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2018 Washington Residential Code Energy Savings Analysis

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GLOSSARY OF ACRONYMS

ACH50	air changes per hour at 50 pascals pressure
AFUE	Annual Fuel Utilization Efficiency
AHRI	Air-Conditioning Heating and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
CEE	Consortium for Energy Efficiency
CFL	compact fluorescent lamp
cfm	cubic feet per meter
Council	Northwest Power and Conservation Council
DHP	ductless heat pump
DHW	domestic hot water
DWR	drain water heat recovery
ES	Energy Star
EUI	Energy Use Intensity
ft	foot
gfac	gas furnace and air conditioning
gfnc	gas furnace no air conditioning
GSHP	ground source heat pump
HP	heat pump
HPWH	heat pump water heater
HSPF	Heating Seasonal Performance Factor
HRV	Heat Recovery Ventilators
HVAC	Heating, Ventilation and Air Conditioning
IECC	International Energy Conservation Code
ISO	International Organization for Standards
kWh	kilowatt-hour
NAECA	National Appliance Energy Conservation Act
NEEA	Northwest Energy Efficiency Alliance
NPCC	Northwest Power and Conservation Council

ORSC	Oregon Residential Specialty Code
RBSA	Residential Building Stock Assessment
RTF	Regional Technical Forum
SBCC	Washington State Building Code Council
SEEM	Simple Energy and Enthalpy Model
SEER	Seasonal Energy Efficiency Rating
sqft	square foot
TMY	Typical Meteorological Year
UA	building heat loss expressed as U-value times area
UEF	Uniform Energy Factor
VIAQ	Washington State Ventilation and Indoor Air Quality Code
W	watt
WSEC	Washington State Energy Code
WSEC-R	Washington State Energy Code Residential provisions

Executive Summary

For more than 30 years, the Pacific Northwest has successfully pursued state residential energy codes and building programs to create ever more efficient housing. Since its inception, the Northwest Energy Efficiency Alliance (NEEA) has played a pivotal role in aiding states to deliver more effective and efficient energy codes. NEEA contracted Ecotope to estimate the energy savings of the 2018 Washington State Energy Code residential provisions (WSEC-R) compared to the 2015 and 2006 WSEC-R codes, as well as the 2018 International Energy Conservation Code (IECC).

The study objectives included:

- Baseline the energy end uses and energy use intensity (EUI) in all four codes.
- Estimate electric and gas savings of the newly adopted 2018 WSEC-R by comparing it to the previous 2015 WSEC-R and 2006 WSEC-R codes as well as the 2018 IECC.
- Update incremental cost information from code proposal estimates to identify incremental costs of measures and packages in the current code analysis.

Comparison of 2015 and 2018 WSEC Residential Provisions

The general structure of the 2015 and 2018 WSEC-R is similar; however, a fuel normalization credit table was added to Section R406 and several significant changes were made to the options table in the 2018 code, including: increased number of optional measures, updated points values for many options, and credits specific to multifamily occupancy. In addition, the newly adopted code increased the number of required credits. In brief, the points went from 3.5 points in 2015 to 6.0 points in 2018 for medium-sized units, which is the size of most new construction single family homes. The requirements for small homes (<1500 sqft) increased from 1.5 points to 3.0 points; large homes (>5000 sqft) increased from 4.5 points to 7 points.

Table 9 in Appendix A shows the points requirements in more detail.

Water saving plumbing fixtures have historically been an option in the WSEC-R but is now mandated through state appliance standards and removed from the energy code options. Another change of note to the 2018 state codes is the requirement within the mechanical code for balanced flow ventilation with heat recovery for multifamily units[1].

Energy Impacts

The energy use and savings estimates are based on simulations and engineering models. This analysis assumes that all prototypes are 100% compliant with each code version evaluated. Therefore, this analysis is likely to produce an upper bound of code energy savings impact. After the new code takes effect, NEEA will conduct the residential code field study to evaluate implementation in newly constructed homes and determine the actual compliance rate.

[1] International Mechanical Code Section 403.4.4.1

Table ES1 gives the estimated energy use by end use for each of the codes modeled in this analysis, while Table ES2 shows the energy use intensity, total energy use, and estimated savings for each code version. The estimates are a weighted average of all construction types, heating system types, and climates. Estimates considering both the electric and gas site savings separately are included in the report.

Table ES1: Energy Use by End Use

Code	Heat (kWh Equivalent)	Cool (kWh)	Fan (kWh)	Light (kWh)	DHW (kWh)	Appliances and Plugs (kWh)	Total (kWh)	Total (therms)
WSEC-R 2006	11901	171	540	1697	4216	3849	8419	476
WSEC-R 2015	7651	160	327	969	2966	3849	6623	317
WSEC-R 2018	4753	125	381	727	2650	3366	5588	232
IECC 2018	9788	121	340	727	3821	3849	6904	401

Table ES2: Overall Energy Use Intensity (EUI), Total Energy Use (kWh Equivalent) and Percent Savings

Code	EUI (kBTU/sqft)	Total (kWh Equivalent)	Percent savings compared to 2006 WSEC-R
WSEC-R 2006	41	22374	---
WSEC-R 2015	29	15922	29%
WSEC-R 2018	23	12386	45%
IECC 2018	34	18646	17%

The analysis shows that the 2018 code achieves on average 22% site energy savings from the 2015 code, 45% site energy savings from the 2006 baseline code and 33% site savings from the 2018 IECC.

Cost Impacts

In addition to estimates of energy use and savings, the analysis estimated incremental costs for the most recent round of the WSEC change from 2015 to 2018. Table ES3 provides estimates of weighted average incremental construction costs per single-family and multifamily unit built to the 2018 WSEC-R, which typically include envelope measures, duct sealing, house sealing, heating, ventilation, and cooling (HVAC) and/or water heating equipment upgrades per the options in R406.

