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Oregon Residential Specialty Code: 2005 Baseline and Code Roadmap to Achieve the 2030 Goal

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Glossary of Acronyms

AFUE	Annual Fuel Utilization Efficiency
ACH	Air Changes per Hour
COP	Coefficient of Performance
DHW	Domestic hot water
DHP	Ductless Heat Pump
DOE ZERH	Department of Energy Zero Energy Ready Home Specification (Rev 6)
EF	Energy Factor
ERV	Energy Recovery Wheel
HFA	Heated Floor Area
HSPF	Heating Seasonal Performance Factor
HP	Heat Pump
HVAC	Heating, Ventilation and Air Conditioning
IECC	International Energy Conservation Code
MELS	Miscellaneous Electric Load Use
NEEA	Northwest Energy Efficiency Alliance
NPCC	Northwest Power and Conservation Council
ORSC	Oregon Residential Specialty Code
RTF	Regional Technical Forum
RBSA	Residential Building Stock Assessment
SEEM	Simplified Energy and Enthalpy Model
SEER	Seasonal Energy Efficiency Ratio
SHGC	Solar Heat Gain Coefficient
SRE	Sensible Heat Recovery Efficiency
SqFt	ft^2
TMY	Typical Meteorological Year
UA	Building heat loss expressed as U-value times area

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Executive Summary

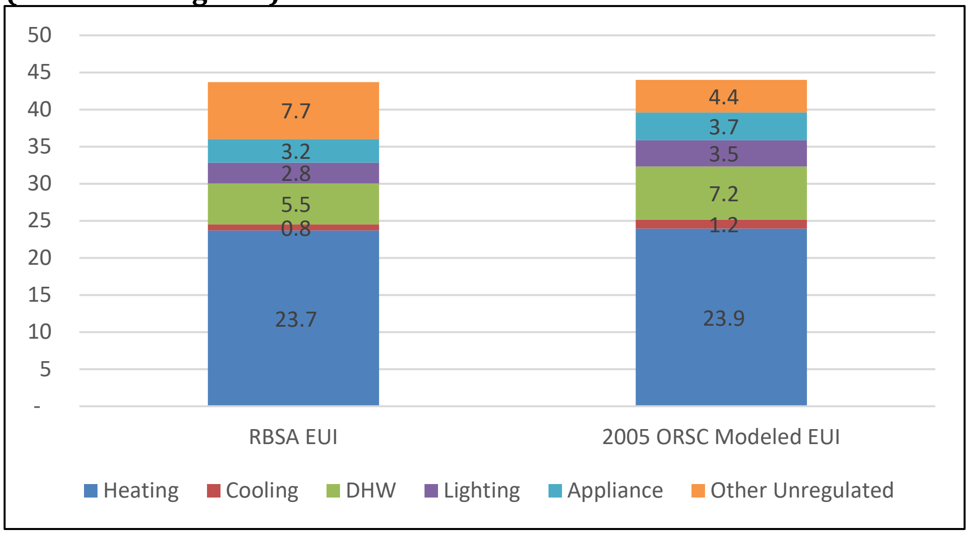
The Oregon Governor's Executive Order 20-04 (EO 20-04) directs the Oregon Building Codes Division (BCD) to adopt building codes by 2030 for new residential and commercial construction that will provide a reduction of 60% of regulated annual site energy consumption, relative to the 2006 Oregon code baseline. Executive Order 17-20 (EO 17-20) also establishes a requirement that BCD adopt a code for residential buildings by 2023 that achieves at least equivalent performance levels with the 2017 U.S. Department of Energy's (DOE) Zero Energy Ready Homes specification (DOE ZERH Revision 6). Together, these executive orders provide a series of benchmarks for evaluating the stringency of different versions of the Oregon Residential Specialty Code (ORSC) in this report.

This study has focused on the residential sector to establish the 2006 baseline, define the 60% reduction goal, and to show the progress of various code years in relation to this new statewide target. The modeling analysis for this report followed the methodology established in previous code saving analyses, the recent Northwest Energy Efficiency Alliance (NEEA) Oregon Residential Specialty Code Energy Efficiency Analysis (Odum 2020), and as described below in this report.

An important piece to any modeling exercise is the provision of a foundation against which modeled results can be compared. In considering code saving analyses, DOE advises that regional measured performance data represent a key calibration tool for considering code performance. This study has referenced metered energy end use data from the 2014 Residential Building Stock Assessment (RBSA) as a comparison to inform the modeling team regarding a reasonable upper bound of expected energy use when completing this modeling study. Since the RBSA dataset is for all vintages of homes (with varying levels of equipment efficiencies), it would be expected that this dataset would have differences in end use breakdowns compared to a newly-built home in 2006. However, since the RBSA dataset is comprised of homes built to older, less stringent energy codes, or to no energy codes at all, it is reasonable to assume that this dataset would represent the upper bound of reasonable energy consumption values for a code that applies to only the very newest homes in the RBSA sample vintage.

Setting a believable 2006 baseline is critical to providing a logical, accurate basis for the 60% reduction target. Figure 1 summarizes this study's calibrated results from the 2006 baseline and comparison to the RBSA dataset. All subsequent code analyses in this report have been built off this 2006 baseline with changes driven by the code requirements from different code editions. Note that while the 2006 baseline established by EO 20-04 uses the year 2006 as a baseline, the version of ORSC in place at that time is referred to as the 2005 ORSC.

Figure 1. Modeled 2005 ORSC Baseline Compared to RBSA Metering Data (All Fuels Weighted)



Results

Table 1 shows relative savings of each code version evaluated, with and without unregulated loads. Since unregulated loads (plugs and appliances) are difficult to predict and remain outside the scope of the energy code, these loads remain unchanged in the analysis of various code versions—except for the DOE ZERH modeling, which includes a small energy savings due to the requirement for the installation of ENERGY STAR appliances.

Although a number of more efficient prescriptive code requirements were adopted in the 2021 ORSC compared to the 2017 code edition, the "Additional Measures" table in the 2021 ORSC introduces a wide range of possible energy performance outcomes, depending on which option is chosen by any given project. When the variability of these options is accounted for, the 2021 ORSC delivers a range of energy savings compared to the 2017 code. Specifically, selection of Option 1 (High Efficiency HVAC System) in Table N1101.1(2) Additional Measures of the 2021 ORSC results in 7.5 % regulated energy savings, while Option 7 (Glazing Area) has about 1% savings. Table 1 shows the range of energy use and savings for the 2021 ORSC, representing the impacts from these two options.

While EO 17-20 specifies that the 2023 code version must achieve energy performance comparable to DOE ZERH, no other specific intermediate goals are identified in the 60% reduction target for the 2030 goal in EO 20-04. While the BCD is directed to evaluate and report on progress toward the 2030 goal, without an explicit roadmap and/or plan in place to meet these interim steps, progress toward the goal may be uneven in the interim code cycles. If some code cycles adopt smaller performance improvements, more drastic savings will be required in other cycles to remain aligned with the performance reduction target.

Table 1. Comparative Energy Savings by Code Version, Total and Regulated (All Fuel Types Converted to kWh Equivalent and Energy Use Intensity)

