTED PURSUANT TO THE STUDY, AND EXPRESSLY DISCLAIM ANY SUCH REPRESENTATION, WARRANTY OR LIABILITY.

For more information about the Study, please contact Meghan Bean at NEEA ([REDACTED]) or Greg Englehart at Industrial Economics (IEc) ([REDACTED]). For more information about NEEA, please visit our website: neea.org.