Table ES3: Average Incremental Costs (per Unit)

		2015 to 2018 Cost Increase
Single-Family	2015 $s	$9,879
Multifamily	2015 $s	$1,870

These cost increases correspond to a 22% energy savings from 2015 WSEC. In this way, incremental costs due to energy code improvements are frequently offset by energy savings to the homeowner or resident making energy efficient homes attractive to prospective home buyers or renters.

1. Introduction

Over the past thirty-plus years, the Pacific Northwest has successfully pursued state residential energy codes and building programs to create ever more efficient housing. Since its inception, Northwest Energy Efficiency Alliance (NEEA) has played a pivotal role in aiding states to deliver more effective and efficient energy codes. NEEA contracted Ecotope to estimate the energy savings of the 2018 Washington State Energy Code residential provisions (WSEC-R) compared to the 2015 and 2006 WSEC-R codes, as well as the 2018 International Energy Conservation Code (IECC).

Specifically, the study objectives included:

- Baseline the energy end uses and energy use intensity (EUI) in all four codes.
- Estimate electric and gas savings of the newly adopted 2018 WSEC-R by comparing it to the previous 2015 WSEC-R and 2006 WSEC-R codes as well as the 2018 IECC.
- Update incremental cost information from code proposal estimates to identify incremental construction costs of measures and packages in the current code analysis.

Ecotope estimated the site energy use and savings for units built under the 2018 WSEC for residential buildings. The energy use is compared against the 2015 and 2006 residential WSEC, as well as the 2018 IECC. The 2015 and 2018 WSEC use the same baseline specifications and require energy credit points (Section R406 in the codes) based on various upgraded measures, with the 2018 code requiring more points than the 2015 code. Details about the 2015 and 2018 WSEC can be found in Appendix A.

Ecotope developed a picture of the new construction markets in Washington using the WSEC specifications and housing characteristics surveys. The analysis was constructed to produce energy use and savings for a given unit using four different space conditioning systems in typical heating and cooling climates. The energy end-uses considered in the house were space heating, space cooling, ventilation, domestic water heating, lighting, and plug loads. The analysis compared the energy use and savings for single-family and low-rise multifamily units (3-stories or less).

Incremental construction costs developed during the code development effort were sourced for this study, and the total incremental costs for the modeled R406 compliance pathways for single-family and multifamily units have been updated. These pathways capture changes to the code including the fuel normalization table and added credits for medium-sized homes, which were approved after the base analysis for the 2018 code was completed.

Cost analyses assume that incremental costs of each option are independent of one another. It should be noted that as buildings become more efficient some interdependency in costs can be expected. For example, more efficient envelope insulation and tighter construction leads to smaller HVAC systems, and therefore a cost credit could be applied in future analyses.

2. Methodology

The methodology for this code analysis follows previous code analyses with some updates in data sources and processes. The full details of the methodology are given in the following sections, including a discussion about the code changes, the modeling approach, baseline assumptions, weather and prototype weighting schemes, and the treatment of the options table.

2.1. Comparison of 2006, 2015, and 2018 Washington Code Provisions

The 2006 residential Washington State Energy Code (WSEC-R) mandated prescriptive requirements by climate zone for new residential construction. In 2008, the Washington State Legislature set a goal for the Washington State Energy Code (WSEC-R) to reduce the overall energy consumption of new residential buildings to 70% of WSEC 2006 levels by the 2030 code revisions. Additionally, the legislature mandated that the WSEC be re-designed to be a part of the IECC.

Since 2012 the structure of the WSEC is essentially taken from the IECC and many of the provisions are translated from this national model code. The most notable difference is the use of an "option table" that was developed in the 2009 WSEC and implemented in 2011. The option table requirements (Section R406) are adjusted in each code cycle to improve energy performance design over the previous code.

For the 2018 code, major updates to Section R406 include: increased number of optional measures, updated points values for many options, credits specific to multifamily occupancy, and a fuel normalization credit table was added. In addition, the newly adopted code increased the number of required credits:

- Small homes (<1,500 sqft): from 1.5 to 3.0 credits
- Medium homes: from 3.5 to 6 credits
- Large Homes (>5,000 sqft): from 4.5 to 7 credits
- Low-rise Multifamily: from 2.5 to 4.5 credits

Another change of note to the 2018 state codes is the requirement for balanced flow ventilation with heat recovery for multifamily units. While this requirement is primarily within the mechanical code, this has a substantial impact on energy use in this building type and has been captured in this analysis. Water saving plumbing fixtures are now mandated through state appliance standards, and removed from the energy code options, but these have been assumed to be installed in all new 2018-compliant homes.

Ecotope evaluated all codes and standards within the same analytical context, updating older analyses as needed, so the results are internally consistent. The energy use and savings estimates are based on simulations and engineering models calibrated to measurements at various points. In this way, the compliance rates with the building codes were assumed to be 100%. Therefore, this analysis is likely to produce an upper bound of energy savings as suggested by recent studies on code compliance and realization rates (Flynn and Caudill 2020).

By referencing state building energy codes and housing characteristics surveys Ecotope developed a picture of the new construction markets in Washington. The analysis was constructed to produce energy use and savings for a given unit using one of four space conditioning systems in each climate. The energy end-uses considered in the house were: space heating, space cooling, ventilation, domestic water heating, lighting, and plug loads.

2.2. Energy Use and Savings Analysis

Broadly, the analysis methodology develops a representative set of prototypical houses whose energy use can be estimated through the Simplified Energy and Enthalpy Model (SEEM) simulation tool. These representative characteristics include climate, occupancy, house size, ground contact type (slab, crawl, or basement), and heating and cooling system type.