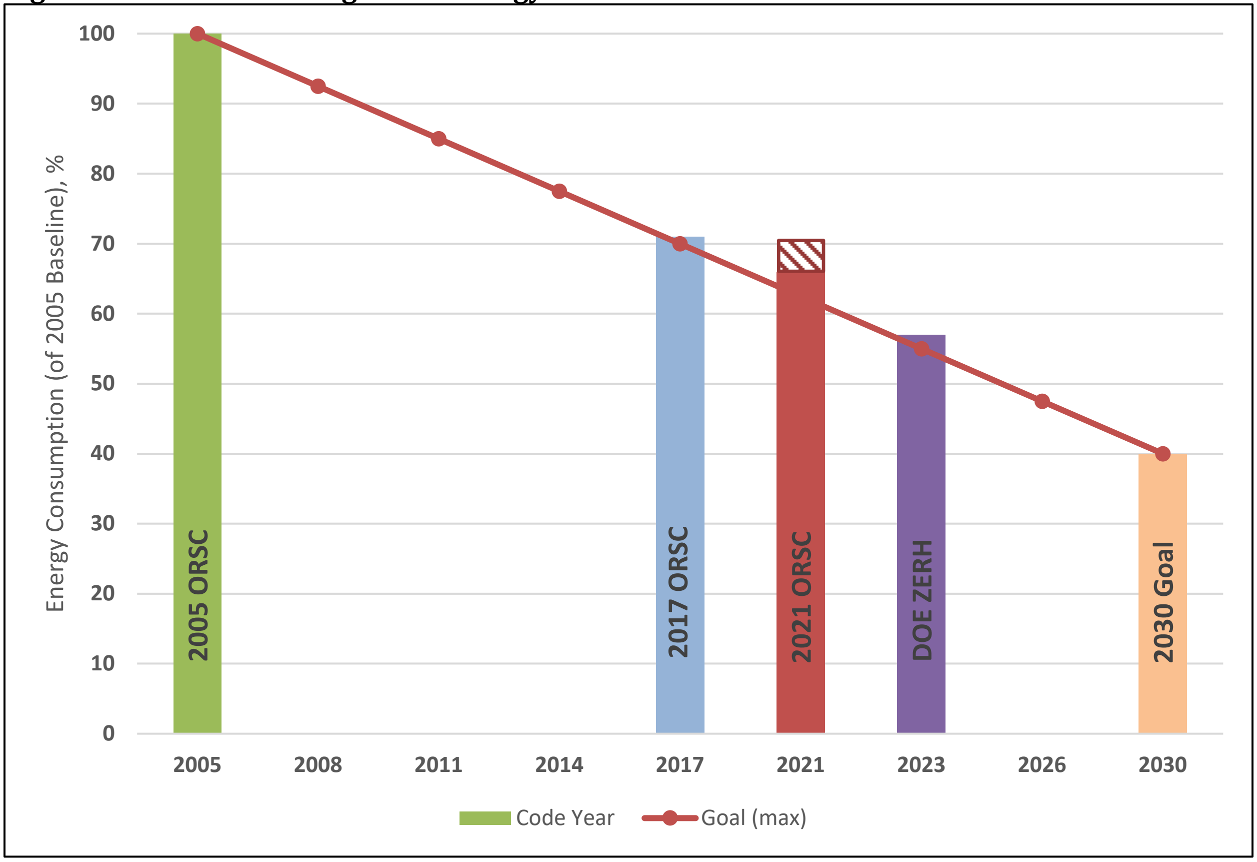
Code Version	Total Energy Use (kWh/yr equivalent)	Total Energy Use Intensity EUI (kBtuh/sf/yr)	Percent TOTAL Savings over 2005	Regulated Energy Use (kWh/yr equiv.)	Regulated EUI (kBtuh/sf/yr)	Percent Regulated Savings over 2005
2005 ORSC	28,363	44.0	---	23,114	35.9	---
2017 ORSC	21,631	33.6	24%	16,381	25.4	29%
2021 ORSC	20,390 (+/- 570)	32.5 (+/- 0.9)	24-28%	15,680 (+/- 570)	24.3 (+/- 0.9)	30-34.5%
DOE ZERH	18,300	28.4	35.5%	13,230	20.5	43%
2030 Goal	14,495	22.5	49%	9,245	14.3	60%

For clarity on alignment with policy goals, the relative performance of individual code versions should be compared to the performance trend needed to achieve the end goal. In Figure 2, the 2030 performance goal is represented as a linear trend from 2005 baseline (100%) to a 60% reduction in 2030 (baseline at 100% - 60% = 40% of baseline). Over the eight successive code cycles (averaging three years per code cycle) in this timeframe, this trajectory suggests that a reduction of approximately 7.5% of regulated energy use in each cycle, from 2005 to 2029, would keep the state on track for its 2030 goal.

The 2017 ORSC nearly aligns with this interim goal, while the proposed 2021 ORSC shows 1% to 7.5% savings over the 2017 code, and may fall out of line with the long-term policy trajectory goal, depending on the additional measure option most commonly used in the market. Also, due to the variable performance of different option paths in the 2021 code, energy savings levels are not consistent among homes that meet this code.

This study also shows that DOE ZERH specification achieves regulated energy savings of roughly 19% as compared to the 2017 ORSC. Adopting a code that achieves at least equivalent performance levels with the DOE ZERH specification in 2023 would put the state back on track to achieve the 2030 goal.

Figure 2. Reduction in Regulated Energy Use Relative to 2005 Baseline



Major changes in 2021 ORSC include improved glazing performance, more airtight construction, and better duct performance. ORSC does not require envelope airtightness and duct sealing to be tested or verified—making their energy savings hard to substantiate. While balanced ventilation is a positive impact for indoor air quality and for ensuring outside air is introduced into each living area, the adoption of balanced ventilation without heat recovery is not necessarily an energy conservation measure because it adds fan energy to a comparable 2017 code compliant home. Since homes built to the 2021 ORSC are not tight enough to require balanced ventilation, this leads to over-ventilation of the home due to high levels of infiltration alongside mechanical ventilation per Chapter 15 of the 2021 ORSC. The current code has reduced the total required airflow, compared to 2017, through the adoption of the ASHRAE 62.1 equation; this has been accounted for in this analysis.

Another notable change is to the option table (Table N1101.1(2)) within the 2021 ORSC. Because the envelope and duct sealing measures as additional measures in 2017 code were moved into the prescriptive requirements in the 2021 code, the requisite number of additional measures was reduced from two (in the 2017 ORSC) to a single measure (in the

2021 ORSC). While prescriptive requirements of the code have been strengthened, the inconsistent energy savings between the optional measures in the 2021 ORSC creates the potential for this new code to result in very little savings over the 2017 code if Option 7 (Glazing Area) is selected. This is illustrated in Figure 2.

The most prominent example of the variability of the compliance options is the comparison of window area reductions in 2021 ORSC (Option 7) vs. HVAC efficiency improvements (Option 1). Space heating equipment efficiency improvements required in other pathways of the option table are much more impactful than a relatively minor reduction in window area, especially after the prescriptive requirements have already increased the glazing's thermal performance. Widespread adoption of the window area option by projects would further reduce the effectiveness of the 2021 ORSC in meeting state-mandated energy code performance goals.

To provide guidance to subsequent code cycles, this analysis also evaluated the potential to achieve regulated energy savings of 60% by 2030, compared to the 2006 baseline. To reach this goal, a clear code roadmap should be developed to help the industry plan for what the future code-compliant home will look like. The goal of this exercise is to help ensure a smooth transition to achieving the performance levels of the 2030 goal.

Modeling has shown that the 60% target can be met with Oregon's current space heating fuel mix by using technologies and practices identified in this report. To allow for maximum design and construction flexibility, more measures should be added to the code—through either additional measures or prescriptive requirements. These decisions depend on whether to make incremental steps on measure stringency, or to make a sweeping change within a single code update. Items such as tighter air envelopes with balanced ventilation and HRV, or mandatory duct leakage testing, should be introduced as optional compliance paths first, then required in the subsequent prescriptive requirements. Without tested performance metrics, the code cannot definitively claim the high levels of energy savings required of the 2030 homes.

1. Introduction

In the Oregon Governor's Executive Order 20-04 (EO 20-04), the Governor directs the Oregon Building Codes Division (BCD) to adopt building energy codes by 2030 for new residential and commercial construction that will provide a reduction of 60% of regulated annual site energy consumption, relative to the 2006 Oregon codes.[1] This study is focused on the residential sector and seeks to define the appropriate statewide 2030 energy use target by determining the appropriate 2006 baseline, and also includes snapshots of the current and upcoming code progression toward the 60% reduction goal.

Prior to issuing EO 20-04, the Governor had released Executive Order 17-20, which tasked the BCD to produce a 2023 residential energy code that achieves at least equivalent performance levels with the 2017 U.S. Department of Energy's (DOE) Zero Energy Ready Homes specification (DOE ZERH Revision 6). The Northwest Energy Efficiency Alliance's (NEEA's) previous study (Odum 2020) provided analytical insights into the current 2017 Oregon Residential Specialty Code (2017 ORSC) compared to the DOE ZERH specification and presented pathways to meet EO 17-20. While this report expands on that study, it includes minor deviations from the previous findings due to updated modeling inputs, including weather files and thermostat setpoint differences, among others. While EO 17-20 and this study are focused on achieving equivalent energy performance with the DOE ZERH specification, those adopting energy efficiency measures should carefully consider other health and comfort elements specified in the ZERH program such as indoor air quality, occupant comfort, and moisture controls.

The work under this study expands on previous work by integrating modeling analyses of the 2006 baseline code and BCD's proposed 2021 ORSC (as voted on in the October 7, 2020 Residential and Manufactured Structures Board review meeting).[2] This study also sets a framework for the Oregon Residential Specialty Code and provides analysis of a select combination of measures by which the goals of Executive Order 20-04 can be achieved.

In order to develop a representative picture of Oregon's new construction single-family homes, the energy modeling methodology was developed to follow guidelines used by the Northwest Power and Conservation Council (NPCC), Regional Technical Forum (RTF), and the Washington State Building Code Council (SBCC). Modeling inputs to establish the 2006 baseline (based upon the 2005 ORSC), the current 2017 ORSC, DOE ZERH Revision 6, and BCD's proposed 2021 ORSC are provided in Appendix A: Detailed Modeling Results.