2.2.1. Modeling Approach

The building energy use was predicted by a combination of numerical simulations and engineering calculations. SEEM was used to simulate heating, cooling, and ventilation energy use. The program 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 of a house. Additionally, engineering calculations calibrated by field studies were employed to determine the energy use for lighting, water heating, and plug loads.

SEEM (version 0.98) is a residential energy-simulation program that was developed by and for the Northwest Power and Conservation Council (Council) and the Northwest Energy Efficiency Alliance (NEEA). It is the simulation engine used to provide heating and cooling energy savings estimates for the residential sector in the Northwest Power Plan as well as numerous utility program offerings. SEEM is also used extensively to support state building energy code revisions.

The SEEM program consists of an hourly thermal, moisture (humidity), and infiltration simulation that interact with ducts, equipment, building shell and weather parameters to calculate the space conditioning requirements of the building. It is based on algorithms consistent with current American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), Air-Conditioning, Heating, and Refrigeration Institute (AHRI), and International Organization for Standards (ISO) calculation standards. The simulation generates outputs used in this analysis; they include building heat loss (UA), heating equipment input energy, cooling equipment input energy, and ventilation equipment input energy.

2.2.2. Weather and Climate Zones

The weather files used in all savings simulations are composite typical meteorological year (TMY) weather files corresponding to the heating and cooling climate zones used by the Council. The current analysis focused on the Seattle and Spokane climates and used NWHZ1CZ1 (Seattle) and NWHZ2CZ2 (Spokane) weather files. Table 16 and Table 11 in the Appendix lists the climate zone weights and the breakdown of single-family and multifamily.

2.2.3. Building Prototypes

Three distinct building prototypes were used in the single-family SEEM simulations: a 1344 sqft ranch style home, a 2200 sqft split level home, and a 2688 sqft home which includes a fully conditioned basement. These are standard analytical prototypes used by the Council to develop and evaluate energy forecasts and conservation plans for the region's utilities. The prototypes and some selected prototype characteristics are listed in Table 8 of the Appendix.

The 1344 sqft and 2200 sqft prototypes are split into crawl space and slab-on-grade construction. Next, each prototype is assigned a weight in proportion to its frequency of occurrence in the building population. The weights used in previous code evaluations were maintained and normalized by the included prototypes. By creating a weighted average of prototypes, a single estimate is made to represent the energy use of constructing a new house in the various climates. Accounting for the different ground contact possibilities there are five prototypes used to describe a single-family house (1344 crawl and slab, 2200 crawl and slab, 2688 basement).

A single prototype was developed to represent the low-rise multifamily sector, as covered by the residential code. The prototype is a 9840 sqft apartment building, with 12-units (820 sqft each), three stories with a crawlspace foundation, and no internal circulation (i.e., walk-up units). This prototype is not a Regional Technical Forum (RTF) prototype, but was developed for this analysis as RTF-approved 952 sqft multifamily prototype has slightly larger average unit sizes observed in both the newest Residential Building Stock Assessment (RBSA; NEEA 2019) and the recently completed DOE Low-rise Multifamily study (Davis 2020).

Each single-family prototype was run with four heating and cooling systems based on the standard methodology used for the Council analysis. The four base systems are gas furnace with no central air conditioning, gas furnace with central air conditioning, central heat pump, and electric zonal heating (with ductless heat pumps for heating and cooling for WSEC-R 2015-2018). Multifamily prototypes were only modeled with electric zonal heating systems, except for WSEC-R 2015 compliant homes, when a DHP measure was selected. HVAC system weights and details about the mechanics of developing the system weightings can be found in the Appendix.

2.3. Input Assumptions and Baselines

2.3.1. Code Changes

In general, code changes include prescriptive requirements of envelopes. lighting, water heating, and heating/cooling efficiency. Prescriptive HVAC and water heating efficiencies are federally mandated (and discussed further in Section 2.3.2). Although there have been requirements for increased equipment efficiency since 2006, all prescriptive equipment efficiencies were assigned the current federal standard to isolate savings based on the state energy code requirements.

Table 1 (on page 10) summarizes the prescriptive requirements for each of the codes included in this analysis. Since the 2006 WSEC-R, Washington has made changes to thermal envelope insulation and air tightness requirements, with additional varying changes to windows, floors, slabs and air sealing required through Section R406 in more recent (2015 and 2018) codes.

Additional code changes include increased duct sealing requirements for those houses with forced air systems and increasing requirements for high efficacy lamps.

Per state appliance efficiency standards, low-flow water fixtures are now mandated. This credit was removed from the code during the 2018 code update but the energy savings still honored through this modeling exercise through reduced annual hot water use.

As summarized in Section 2.1, the WSEC-R Section R406 options table outlines energy efficiency improvements beyond the prescriptive requirements. Each home must also implement some combination of options to fulfill energy credit requirements. These 'options' are not summarized in Table 1, but are discussed in more detail in Section 2.3.3.

2.3.2. Baseline and Measure Assumptions

Equipment efficiency baselines are set by the National Appliance Energy Conservation Act (NAECA). The WSEC includes options that allow added measures that exceed the NAECA standard; the use of these options is discussed in Section 2.3.3. The improved equipment efficiencies used in this analysis are listed in Table 12 and Table 13 of the Appendix.

The prescriptive energy codes included in this analysis spanned several iterations of efficiency improvements in federal requirements. However, when working with the federal minimum efficiencies, each of the modeled codes in this analysis is assigned the same minimum standard equivalent to current year federal requirements (as reflected in the 2018 WSEC-R details of Table 1). This allows a summary of just the code impact without including federal equipment efficiency impacts in the analysis.

High efficacy lamps were modeled as CFLs in this analysis. Lighting energy calculations were done using a lighting power density method corresponding to the level of regular and high efficacy lights required by the codes. This method assumes all lamps in the house operate 1.8 hours per day throughout the year.

Water heating energy was calibrated to the equivalent of [23+11(#occ-1)] gallons per day per occupant (Larson et al. 2015). Single-family occupancy is 2.4 people/house (small homes) and 2.8 people/house for medium homes. Multifamily occupancy is 1.9 people/house, taken from the RBSA Multifamily Report (Baylon et al, 2013). The loads not regulated by the code, including appliances and plug loads, correspond to historical analyses, which used 4000 kWh for single-family homes. Low-rise multifamily were assessed at 3167 kWh per unit.

2.3.3. WSEC Options Tables

The WSEC provides a challenge for the analysis compared to other state energy codes. Since the 2009 WSEC, the code specifies a set of prescriptive building requirements and a list of additional measures. The builder must select several items from the optional measure list to meet the total point requirement for the given code year.

Table 9 in the Appendix lists the total points required by code year and by building type. In 2018, an additional credits table to normalize between fuels was added to the WSEC (Table R406.2). The sum of energy options credits and fuel normalization credits is assessed to meet the requirements of the 2018 WSEC-R.

For the code years in this analysis requiring compliance with additional credits (WSEC-R 2015 and 2018), a least-cost path (i.e., the lowest construction cost) was assigned to each of the prototypes based on code year, building type, and floor area. WSEC-R 2015 options were sourced from a recent NEEA field study assessing the 2015 code (Flynn and Caudill 2020), which found equipment efficiency upgrades and affordable envelope measures were most prevalent. Comparable pathways, allowing for increased credits where required, were selected for 2018 homes. Future field studies of homes built under WSEC-R 2018 requirements will be useful in understanding the common prescriptive pathways used by builders under the most recent residential energy code. Summaries of the pathways chosen for 2015 and 2018 homes are available in Table 12 and Table 13, respectively. WSEC-R 2006 and IECC 2018 homes were modeled based on prescriptive compliance requirements (summarized in Table 1).

Modelling results of compliant homes for each of the four included codes were then weighted to calculate energy use and savings summaries by each of the included codes, and single-family and multifamily savings details. Weighting schemes are discussed in the weighting section of the Appendix.

Table 1. Prescriptive Modeling Input Summary for all Codes (excluding Section R406 measures – See Table 12 and Table 13)

Component	**2006 WSEC-R**	**2015 WSEC-R**	**2018 WSEC-R**	**2018 IECC**
	Envelope			
Above Grade Wall	2x6 int. R-21 (4C) / R-19adv+5 (5B)	2x6 int. R-21	2x6 int. R-21	2x6 int. R-20
Glazing	U-0.35	U-0.30	U-0.30	U-0.30, SHGC-0.40
Roof (Flat Ceiling)	R-38	R-49	R-49	R-49
Floor Over Unheated	R-30	R-30	R-30	R-30
Slab-on-Grade	R-10 for 2ft	R-10 for 2ft	R-10 for 2ft	R-10 for 2ft
Doors	U-0.2	U-0.3	U-0.3	U-0.3
Air-tightness	7 ACH50	5 ACH50	5 ACH50	3 ACH50
	Heating and Cooling[2]			
Gas Furnace	Heat: 80% AFUE	Heat: 80% AFUE	Heat: 80% AFUE	Heat: 80% AFUE
Gas Furnace w/ AC	80% AFUE, 14 SEER	80% AFUE, 14 SEER	80% AFUE, 14 SEER	80% AFUE, 14 SEER
DHP w/ Elec Zonal	8.2 HSPF, 14 SEER	8.2 HSPF, 14 SEER	8.2 HSPF, 14 SEER	8.2 HSPF, 14 SEER
Central Heat Pump	8.2 HSPF, 14 SEER	8.2 HSPF, 14 SEER	8.2 HSPF, 14 SEER	8.2 HSPF, 14 SEER
	Vent, Ducts & Control			
Ventilation	Exhaust fan, 0.86 cfm/W, Airflow per VIAQ[3], Schedule: Cycle 4 hr/day Multifamily Schedule: 24 hr/day	Exhaust fan, 1.4 cfm/W, Airflow per ASHRAE 62.2, 8 hr/day Multifamily Schedule: 24 hr/day	Single-family: Exhaust fan, 1.4 cfm/W, 8hr/day Multifamily: HRV required, min 60%SRE, 1.0 cfm/W, Airflow per ASHRAE 62.2, 24 hr/day	Exhaust fan, 2.8 cfm/W, Airflow per ASHRAE 62.2, 8 hr/day Multifamily Schedule: 24 hr/day

[2] Current federal equipment efficiency standards are used for all codes as reflected in the 2018 WSEC-R details. This keeps equipment efficiencies consistent across prescriptive code requirements. Note, an equipment efficiency measure has been selected for the majority of WSEC-R compliance paths.

[3] Washington State Ventilation and Indoor Air Quality Code (VIAQ)

Component	2006 WSEC-R	2015 WSEC-R	2018 WSEC-R	2018 IECC
Duct Location	Ducts outside, R-8 insulation, 12cfm/100sqft @ 25Pa	Ducts located outside conditioned space, R-8 insulation (4cfm/100sqft @ 25Pa)	Ducts located outside conditioned space, R-8 insulation (4cfm/100sqft @ 25Pa)	Ducts located outside conditioned space, R-8 insulation (4cfm/100sqft @ 25Pa)
Thermostat	7-Day Programmable	7-Day Programmable	7-Day Programmable	7-Day Programmable
	Water Heating (DHW)[1, 4]			
Gas	0.57 UEF	0.0.57 UEF	0.57 UEF	0.57 UEF
Electric	0.92 UEF	0.92 UEF	0.92 UEF	0.92 UEF
Hot Water Consumption	Gallons/day: 23 +11*(#occ-1)	Same as WSEC-R 2006	10% reduction over 2006 for low-flow showerheads	10% reduction over 2006 for low-flow showerheads
	Lighting and Unregulated Use			
Lighting – ON: 1.8hr/day[5]	30% high efficacy (CFL fixtures)[5]	75% high efficacy (CFL fixtures)	90% high efficacy (CFL fixtures)	90% high efficacy (CFL fixtures)
Plugs and Appliances	**SF:** 4,000 kWh/yr **MF:** 3,167 kWh/yr	Same as WSEC-R 2006	Same as WSEC-R 2006	Same as WSEC-R 2006

[4] 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: Larson (2015). *Heat Pump Water Heater Model Validation Study*. Ecotope.