NEEA's 2014 Residential Building Stock Assessment (RBSA) Metering Study (Baylon 2014) provides a metered dataset with which to calibrate this study's modeled 2006 baseline

[1] The 2006 baseline residential energy code refers to 2005 Oregon Residential Specialty Code.

[2] https://www.oregon.gov/bcd/boards/Documents/rmsb-20201007-agenda.pdf

energy use. The RBSA study provides regional metered data of the average annual energy consumption for vintages of homes ranging back to 1950. Since the RBSA dataset is comprised of homes built to older, less stringent energy codes, or to no energy codes at all, it is reasonable to assume that this dataset would represent the upper bound of reasonable energy consumption values for a code that applies to only the very newest homes in the RBSA sample vintage.

2. Methodology

The modeling process and selection of residential prototypes in this study remained consistent with the framework developed by the Regional Technical Forum (RTF) and the Northwest Power and Conservation Council (NPCC) for energy forecasting for the region. NEEA has used the same methodology to conduct code-to-code saving analyses in the region as well.

This study focused on single-family detached homes and modeled two housing prototypes. By focusing on the most common residential prototypes and modeling them within the state's two most populous climate zones, a representative picture of annual energy use can be characterized within Oregon's single-family sector constructed to any given code cycle.

Energy use was predicted by a combination of numerical simulations and engineering calculations. The study team used the Simplified Energy Enthalpy Model (SEEM)[3] tool to simulate heating, cooling, and ventilation energy use. SEEM combines building shell characteristics, thermostat settings, occupant behavior inputs, descriptions of heating and cooling systems, and duct distribution efficiency to develop an overall estimate of energy requirements for a house. Additionally, engineering calculations calibrated by field studies were employed to determine the energy use of other end uses such as lighting, water heating, appliances, and miscellaneous electric loads (MELs). Since appliances and MELs are the only unregulated loads in a single-family home, this value was kept constant across all modeling runs and incorporated gas and electric cooking (represented in equivalent kWh usage). The only exception is the DOE ZERH specification, which requires ENERGY STAR appliances; this scenario gave a 180 kWh/yr savings credit to the appliance end use.

This study focused on regulated loads. These end uses included building performance aspects such as heating and cooling efficiency, envelope performance, domestic hot water systems, and connected lighting. Miscellaneous electric loads were accounted for in the modeling to predict their impacts on regulated end use, but reductions in MELs are not specifically targeted since they lie outside the scope of the 60% reduction target.

This methodology is consistent with the first phase of this analysis (Odum 2020) with several specific modifications to reflect efforts to better align this analysis with current assumptions used in the development of the ORSC by the BCD. These modifications, discussed in various sections of this report, include the following:

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

- Duct leakage rate assumptions, as well as location of ductwork for 2021 ORSC "Ducts Inside" measure
- Modified assumptions about ventilation strategies for the 2017 and 2021 ORSC
- Thermostat setpoints and setbacks
- Update to furnace fan efficiencies to meet the 2020 federal standards
- Update to exhaust fan efficiencies to meet new Oregon state appliance standards

2.1. Input Assumptions

The following inputs and weightings remained constant throughout the modeling study. This provided a consistent basis upon which individual conservation measures, packages of measures, and code/DOE ZERH-compliant runs were built.

2.1.1. Prototype and Heating System Selection

The team modeled two building prototypes (with four heating systems each) and placed them within the Portland (4C) and Pendleton (5B) climate zones. This totaled 16 simulation runs for each individual measure or condition analyzed. The diversity of home foundation types, climate zones, and heating system types represent the variation in typical home energy use driven by climate impacts, foundation type, and heating system selection.

The two prototypes were both 2,200 ft^2 detached single-family homes, with one placed over a crawlspace and the other on a concrete slab. These two prototypes represent 67% of all Oregon single-family homes. Table 2 describes the building characteristics of these two prototypes and their corresponding weighting factors. The team held these characteristics constant across all modeling runs.

Table 2. Prototype Characteristics of Selected Single-Family Homes

Characteristics	2200c	2200s
Foundation	Crawl	Slab
Units	1	1
Bedrooms	4	4
Floors	1.5	1.5
Occupants per Unit	2.75	2.75
Duct Locations	Supply: Crawl Return: Attic	Supply: Attic Return: Attic
Prototype Weight	0.73	0.27

Based on the standard methodology used by the RTF, each of the two prototypes were simulated with the following four heating systems: gas furnace with central air conditioning, gas furnace with no central air conditioning, central air source heat pump (ASHP), and ductless heat pump (DHP) with electric zonal heating. The team sourced weights for the base heating systems of single-family prototypes from a combination of the field study conducted by RLW Analytics (RLW 2007) and the RBSA field study (Baylon 2012). Table 3 presents the weights for these four heating systems.

Table 3. Heating System Weights

Heating System	Gas Furnace with Central Air Conditioning (GFAC)	Gas Furnace with no Air Conditioning (GFNC)	Central Air Source Heat Pump (ASHP)	DHP with Electric Zonal Heating (ZONL/DHP)
Weights	0.53	0.29	0.09	0.09

2.1.2. Climate Zone Weighting

The weather files used in this study were composite typical meteorological year (TMY3) weather files, which correspond to the International Energy Conservation Code (IECC) climate zone maps of 4C and 5B. Based on 2000 Census data, the Portland (4C) weather file is estimated to represent 59% and the Pendleton (5B) weather file represents the remaining 41% population of the state's single-family home population.

2.1.3. Federal Minimum Equipment Efficiency Standards

An important consideration in developing predicted code savings is understanding the federal minimum equipment efficiencies upon which energy savings are calculated. Federal pre-emption precludes states from adopting heating, cooling, and domestic hot water equipment efficiency requirements that exceed federal standards. Table 4 summarizes the equipment efficiencies set in place on January 1, 2006 and January 1, 2020. For the 2005 ORSC baseline, the representative 2006 federal efficiencies were used; 2020 efficiencies levels were applied to all other code baselines.

Table 4. List of Equipment Federal Minimum Efficiency Standards

Equipment	2006 Federal Minimum Efficiency	2020 Federal Minimum Efficiency
Air Conditioner	13 SEER	13 SEER
Central Heat Pump	7.7 HSPF, 13 SEER	8.2 HSPF, 14 SEER
Gas Furnace	78% AFUE	80% AFUE
Electric Water Heater	0.90 EF	0.95 EF
Gas Water Heater	0.57 EF	0.62 EF

2.2. Comparison of 2005 ORSC, 2017 ORSC, 2021 ORSC, and DOE ZERH

Building upon the input assumptions summarized in the preceding section, the team developed modeling runs in compliance with the various code specifications. The team weighted the 16 simulation runs for each code edition or specification into two representative values (gas and electric heating source), and the difference in modeled annual energy consumption between each code cycle set the basis for the prediction of the state's code progress from the 2006 baseline (i.e., the 2005 ORSC). Table 5 compares the component performance requirements for the various codes evaluated.

The 2005 ORSC allowed residential builders to choose one of 10 prescriptive paths for compliance. This study considered all 10 pathways to be approximately equivalent in stringency. For purposes of this analysis, compliance is assumed to follow Path 1 in Table N1104.1(1). This path has no limit on glazing area (U-value of 0.4) and requires R-21 walls.

To comply with the 2017 ORSC, builders must choose two measures from Table N1101.1(2), Additional Measures. To model compliance to code, this study referenced a recently completed Oregon residential code field study for new homes conducted by NEEA and Pacific Northwest National Laboratory (PNNL). The field compliance data showed that Option A: High Efficiency HVAC System, and Option 5: Air Sealing Home and Ducts were most commonly used to meet the code requirements (Bartlett 2020).

Major changes in 2021 ORSC include requirements for improved glazing performance, more airtight construction, and better duct performance. In addition, the Additional Measures table, Table N1101.1(2), has been reworked in the 2021 code. Notable changes include:

- Move Measure 5,"envelope and duct sealing," from Additional Measures table in 2017 code to the mandatory requirements in 2021 code
- Add new measure options in 2021 code
- Reduce the number of required optional measures from two measures to a single measure.

This modeling study evaluated all the optional measures within this table and found substantial variation in expected savings among the different measures in the updated table. BCD has suggested that the baseline strategy for meeting code should utilize Option 7, which adopts a reduced window area requirement (12% of floor area), rather than assuming that Option 1, High Efficiency HVAC, is commonly adopted. Use of this pathway results in substantially increased energy use for the modeled 2021 ORSC – potentially counteracting all savings brought by the other prescriptive measures introduced in this code.

The prescriptive compliance path in DOE ZERH Rev. 06 specification limits builders to a single path of compliance for any given heating system. Therefore, the development of those simulation runs was relatively straightforward.

Since none of the ORSC codes have a mandatory requirement for duct leakage testing, typical leakage of untested and unsealed residential ductwork was assumed to be 10 cfm/100 sf (@25Pa) in 2006 (Mendon 2013). Sealing ductwork with mastic under the 2017 ORSC assumed that the overall leakage would drop to roughly 6.8 cfm/100 sf (@25Pa).[4] The 2021 ORSC included a slight performance improvement in the evaluation, and all ducts are assumed to have 5 cfm/100 sf (@25Pa) leakage to the exterior. Note that exemptions in the 2021 code allow untested ductwork to be deeply buried within the attic insulation.

The ORSC does not require builders to test the air leakage rate of the home's envelope. The assumed leakage rate has a big impact on modeled energy savings of any given code year. To model this component, this study referenced PNNL's assumption of 8 ACH50 for homes built to the 2006 IECC (Mendon 2013). For the 2017 and 2021 codes, NEEA's recently completed field study of Oregon's code compliance provides onsite measured data to incorporate for both code compliant homes and above-code homes. Therefore, this study used 5 ACH50 for the 2017 ORSC and assumed an incremental improvement to 4 ACH50 for the 2021 ORSC (Bartlett 2020).

[4] This value is consistent with the *Oregon Residential Energy Code Field Study* (Bartlett 2020).

Table 5. Modeling Input Summary for Oregon Codes and ZERH

Component	2005 ORSC	2017 ORSC	DOE ZERH Rev6[5]	2021 ORSC
Envelope				
Above Grade Wall	2x6 R-21/U-0.06[6]	2x6 int. R-21/ U-0.059	2x6 int. R-20/ U-0.06	2x6 int. R-21/U-0.059
Glazing	U-0.40, SHGC-0.4	U-0.30, SHGC-0.4	U-0.27, SHGC-0.3	U-0.27, SHGC-0.3
Window Area (% of Heated Floor Area)	16.6%	16.6%	16.6%	12%[7]
Roof (Flat Ceiling)	R-38/U-0.027	R-49/U-0.021	R-49/U-0.021	R-49/U-0.021
Floor Over Unheated	R-25/U-0.04	R-30/U-0.033	R-30/U-0.033	R-30/U-0.033
Slab-on-Grade	R-15 for 2ft	R-15 for 2ft	R-10 for 2ft	R-15 for 2ft
Doors	U-0.2	U-0.2	U-0.3	U-0.2
Airtightness	8 ACH50[8]	5 ACH50	2.5 ACH50 (Zone 4C) 2.0 ACH50 (Zone 5B)	4 ACH50[9]
Heating and Cooling[10, 11]				
Gas Furnace	Heat: 78% AFUE	Heat: 94% AFUE	Heat: 94% AFUE	Heat: 80% AFUE
Gas Furnace w/ AC	78% AFUE, 13 SEER	94% AFUE, 13 SEER	94% AFUE, 13 SEER	80% AFUE, 13 SEER
DHP w/ Elec Zonal	Elec Zonal, no cooling	10 HSPF, 13 SEER	10 HSPF, 13 SEER	8.2 HSPF, 13 SEER
Central Heat Pump	7.7 HSPF, 13 SEER	9.5 HSPF, 15 SEER	10 HSPF, 13 SEER	10 HSPF, 14 SEER

[5] All inputs presented for DOE ZERH represent measures that would need to be met or exceeded for prescriptive compliance, but do not necessarily imply mandatory requirements under the program.

[6] Per Table 1104.1(3) of the 2005 ORSC

[7] Additional Measure: 7 Glazing Area under Table N1101.1(2) of the 2021 ORSC

[8] (Mendon 2013)

[9] (Bartlett 2020)

[10] 2006 federal efficiencies are used for the 2006 baseline (2005 ORSC)

[11] 2020 federal minimum efficiencies were assumed for all current and future codes when no optional efficiency measure was selected from Table N1101.1(2)

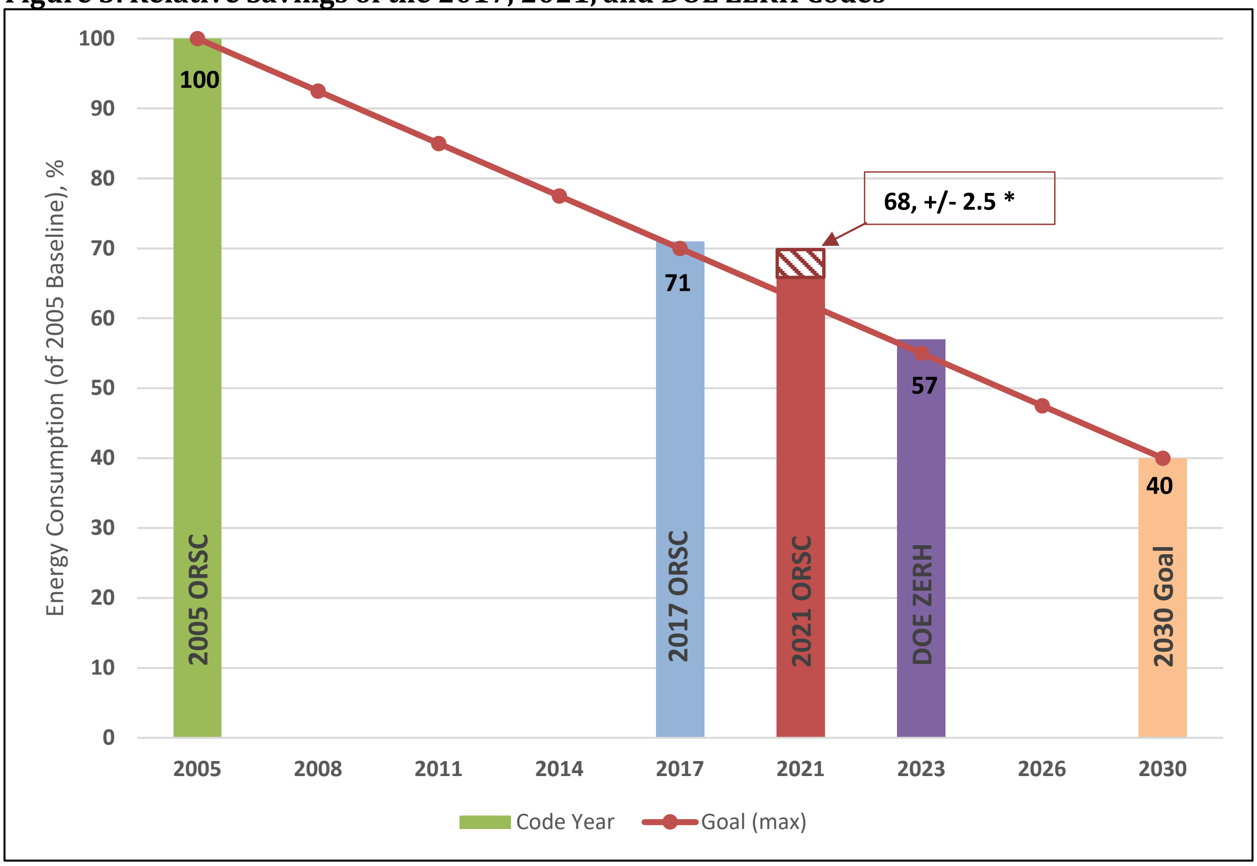
Component	2005 ORSC	2017 ORSC	DOE ZERH Rev6[5]	2021 ORSC
Vent, Ducts, and Control				
Ventilation	Exhaust fan, 0.5 cfm/W, 50 cfm Schedule: Cycle 8 hr/day	ENERGY STAR Rated fan, 2.8 cfm/W, 75 cfm Schedule: 24 hr/day	HRV, 60%SRE, 1.2 cfm/W, 60 cfm Schedule: 24 hr/day	Two (2x) ENERGY STAR Rated fans; each fan 2.8 cfm/W, 60 cfm Schedule: 24 hr/day
Duct Location	Outside conditioned space, R-8 insulation, 10cfm/100sf @ 25Pa[12]	Outside conditioned space, R-8 insulation, 6.8cfm/100sf @ 25Pa[13]	Deeply buried per End Note #16, item c (see spec for specifics), 3cfm/100sf @ 25Pa[14]	Deeply buried per Section N1105.3.3, 5cfm/100sf @ 25Pa
Thermostat	Manual, no setback (69/74)	Manual, no setback (69/74)	7-Day Programmable	Manual, no setback (69/74)
Water Heating (DHW)[15]				
Gas	0.57 EF	0.62 UEF	0.67 EF	0.62 UEF
Electric	0.90 EF	0.95 EF	2.0 EF	0.95 EF
Hot Water Consumption	Gallons/day (2.75occ): 23 +11*(#occ-1)	10% reduction over 2005 for low-flow showerheads	10% reduction over 2005 for low-flow showerheads	10% reduction over 2005 for low-flow showerheads
Lighting and Unregulated Use				
Lighting – ON: 1.8hr/day[16]	13% high efficacy[17]	95% high efficacy (LED fixtures)[18]	80% high efficacy (LED fixtures)	95% high efficacy (LED fixtures)
Appliances	Federal Minimum	Federal Minimum	EnergyStar	Federal Minimum
Plugs	2,850 kWh/yr	2,850 kWh/yr	2,850 kWh/yr	2,850 kWh/yr

12 (Mendon 2013)
13 (Bartlett 2020)
14 See DOEZER Rev.06 endnote #16.
15 Gas heated homes are assumed to have gas water heating, and electric heated homes are assumed to have electric water heating. 50-gallon tank. DHW Consumption: NEEA (2015). *Heat Pump Water Heater Model Validation Study*. Ecotope.
16 (Baylon 2012)
17 (RLW 2007)
18 Section N1107.2 exception of the 2017 ORSC allows up to two permanently installed lighting fixtures as non-high efficiency. The modeled home is assumed to have 40 installed fixtures.