[5] RBSA metering study (Baylon 2014)

2.4. Cost Analysis

The WSEC-R code development process requires the development of incremental costs for each code cycle. During WSEC-R 2018 code development, Ecotope built upon and updated previous cost estimates (Storm 2019) for the options included in WSEC 2018 Section R406.

First-cost estimates were developed using a procedure employed by the Northwest Power and Conservation Council (NPCC) and ran through the Office of Financial Management Life Cycle Cost Tool. All costs presented in this study remain consistent with those used for the 2018 code development, as reviewed in the code development process and accepted by the Technical Advisory Group, Washington State Building Code Council (SBCC), and state legislature. The first costs were developed using multiple sources of information:

- The NPCC RTF[6] is a federally mandated multi-state compact that develops the efficiency resources for the region's electric utilities
- Navigant[7] is a business consulting firm which provides resource planning for both gas and electric utilities, including gas utilities in Washington State.
- Consortium for Energy Efficiency[8] (CEE) is the US and Canadian consortium of gas and electric efficiency program administrators.
- This study also uses cost information provided to the SBCC by Ecotope.
- PassiveHouse consultant aided with pricing the higher insulation and envelope detailing.

The incremental costs were calculated separately for single-family and multifamily, and weighted to provide a representative cost for each option for each unit type. Weighted individual options measure costs were then combined in compliant pathways used for modeled homes and weighted in a similar manner as energy summaries to provide an average incremental cost.

3. Energy End Use Estimates

Table 2 presents the average energy use by end use for each of the analyzed codes. Baseline HVAC and water heating equipment efficiencies were held constant over all codes, allowing a summary of just the code impact without including federal equipment efficiency impacts in the analysis; however, all WSEC-R 2015 and 2018 compliance pathways included upgraded HVAC and/or water-heating equipment above federal minimums per selection of relevant R406 measures.

[6] http://rtf.nwcouncil.org/

[7] http://www.navigant.com/industries/energy/

[8] http://www.cee1.org/

Table 2. Energy Use by End Use

Code	Heat (kWh Equivalent)	Cool (kWh)	Fan (kWh)	Light (kWh)	DHW (kWh)	Appliances and Plugs (kWh)	Total (kWh)	Total (therms)
WSEC-R 2006	11901	171	540	1697	4216	3849	8419	476
WSEC-R 2015	7651	160	327	969	2966	3849	6623	317
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IECC 2018	9788	121	340	727	3821	3849	6904	401

Table 3. Overall Energy Use Intensity (EUI), Total Energy Use (kWh Equivalent) and Percent Savings

Code	EUI (kBTU/sqft)	Total (kWh Equivalent)	Percent savings compared to 2006 WSEC-R
WSEC-R 2006	41	22374	---
WSEC-R 2015	29	15922	29%
WSEC-R 2018	23	12386	45%
IECC 2018	34	18646	17%

Table 3 shows the EUI and total energy use for each modeled code year, as well as the percent savings from 2006 for each case. The summary indicates an overall 45% reduction in energy use from the WSEC-R 2006 code to the 2018 code. A similar comparison (not shown in Table 3) can be made between the 2015 and 2018 WSEC-R, which indicates a 22% reduction from WSEC 2015. Although many of the compliant pathways for both 2015 and 2018 included similar equipment upgrade options, heating loads in 2018 code were reduced substantially through expanded selection of efficient building envelope and HVAC distribution options. Despite increased fan efficiencies in new furnaces between 2015 and 2018, overall fan energy use went up mostly due to increased use of HRVs.

Prescriptive code requirements have historically worked to ratchet down the energy use associated with regulated loads (e.g., heating, cooling, ventilation, lighting, and water heating). This means that the unregulated loads, mainly plug and appliance loads, are becoming a greater fraction of residential energy use. In 2006, unregulated loads may have been less than 20% of overall residential energy use. However, in 2018, those end uses comprise almost 30% of a home's energy use. In this code cycle, an energy efficient appliance option was added to the WSEC-R options table. Additional options to address unregulated loads should be considered in future code cycles in order for the state to meet its energy reduction goals by 2030.

4. Savings Estimates

Table 4 presents the estimated savings of the 2018 code compared to the three other codes on a per unit basis. The estimates are weighted averages of all construction types, heating system types, and climates, with electric and gas savings shown separately. For example, a single-family residence constructed to the new 2018 code is expected to save 1,036 kWh/year and 104 therm/year over the 2015 code. These estimates assume there is no measurable change in heating fuel selections between different code years.

Table 4 also shows improvements of Washington's newly adopted code over the 2018 IECC, which it was adapted from. Although the prescriptive requirements of the IECC and the WSEC-R are similar, credit requirements in Section R406 improve the efficiency upgrades beyond just the prescriptive code. This option table in Section R406 introduces the majority of energy savings in the WA code when compared to the updates to the IECC and prescriptive requirements of each code. This is evidenced by the 2015 WSEC-R modeling as more stringent than even the current IECC.

Unsurprisingly, savings are highest in comparison to WSEC 2006 requirements when the prescriptive code was least stringent and before the advent of Section R406. This can also be seen in

Table 5, which expresses the percent savings of WSEC-R 2018 from the comparison codes.

Table 4. Average Per Unit Savings by Unit Type (WSEC 2018 vs comparison codes)

Unit Type	WSEC 2018 Savings from:	2006	IECC 2018	2015
Single-Family (per home)	kWh/yr	2720	1160	1036
	therm/yr	298	206	104
Multifamily (per dwelling unit)	kWh/yr	3336	2027	1032
	therm/yr	0	0	0

Table 5. Percent Savings by Unit Type (WSEC 2018 Savings vs comparison codes)

Unit Type		2006	IECC 2018	2015
Single-Family (per home)	% kWh/yr savings	33 %	17 %	16 %
	% therm/yr savings	51 %	42 %	27 %
Multifamily (per dwelling unit)	% kWh/yr savings	36 %	25 %	15 %
	% therm/yr savings	0	0	0

5. Incremental Costs Estimates

Estimates of average incremental costs for each option are provided in Table 6 and

Table 7 for single-family and multi-family units, respectively. All costs shown are incremental construction costs (also referred to as first costs) for each optional requirement of Table R406.3. The base cost is related to the prescriptive requirements of the code. Keeping this in mind, the incremental cost for a ductless heat pump (DHP) in single-family is the added equipment cost associated with purchasing a higher efficiency heat pump (since DHPs are required in the prescriptive code for electric zonal homes); while in multifamily, the incremental cost of a heat pump is higher because it is compared to electric baseboards. Water heating systems in multifamily are assumed to serve more than one unit, therefore their incremental costs are lower than for single-family.

The first cost numbers are a fixed value for each energy measure and do not change based on a selected package of measures. This assumes that incremental costs of each option do not have any interdependency. This will no longer be the case as buildings become more efficient. Higher levels of envelope insulation and tighter construction leads to smaller HVAC systems, and therefore a cost credit should be applied. But as mentioned, this approach was not applied in this analysis therefore the cost estimates presented in this study is on the high end.

Table 6. Incremental Cost of Single-Family Options in 2018 WSEC (Section R406)

Option-Description	Credit Value	Weighted Measure Cost
1.1 - U-.24 Glaze	0.5	**$ 1,583**
1.2 - U-.20 Glaze	1	**$ 3,166**
1.3 - 5% UA reduction	0.5	**$ 1,102**
1.4 - 15% UA reduction	1	**$ 4,311**
1.5 - 30% UA reduction	2	**$ 7,947**
1.6 - 40% UA reduction	3	**$ 11,889**
2.1 – 3 ACH, fan efficiency	0.5	**$ 517**
2.2 - 2 ACH, HRV	1	**$ 2,727**
2.3 - 1.5 ACH, HRV	1.5	**$ 6,108**
2.4 - 0.6 ACH, HRV	2	**$ 8,725**
3.1 - Furnace	1	**$ 230**
3.2 - 9.5 HSPF HP	1	**$ 1,270**
3.3 - GSHP	1.5	**$ 11,034**
3.4 - DHP	1.5	**$ 1,400**
3.5 - 11.0 HSPF HP	1.5	**$ 5,400**
3.6 - DHP (15% elec)	2	**$ 5,400**
4.2 - HVAC inside	1	**$ 300**
5.1 - DWR	0.5	**$ 400**
5.2 - 0.80 gas DHW	0.5	**$ 586**
5.3 - 0.91 gas DHW, GSHP	1	**$ 923**
5.4 - Tier I HPWH	1.5	**$ 874**
5.5 - Tier III HPWH	2	**$ 874**
5.6 - Tier III HPWH Split	2.5	**$ 3,500**
6.1 - Solar PV	1	**$ 5,040**
7.1 - ES Appliance+ventless Dryer	0.5	**$ 462**

Table 7. Incremental Cost of Multifamily Options in 2018 WSEC (Section R406)

Option-Description	Credit Value	Measure Cost[9]
1.1 - U-.24 Glaze	0.5	**$ 554**
1.2 - U-.20 Glaze	1	**$ 1,107**
1.3 - 5% UA reduction	N/A	not evaluated
1.4 - 15% UA reduction	1	**$ 1,359**
1.5 - 30% UA reduction	1.5	**$ 2,615**
1.6 - 40% UA reduction	2	**$ 3,773**
2.1 - 3ACH, fan efficiency	1	**$ 245**
2.2 - 2 ACH, HRV	1.5	**$ 1,025**
2.3 - 1.5 ACH, HRV	2	**$ 2,296**
2.4 - 0.6 ACH, HRV	2.5	**$ 3,280**
3.1 - Furnace	1	not evaluated
3.2 - 9.5 HSPF HP	N/A	not evaluated
3.3 - GSHP	1	not evaluated
3.4 - DHP	2	**$ 2,800**
3.5 - 11.0 HSPF HP	N/A	not evaluated
3.6 - DHP (15% elec)	3	**$ 4,800**
4.2 - HVAC inside	N/A	not evaluated
5.1 - DWR	0.5	**$ 133**
5.2 - 0.80 gas DHW	0.5	not evaluated
5.3 - 0.91 gas DHW, GSHP	1	not evaluated
5.4 - Tier I HPWH	2	**$ 291**
5.5 - Tier III HPWH	2.5	**$ 291**
5.6 - Tier III HPWH Split	3	**$ 1,167**
6.1 - Solar pV	1	**$ 5,040**
7.1 - HP dryers, ES Appliance	1.5	**$ 462**

Table 8 provides estimates of weighted average incremental cost per single-family and multifamily unit built to the 2018 WSEC-R. The costs typically include envelope measures, duct sealing, house sealing, and HVAC and/or water heating equipment upgrades per the options in Section R406.