3. Results and Savings Estimates

Over the eight successive code cycles (averaging three years each) in the time period between 2005 and 2030, a steady progression to the 60% reduction goal would yield approximately 7.5% of regulated energy savings per cycle. As illustrated Figure 3, the analysis shows the 2017 ORSC aligns with the state's needed progress toward the 2030 goal. However, the performance of the 2021 ORSC does not align with the trendline of consistent progress towards the 60% savings target if Option 7 (Glazing Area) in the Additional Measures table were selected to comply with the code. The DOE ZERH specification, if adopted as code in 2023, would put the state back on track to meeting the 2030 goal.

Figure 3. Relative Savings of the 2017, 2021, and DOE ZERH Codes



* *Note:* The crosshatched segment of the column for 2021 represents the range of potential savings based on whether Option 7 (Glazing Area) is selected.

3.1. Comparison of DOE ZERH and 2021 ORSC

While different modeling studies can have different assumptions about variables such as occupant density, weather files, equipment schedules, and thermostat setpoints, understanding comparative stringency requires modeling consistency across the baseline and subsequent code analyses. This analysis is focused on the differences in code language and stringencies between the various code versions, to evaluate what elements of each code version are contributing to energy savings. Table 6 attempts to simplify the comparison of the DOE ZERH and the proposed 2021 ORSC, identifying specific requirements and optional measures in each code. This comparison is independent of any variation among input data sources or modeling methodologies.

Table 6. Comparison of DOE ZERH to Proposed 2021 ORSC

Energy Measure	DOE ZERH	2021 ORSC
Space conditioning efficiency above federal minimum	Prescriptive requirement	Pick 1 optional measure from Table 1101.1(2): High Efficiency HVAC
Envelope air sealing (tested)	Prescriptive requirement	No
Water heating efficiency above federal minimum	Prescriptive requirement	Pick 1 optional measure from Table 1101.1(2): High Efficiency Water Heating
Ducts inside, tested duct leakage to exterior (LTO)	Prescriptive requirement	Requirements vague, ducts not tested (see Section 3.2 of this report)
Heat recovery ventilation	Prescriptive requirement	Pick 1 optional measure from Table 1101.1(2): Efficient Ventilation
High efficacy lighting	80%	95%

As shown above, the DOE ZERH specification requires several important energy efficiency measures, while the 2021 ORSC proposal requires only one optional measure to be selected and proposes more lenient language on several other measures. Lighting is the only end use which the proposed 2021 ORSC is clearly more stringent than the DOE ZERH specification. The comparisons in Table 6 makes it evident that the proposed 2021 ORSC is substantially less stringent than the DOE ZERH specification. For three of the measures required by DOE ZERH (grey shaded rows in Table 6), the 2021 ORSC requires only one measure to be selected from the Additional Measures table (Table 1101.1(2)).

Furthermore, a builder may instead choose the less efficient 'Reduced Glazing Area" option (Option 7 in the 2021 code) and incorporate none of the HVAC system efficiency measures.

Energy savings for these code versions and ZERH are presented in Table 7. For the 2021 code, the table includes a range of energy use and savings levels, with Option 1 (HVAC Efficiency) representing the most savings and Option 7 (Glazing Area) representing the least savings.

Table 7. Comparative Energy Savings by Code Version and ZERH, Total and Regulated (all fuel types converted to kWh equivalent and Energy Use Intensity)

Code Version	Total Energy Use (kWh/yr equivalent)	Total Energy Use Intensity EUI (kBtuh/sf/yr)	Percent TOTAL Savings over 2005	Regulated Energy Use (kWh/yr equiv.)	Regulated EUI (kBtuh/sf/yr)	Percent Regulated Savings over 2005
2005 ORSC	28,363	44.0	---	23,114	35.9	---
2017 ORSC	21,631	33.6	24%	16,381	25.4	29%
2021 ORSC	20,390 (+/- 570)	32.5 (+/- 0.9)	24-28%	15,680 (+/- 570)	24.3 (+/- 0.9)	30-34.5%
DOE ZERH	18,300	28.4	35.5%	13,230	20.5	43%
2030 Goal	14,495	22.5	49%	9,245	14.3	60%

DOE ZERH targets substantial savings in the DHW end use with required heat pump water heater deployment, and savings in cooling and heating energy use. In DOE ZERH, lighting is assumed to be worse than current code requirements due to the requirement that only 80% of the lighting must be high efficacy (compared to 95% in the 2021 ORSC).

DOE ZERH requires heat recovery ventilators, while the 2021 ORSC introduces this as an optional measure under Table 1101.1(2). Mandating balanced flow ventilation without heat recovery and without air tightness testing of the home increases the fan energy use of the ventilation system while omitting the benefits of controlling infiltration and harnessing energy recovery from the exhaust airstream.

3.2. Impacts of Proposed 2021 ORSC

A few sections of the proposed 2021 ORSC (described below) stand out as overly vague and will cause confusion, at best, as builders evaluate compliance options. At worst, builders may select the simple (cheaper) path through the code and substantial energy savings anticipated by this code will be lost.

2021 ORSC Chapter 11 Energy Efficiency—Section N1105.3 Installation/Insulation of Ducts: A major source of potential savings within the proposed 2021 ORSC is the requirement that ductwork be placed inside the heated envelope ("ducts inside"). While the ducts inside requirement brings savings, the "deeply buried" exemption allowing R-8 insulated ductwork in attics to be buried under R-19 insulation, with no limit to duct leakage, does little to ensure air leakage from the system is not lost into the attic. The study team suggests that the code follow the DOE ZERH language for deeply buried ducts (duct leakage to outdoors ≤ 3cfm25/100sf of conditioned floor area with 1.5" closed cell insulation, duct wrap, and blown-in insulation) for all climate zones.

2021 ORSC Chapter 15 Exhaust Systems—Section M1505.4 Whole-House Mechanical Ventilation Requirements: The only reference to ventilation requirements in Chapter 11 of the 2021 ORSC is through one of the options in the Additional Measures Table 1101.1(2), which allows air sealing and heat recovery ventilation as an optional path. Otherwise, the 2021 ORSC introduces the new language requiring balanced ventilation systems within the mechanical code (Chapter 15).

The new language focuses on the requirement for balanced ventilation by specifically allowing a supply fan ducted to the return side of the air handler, in conjunction with a balanced exhaust fan, to achieve whole house ventilation. While it includes an allowance for intermittent operation of the ventilation system, this study assumed ventilation to run 24/7 (in both the 2017 ORSC as well as the 2021 ORSC) and modeled the system to be entirely independent from the furnace ductwork (or other heating/cooling system). Therefore, the energy penalty applied to the 2021 ORSC requirement of balanced ventilation is conservative because it is only represented by the addition of an extra ENERGY STAR fan (2.8cfm/W) running year-round.

However, the 2021 code does not specifically disallow the furnace fan from operating as the ventilation supply fan. This approach has been widely used by builders in the region and would add a substantial fan energy penalty over the 2017 ORSC (nearly doubling the annual ventilation fan energy and adding upwards of 1.5% to the overall energy use), since the oversized furnace fan would be relied upon to move a small amount of ventilation air. Furnace controllers that manage the timing of the ventilation and/or outside air dampers are rarely set up correctly; when they fail, they can cause excessive amount of outside air to leak into the heating system. To close this potential loophole, the study team suggests BCD issue an official code interpretation indicating that the 2021 code requires a balanced ventilation system with a supply fan independent of the central furnace fan.