Table 8. Average Incremental Costs (per Unit)

		2015 to 2018 Cost Increase
Single-Family	2015 $s	$9,879
Multifamily	2015 $s	$1,870

It is worth noting that estimated incremental costs due to energy code improvements are frequently offset by energy savings to the homeowner or resident. For this reason, energy

[9] Multifamily measure costs were not evaluated in cases where an option has no credit applicable to multifamily or where the measure was unlikely to be implemented widely.

efficient homes can be attractive to prospective home buyers or renters. As described in Section 3, WSEC-R 2018 modeled homes estimate 22% savings from WSEC 2015.

6. Conclusion

Each code cycle is an opportunity to create more energy efficient housing for Washington state. The most recent 2018 WSEC-R incorporated several changes from the previous 2015 residential energy code including: an increased number of optional measures, updated points values for many options, credits specific to multifamily occupancy, increased required credits for all home types, and an added fuel normalization credit table. While most of these updates impacted the options table in Section R406, other changes of note to the 2018 state codes is the requirement for balanced flow ventilation with heat recovery for multifamily units (per the mechanical code), and mandated water saving plumbing fixtures (through state appliance standards).

This analysis provides a code-to-code comparison of the 2018 WSEC-R compared to the previous 2015 and 2006 WSEC-R codes, as well as the 2018 IECC national model code. The energy use and savings estimates are based on simulations and engineering models calibrated to measurements at various points. Results show continued improvement in WSEC code performance, demonstrated by decreased energy usage and increased savings relative to comparison codes. For the 2018 WSEC-R this analysis estimates a 22% savings from WSEC 2015 and a 45% savings from WSEC 2006.

Increased code stringency requires implementation of increased energy efficiency measures. To estimate the incremental costs of code compliant homes, incremental construction costs for each optional requirement of Table R406.3 were developed, and combined into least-cost compliance pathways used in the modeled homes to provide weighted average estimates of incremental costs per single-family and multifamily unit built to the 2018 WSEC-R. First costs are offset as the modeled least-cost pathways offer substantial energy savings from prior energy codes.

7. References

Baylon, D., Larson B., Logsdon M., Davis B. September 28, 2014. *Residential Building Stock Assessment: Metering Study*. Portland OR: Northwest Energy Efficiency Alliance.

Baylon D. et al. September 5, 2013. *Residential Building Stock Assessment: Multifamily Characteristics and Energy Use*. (Report No.13-263) Portland OR: Northwest Energy Efficiency Alliance.

Baylon D., Storm P., Geraghty K., Davis B. September 18, 2012. *2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use*. Portland OR: Northwest Energy Efficiency Alliance.

Davis, R. et al. June 24, 2020. *Residential Building Energy Efficiency Field Studies: Low-Rise Multifamily.* Prepared for Department of Energy, Office of Energy Efficiency and Renewable Energy.

Larson, B. March 2, 2015. *Heat Pump Water Heater Validation Study*. (Report No. E15-306) Portland, OR: Northwest Energy Efficiency Alliance.

Flynn, P. and E. Caudill. *2019-2020 Washington Residential New Construction Code Study.* (Report No. E20-405). Portland, OR: Northwest Energy Efficiency Alliance.

Northwest Energy Efficiency Alliance. April 2019. *Residential Building Stock Assessment II: Multifamily Buildings Report 2016-2017*.

Northwest Power and Conservation Council. February 2010. *Sixth Northwest Conservation and Electric Power Plan*. Portland, OR: Northwest Power and Conservation Council.

Odum H., Spielman S., Banks A., Kintner P., Frankel M. September 18, 2020. *Modeling the Washington State Energy Code - 2006 & 2018 Baseline Energy Consumption.* Department of Enterprise Services.

Regional Technical Forum. April 20, 2015a. *RTF Additional/Supporting Documents: Standard Information Workbook v2.2.* Portland, OR: Regional Technical Forum.

Regional Technical Forum. March 19, 2015. *RTF provisionally approved savings measure: Residential: DHW – HPWH.* Portland, OR: Regional Technical Forum.

Regional Technical Forum et al. February 2011 through March 2015. *RTF Unit Energy Savings (UES) Measures.* Portland, OR: Regional Technical Forum.

RLW Analytics. March 27, 2007. *Single-Family Residential New Construction Characteristics and Practices Study*. Portland, OR: Northwest Energy Efficiency Alliance.

RLW Analytics. June 14, 2007. *Multi-Family Residential New Construction Characteristics and Practices Study.* Portland, OR: Northwest Energy Efficiency Alliance.

Storm P., Hannas B., Baylon D. Revised April 8, 2019. 2015 Washington State Energy Code: Residential Impact Assessment. Portland, OR: Northwest Energy Efficiency Alliance.

Appendix A: Detailed Modeling Assumptions

This appendix provides more detail on the modeling assumptions used in the analysis. Assumptions related to the code are presented first, followed by a discussion and presentation of the weights used in the analysis.

2015 vs 2018 WSEC Specifications

The following tables describe the WSEC for 2015 and 2018, along with assumptions related to the code specifications. Table 9 shows the total points necessary to meet the code for various building types in 2015 and 2018. Table 10 is the new fuel normalization table introduced into WSEC-R 2018. Table 11 is a condensed summary of the energy credits table from Section R406.

Table 12 and Table 13 show the compliant pathways chosen for each dwelling size and type for 2015 and 2018 residential codes, respectively.