Unequal Stringency of the Options Table: Table 1101.1(2) Additional Measures has been updated in the 2021 ORSC. The new table in the 2021 code moves envelope and airtightness measures from the Additional Measures into the mandatory requirements and reduces required additional measures from two measures to one measure. In addition, the relative stringency among the optional measures in the new table is not equal, leading to the potential for highly varied energy performance outcomes depending on which option is selected. For example, Option 7 allows projects to limit glazing area to 12% or less of conditioned floor area—an option that was not included in the 2017 ORSC Additional Measures table. Although a home with reduced window area uses less energy compared to a home with more window area, this option allows the home to forgo other more efficient measures such as higher HAVC equipment and system efficiency with bigger energy saving impacts. In many home designs, 12% window area may not even represent a significant change to default window area. The impact of this option is further reduced by the fact that the code has already mandated the use of more efficient glazing in all cases. The energy savings associated with this measure option is substantially less than other options, and selection of this measure essentially leads to virtually no savings over the 2017 ORSC (about 1% savings). The performance variability of the different option paths is represented as a range of potential savings in Figure 3.

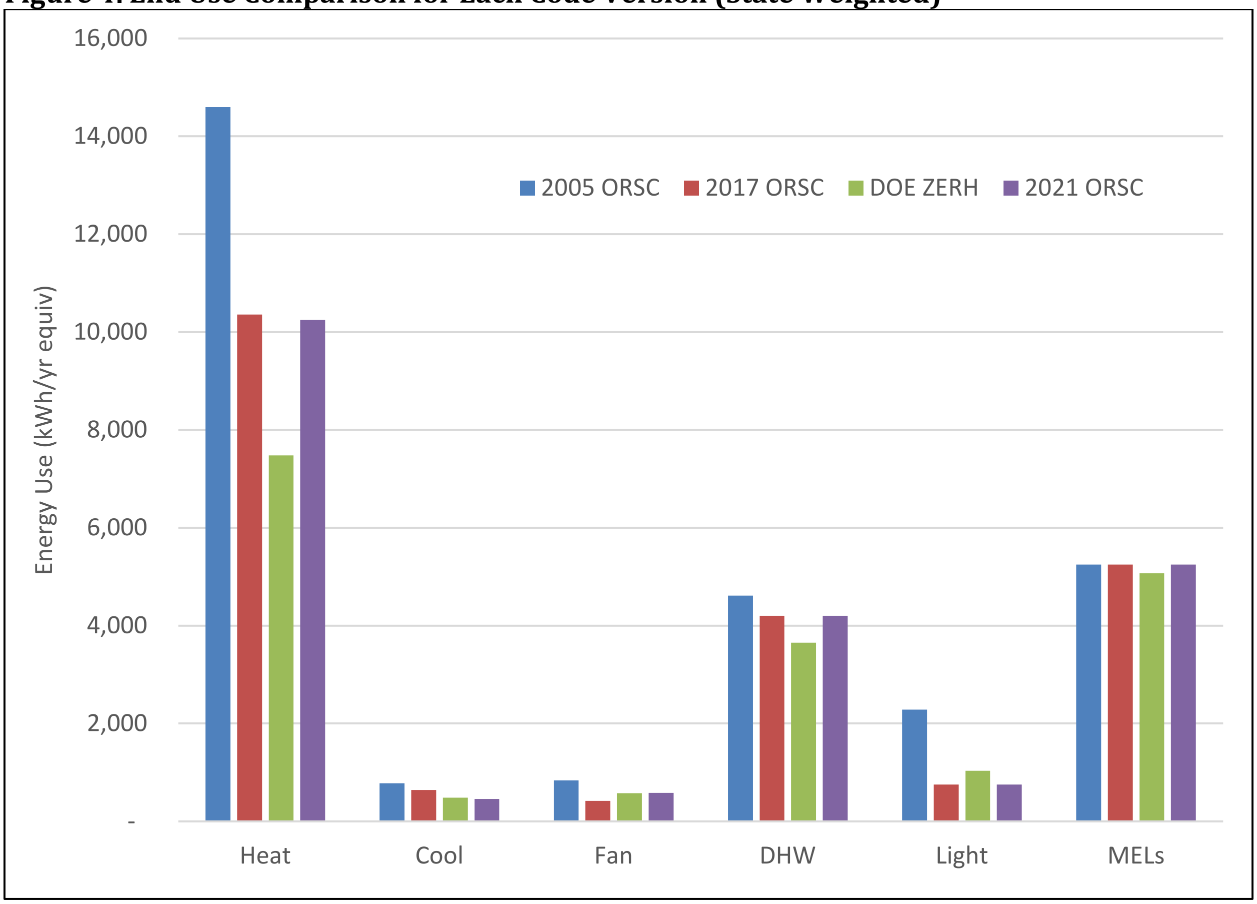
Ventilation control strategies: Chapter 15 in both the 2017 and 2021 ORSC states the ventilation system shall provide air at a continuous rate in accordance with Table 1505.4.3(1) or Equation 15-1. Introducing ventilation air 24/7 (or intermittently with airflows in accordance with Table M1505.4.3(2)) imposes added load on the home's heating/cooling system. This study has quantified this added load to be a 5% increase on the home's overall energy use; the majority of the energy increase comes from heating energy, with the fan energy increase being roughly 1%. Continuous, balanced ventilation to each living area is a key feature to building healthy homes, but it can come with a negative impact on a home's annual energy use. This highlights the importance of providing heat recovery on the ventilation air and controlling the air infiltration through the envelope.

4. Code Comparison and Roadmap

4.1. Code Comparison by End Use

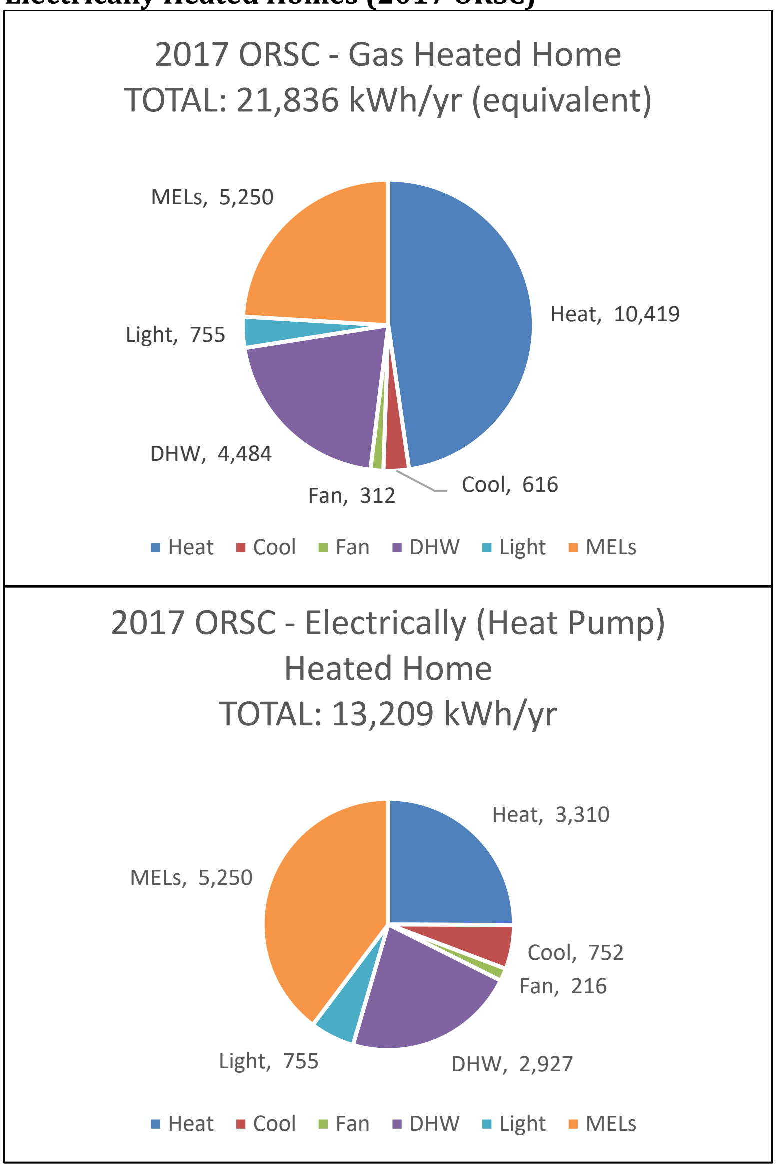
Comparing the modeled end use energy breakdown for each code version helps identify the key strategies in each code that distinguish anticipated residential performance outcomes. As highlighted in the end use breakdowns in Figure 4, the primary savings category for codes beyond 2005 ORSC comes from heating energy savings. This is the result of increases in envelope performance as well as improvements in heating system efficiency. Lighting energy savings were achieved in all codes compared to the 2006 baseline, though this represents a small portion of total energy use. This figure also illustrates that the DOE ZERH code achieves additional savings beyond the other codes considered in heating and domestic hot water (DHW) energy use.

Figure 4. End Use Comparison for Each Code Version (State Weighted)



One key issue is that for all of these code permutations, homes heated by electric heat pumps use 40% less site energy than homes heated with gas (including water heating), as represented in Figure 5 below. Weighted through the analysis, gas heating energy use represents over half of all regulated site energy use. The energy end use comparison presented in Figure 5 assumes that all 2017 gas-heated homes are installed with a gas furnace at an AFUE of 94%, above the federal minimum equipment standard of AFUE 80%. This analysis also assumes that a home with a gas furnace also has a gas water heater. The end use analysis shows that gas heated homes will need to use newly emerging technology to achieve the 60% site energy reduction goal by 2030 because higher site energy use in these homes and existing gas combustion technology cannot exceed 100% fuel efficiency. Emerging technologies such as gas-fired heat pump water heaters and more efficient envelope and ventilation strategies can help these homes achieve the 2030 goal.

Figure 5. Site Energy End Use Breakdown of Gas and Electrically Heated Homes (2017 ORSC)



4.2. Code Roadmap and 2030 Measures

To demonstrate how the Oregon code can achieve the 2030 goal for 60% site energy reduction from the 2006 baseline, this study assembled a selection of energy measures typically found in above-code homes and within stretch codes (akin to the DOE ZERH specification). Summarized in Table 8, all of these measures (except for the gas-fired heat pump water heater) are available technologies that have been successfully implemented by the building industry. For gas-fired heat pump water heaters, NEEA has conducted multiple lab and field trials validating prototype performance of up to 1.4 UEF and is driving the field demonstration of 60 near-production units installed in various climates across North America. It is expected that this technology will be available in the market soon.

The code roadmap and selection of measures expand on analysis presented in the previous study (Odum 2020) and have been augmented to provide brief insights into the measures that should be targeted within the coming code cycles in order to meet the performance goals of EO 20-04. The study team recommends that the State pursue steady progress toward the 2030 target by presenting a wide range of measures to help guide the industry to 2030. The equipment efficiencies presented in the table below do not reflect current market availability; they are instead intended to provide the range of savings delivered by the measures.

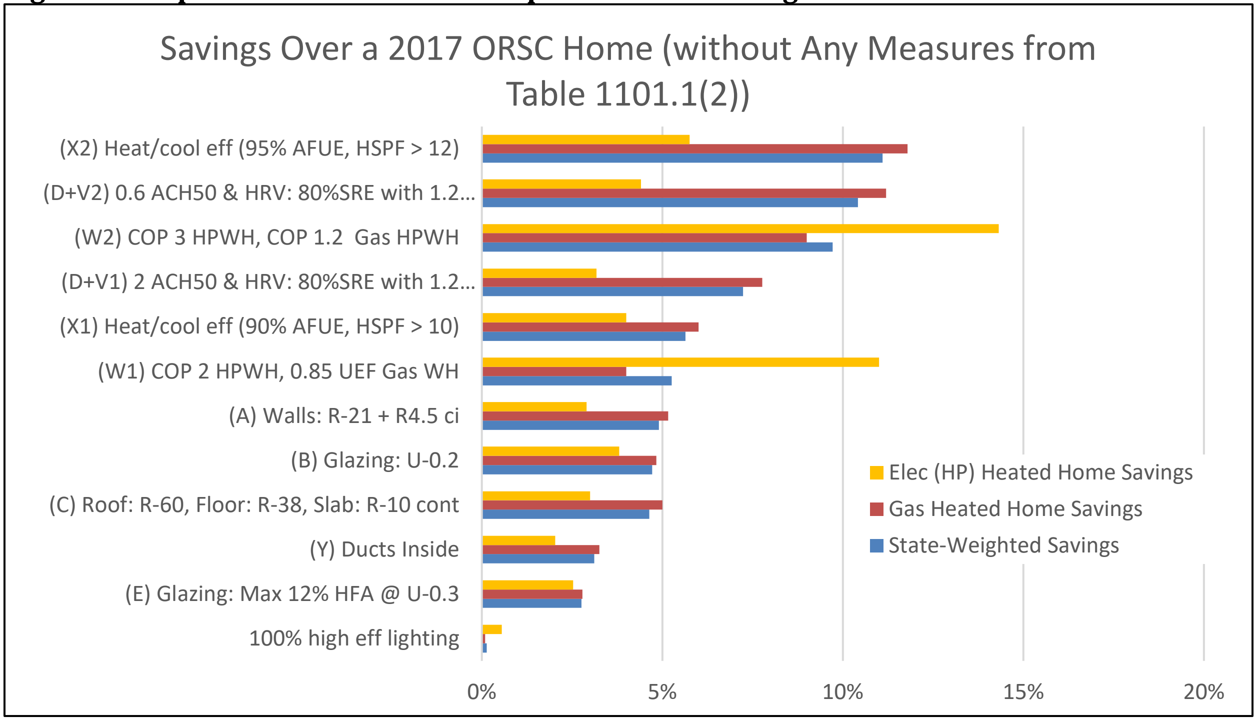
Table 8. Proposed ORSC Roadmap Measures

Envelope Measures					
A	Super-Efficient Wall	Wall U ≤ 0.045 (2x6 in. wood R-21 cavity insulation + R-4.5 cont. exterior), or equivalent			
B	Super-Efficient Window	Window U ≤ 0.21, SHGC 0.27 Skylight U ≤ 0.43			
C	Roofs & Floors	Flat Roof U ≤ 0.017 (R-60 w/ partial raised heel), or equivalent Vaulted Ceiling U ≤ 0.017 (10" structural insulated panel (SIP), or equivalent Floor over crawlspace U ≤ 0.025 (R-38 batts in floor joists), or equivalent Slab on Grade R-10 continuous rigid			
D	Air Sealing*	ACH50 ≤ 2.0 (tested) * Must be paired with HVAC measure for balanced mechanical ventilation			
E	Glazing Limit	Glazing area (frame opening) is less than 12% of floor area			
F	UA Rated	Third Party Rater Verified UA Value 1 Credit - 6% lower heat loss than code baseline 2 Credits - 12% lower heat loss than code baseline 3 Credits - 18% lower heat loss than code baseline			
HVAC Measures					
V	Balanced Heat Recovery Ventilation (HRV)*		**Tier 1**	**Tier 2**	
		Sensible Recovery Efficiency	66%	80%	
		Fan Power (cfm/W)	1.2	1.5	
W	Water Heating		**Tier 1**	**Tier 2**	
		Electric Water Heater	2.0	2.9	UEF
		Gas Water Heater	0.85	1.2	UEF
X	HVAC System		**Tier 1**	**Tier 2**	
		DHP w/Zonal ER***	9.5	11.4	HSPF
		Gas Furnace	90%	95%	AFUE
		Air Source Heat Pump	10	12	HSPF
		Ground Source Heat Pump	3.0	4.0	COP
Y	Ducts Inside	All ducts are located inside conditioned space or meet duct leakage of 3cfm/100sf @ 25Pa			

Notably, the proposed 2021 ORSC only explicitly requires selection of one measure comparable to all of those presented above. This has the potential to make future code updates more disruptive to the building industry as they will be forced to make substantial changes in a short amount of time to get back in line with a smooth code trajectory to 2030. For reference, in 2030, six or more of these measures would need to be selected to meet the 60% reduction target.

Figure 6 illustrates energy savings for each of the measures shown in Table 8, broken out by gas heat, electric (heat pump) heat, and combined state-weighted values (assuming ~80% homes heated with gas).

Figure 6. Proposed ORSC Code Roadmap Measures—Savings over a 2017 ORSC Home



As illustrated in the previous report (Odum 2020), four of the optional measures from the proposed future ORSC code (see Table 8) are needed to roughly match the energy performance equivalency of DOE ZERH specification, and therefore to meet EO 17-20. Table 9 below summarizes example packages of measures that could be assembled to meet the stepped approach to achieving the 2030 targets. The examples shown are intended to represent a least first cost approach to meeting code, but other combinations of measures are possible to achieve a similar outcome.

The bundles of measures in the 2023 and 2029 code versions in Table 9 are based on modeling conducted in this analysis. The savings and measure package in the 2026 code version represents a potential interim package of measures that would achieve a savings level approximately in line with the savings target listed in the table and aligned with the code performance trajectory identified between 2006 baseline and the 2030 performance target. All packages of measures were modeled to capture interactive effects of individual measures, and savings are cumulative over the 2005 ORSC baseline.

Table 9. Example Measures for 2023, 2026, and 2029 ORSC

Code Year	Target Savings Percentage (over 2005 ORSC)	Home Fuel Type	Example measures to be added to code to meet target savings percentage (see detailed labels in Table 8)
2023	45%	Electric (HP)	• Tier 1 HVAC • Tier 1 DHW • Air Sealing with Tier 1 Ventilation • Ducts Inside
		Gas	• Tier 1 HVAC • Tier 1 DHW • Air Sealing with Tier 1 Ventilation • Ducts Inside
2026	53%	Electric (HP)	• Tier 2 HVAC • Tier 1 DHW • Air Sealing with Tier 1 Ventilation • Ducts Inside • Super Windows • Super-Efficient Walls
		Gas	• Tier 2 HVAC • Tier 1 DHW • Air Sealing with Tier 1 Ventilation • Ducts Inside • Super Windows • Super-Efficient Walls
2029	60%	Electric (HP)	• Tier 2 HVAC • Tier 2 DHW • Air Sealing with Tier 2 Ventilation • Ducts Inside • Super Windows • Super-Efficient Walls
		Gas	• Tier 2 HVAC • Tier 2 DHW • Air Sealing with Tier 2 Ventilation • Ducts Inside • Super Windows • Super-Efficient Walls

Code improvements can also be viewed by examining how interim measure stringencies might be adopted to move between the 2021 code and the 2030 targets. The degree to which any of these measures summarized in Table 10 on the following page should be prioritized might depend on whether it is desirable for codes to once again align with long-term stringency goals, as discussed above.

Note that not every measure lends itself to incremental improvements, but interim codes may choose to target some individual measures to move ahead to 2030 targets. Also note that certain strategies include a significant change in practice along the way, as opposed to discrete incremental improvements. For example, requiring continuous insulation on exterior walls represents a significant change in construction practice, while the actual incremental value of the insulation required in this assembly is of less consequence.

Table 10. Comparison of Measures and Strategies to Reach 2030 Goal

	2005 ORSC	2021 ORSC	Notes on Interim Strategies	2030 Potential Strategies
Envelope				
Above Grade Wall	2x6 R-21	2x6 int. R-21	Adding continuous insulation (ci) is a big change. Incremental value of ci is less impact	2x6 R-21+4.5 ci
Glazing	U-0.40	U-0.27	Thin triple-pane glazing with affordable cost and available supply chain	U<=0.21
Glazing Area	No limit	Max 16.6% HFA; one pathway limits glazing to 12%	Modify options pathways to encourage glazing reductions in several pathways	Max 12% HFA
Roof (Flat Ceiling)	R-38	R-49		R-60
Floor Over Unheated	R-25	R-30		R-38
Airtightness	8 ACH50	4 ACH50	Widespread testing requirements would support this strategy	≤ 2 ACH50
HVAC				
Gas Furnace	Heat: 78% AFUE	Heat: 94% AFUE	Limited by federal pre-emption	Heat: 95% AFUE
Heat Pumps	7.7 HSPF, 13 SEER	10 HSPF, 14 SEER	Limited by federal pre-emption	12 HSPF, 14 SEER
Ventilation	Exhaust fan, 0.5 cfm/W, 50 cfm, Cycle 8 hr/day	Balanced Ventilation, no heat recovery	Adopt HRV requirements as soon as possible	HRV, 80%, >1.5 cfm/watt
Duct Location	Ducts outside, R-8, 10cfm/100sf leakage	Ducts deeply buried, 5cfm/100sf leakage		Ducts inside heated envelope
Thermostat	Manual, no setback (69/74)	Manual, no setback (69/74)	Smart thermostats	
Gas	0.57 EF	0.62 UEF	Opportunity for the gas-fired heat pump water heater	NEEA Tier 3 (UEF >1.3)[19]
Electric	0.90 EF	0.95 EF	Encourage adoption of HPWH technologies	NEEA Tier 4 (COP 3.0)[15]
Lighting and Appliances				
Lighting	13% high efficacy	95% high efficacy (LED fixtures)	Not much additional savings opportunity	100% high efficacy (LED fixtures)
Appliances	Federal Minimum	Federal Minimum		ENERGY STAR

[19] Advanced Water Heater Specification for Gas-Fueled Residential Storage Water Heaters, published by NEEA

5. Conclusions

This analysis has established a baseline for the 2006 residential code in Oregon. This baseline is based on the requirements of the 2005 ORSC and is cross-calibrated with RBSA field data, as recommended by DOE protocols. The key modeling inputs have been coordinated with BCD and Oregon Department of Energy and were presented at Oregon's Code Stakeholder Panel Meetings.[20] Establishing the 2006 baseline represents a foundation to evaluate the stringency and track the progress of future versions of the residential energy code in Oregon. Several subsequent energy code versions have been compared to this baseline to better understand the progress that has been made toward the goals identified in Executive Order 20-04, which sets a target of a 60% site energy use reduction in regulated energy use in the residential sector by 2030.

The proposed 2021 ORSC represents a key area of focus, with respect to its requirements and stringency compared to the DOE ZERH specification and other Oregon code cycles. Modeling has shown that the 2021 ORSC may not achieve enough savings to remain on the straight savings trajectory if Option 7 (reduced glazing area) is selected. Subsequent adoption of many of the DOE ZERH requirements in the 2023 code cycle could help align the code progress once again with the desired trajectory.

In all code analyses, the assumed HVAC system weighting across the state remained constant. The current distribution is based on recent field studies identifying which type of systems are most commonly installed in Oregon for new homes. System choice has a huge impact on overall site energy use in both heating and hot water systems. Changes in market preference among these systems have a significant impact on the success or failure of the code to achieve 2030 goals; therefore, studies such as this should be completed with the most current building stock information as the State progresses toward its 2030 goals.

The analysis was also able to identify a set of prescriptive strategies that could achieve the 60% regulated energy reduction goal. These strategies build upon the prescriptive approach currently used in the 2017 code but significantly expand the current option table. Through interim code cycles, additional measures could either be adopted and required within the prescriptive portions of the code, or kept within an optional table format. Modeling the proposed 2021 ORSC makes clear that more energy conservation measures, and significantly increased stringency, are needed to move the market toward the Governor's 2030 goal.

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[20] Oregon Energy Code Stakeholder Panel Meeting, July 15, 2020. https://www.oregon.gov/energy/Get-Involved/Pages/Energy-Code-Stakeholder-Panel.aspx

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Appendix A: Detailed Modeling Results

System types: DHP = electric zonal w/ ductless heat pumps, ASHP = Air-source (central air) heat pump, GFAC = gas furnace with air conditioning, GFNC = gas furnace without air conditioning

Base Code	HVAC System	Heat (kWh)	Heat (therm)	Cool (kWh)	Fan (kWh)	DHW (kWh)	DHW (therm)	Light (kWh)	MELS	Total kWh	Total therm	Equivalent TOTAL kWh	EUI
ORSC2005	DHP	10587	0	0	605	3414	0	2287	5250	22142	0	22,142	34.4
ORSC2005	ASHP	4728	0	1262	1291	3414	0	2287	5250	18231	0	18,231	28.3
ORSC2005	GFAC	0	552	1256	892	0	166	2287	5250	9685	718	30,728	47.7
ORSC2005	GFNC	0	548	0	662	0	166	2287	5250	8198	714	29,118	45.2
2017OSRC	DHP	3833	0	582	248	2927	0	755	5250	13594	0	13,594	21.1
2017OSRC	ASHP	3646	0	929	422	2927	0	755	5250	13928	0	13,928	21.6
2017OSRC	GFAC	0	405	957	447	0	153	755	5250	7408	558	23,772	36.9
2017OSRC	GFNC	0	399	0	427	0	153	755	5250	6432	552	22,603	35.1
DOE ZERH6	DHP	2898	0	469	448	1390	0	1035	5070	11311	0	11,311	17.5
DOE ZERH6	ASHP	2556	0	694	570	1390	0	1035	5070	11315	0	11,315	17.6
DOE ZERH6	GFAC	0	292	720	593	0	142	1035	5070	7419	434	20,136	31.2
DOE ZERH6	GFNC	0	288	0	577	0	142	1035	5070	6682	430	19,282	29.9
2021ORSC	DHP	4479	0	353	389	2927	0	755	5250	14153	0	14,153	22.0
2021ORSC	ASHP	3222	0	638	696	2927	0	755	5250	13487	0	13,487	20.9
2021ORSC	GFAC	0	398	701	619	0	153	755	5250	7324	552	23,484	36.4
2021ORSC	GFNC	0	396	0	538	0	153	755	5250	6543	549	22,638	35.1
2029ORSC	DHP	2906	0	408	450	927	0	662	5250	10603	0	10,603	16.4
2029ORSC	ASHP	2115	0	790	660	927	0	662	5250	10404	0	10,404	16.1
2029ORSC	GFAC	0	208	769	622	0	79	662	5250	7303	287	15,707	24.4
2029ORSC	GFNC	0	206	0	539	0	79	662	5250	6450	286	14,817	23.0