Table 9. Required Points for 2015 and 2018 WSEC

Building Size and Type	Points Requirement	
	2015	2018
Small Unit (less than 1500 sqft)	1.5	3.0
Medium Unit (1500–5000 sqft)	3.5	6.0
Large Unit (greater than 5000 sqft)	4.5	7.0
R-2 Unit (Multifamily three stories and less)	2.5	4.5
Small Additions (less than 500 sqft)	0.5	1.5

Table 10. Fuel Normalization Credits (Table R406.2 in WSEC-R 2018)

System Type	Primary Heating Source	Credits	
		Single-family	Multifamily (R-2)
1	Combustion heating equipment meeting minimum federal efficiency standards for the equipment listed in Table C403.3.2(4) or C403.3.2(5)	0	0
2	For an initial heating system using a heat pump that meets federal standards for the equipment listed in Table C403.3.2(1)C or C403.3.2(2) **or** Air to water heat pump units that are configured to provide both heating and cooling and are rated in accordance with AHRI 550/590	1.0	1.0
3	For heating system based on electric resistance only (either forced air or Zonal)	-1.0	-1.0
4	For heating system based on electric resistance with a ductless mini-split heat pump system in accordance with Section R403.7.1 including the exception	0.5	N/A
5	All other heating systems	-1.0	-0.5

Table 11. Summary of 2018 Residential Energy Code Energy Credits Table

Option	Description	Credits (All Other)	Credits (Multifamily Group R-2)
1.1	Glazing at U-0.24	0.5	0.5
1.2	Glazing at U-0.20	1.0	1.0
1.3	5% UA reduction	0.5	N/A
1.4	15% UA reduction	1.0	1.0
1.5	30% UA reduction	2.0	1.5
1.6	40% UA reduction	3.0	2.0
1.7	Adv. framing, raised heel trusses (R-49) and glazing at U-0.28	0.5	0.5
2.1	3 ACH50 and 0.35 W/cfm whole-house fan	0.5	1.0
2.2	2 ACH50 and HRV at 65% sensible recovery	1.0	1.5
2.3	1.5 ACH50 and HRV at 75% sensible recovery	1.5	2.0
2.4	0.6 ACH50 and HRV at 80% sensible recovery	2.0	2.5
3.1	95% AFUE furnace	1.0	1.0
3.2	Air-source heat pump at 9.5 HSPF	1.0	N/A
3.3	Ground source heat pump at 3.3 COP	1.5	1.0
3.4	DHP at 10 HSPF	1.5	2.0
3.5	Air-source heat pump at 11.0 HSPF	1.5	N/A
3.6	DHP at 10 HSPF for entire dwelling unit	2.0	3.0
4.1	Deeply buried ducts	0.5	0.5
4.2	Ducts inside	1.0	N/A
5.1	Drain water heat recovery	0.5	0.5
5.2	Gas water heater at 0.8 UEF	0.5	0.5
5.3	Gas water heater at 0.91 UEF	1.0	1.0
5.4	Heat pump water heater at NEEA Tier I	1.5	2.0
5.5	Heat pump water heater at NEEA Tier III	2.0	2.5
5.6	Split-system Heat pump water heater	2.5	3.0
6.1	1,200 kWh/yr renewable energy generation (max 3 credits)	1.0	1.0
7.1	EnergyStar appliances and ventless dryer	0.5	1.5

Compliance Paths

Single-family and multifamily homes must select a number of options to fulfill the points requirement based on unit type and size (see Table 9). In WSEC-2015 the points were assigned based on the energy credit options table; in WSEC-2018 the sum of credits from the energy credit options and fuel normalization credits tables must meet the required points. The following energy efficiency upgrades were chosen by dwelling size and type for WSEC-R 2015 (Table 12) and WSEC-R 2018 (Table 13).

Table 12. Least-cost Pathways Through Section R406 for 2015 WSEC Compliance[10]

Dwelling size/type*	Base Heating Equip.	Envelope	Air Leakage - Ventilation Controls	High-Efficiency HVAC Equipment	High-Efficiency HVAC Distribution	Water Heating Equip.
Small	zonal					Tier I HPWH
Small	gfac		3 ACH , fan eff	Furnace 0.94		Low Flow, 0.91 gas
Small	gfnc		3 ACH , fan eff	Furnace 0.94		Low Flow, 0.91 gas
Small	hp			9 HSPF HP		Low Flow
Med	zonal		3 ACH, fan eff	DHP		Low Flow, Tier I HPWH
Med	gfac		3 ACH , fan eff	Furnace 0.94		Low Flow, 0.91 gas
Med	gfnc		3 ACH , fan eff	Furnace 0.94		Low Flow, 0.91 gas
Med	hp			9 HSPF HP	HVAC Inside	Tier I HPWH
Multifamily	zonal	5% UA: U-0.28 glazing, R-38 floor	3 ACH , fan eff	DHP		Low Flow

** Required credits listed in Table 9*

[10] Option combinations sourced from: 2019-2020 Washington Residential New Construction Code Study (Flynn and Caudill 2020)

Table 13. Least-cost Pathways Through Section R406 for 2018 WSEC Compliance

Dwelling size/type†	Base Heating Equip.	Envelope	Air Leakage - Ventilation Controls	High-Efficiency HVAC Equipment #	High-Efficiency HVAC Distribution	Water Heating Equip.	Appliance Package
Small	zonal	U-0.20 glazing		DHP #			
Small	gfac	5% UA reduc	3 ACH , fan eff	Furnace 0.95		0.91 gas DHW	
Small	gfnc	5% UA reduc	3 ACH , fan eff	Furnace 0.95		0.91 gas DHW	
Small	hp			9.5 HSPF HP #	HVAC Inside		
Med	zonal	5% UA reduc	2 ACH, HRV	DHP #		Tier III HPWH (split)	
Med	gfac	15% UA reduc	1.5 ACH, HRV	Furnace 0.95	HVAC inside	0.91 gas DHW	ES Appl+ ventless Dryer
Med	gfnc	15% UA reduc	1.5 ACH, HRV	Furnace 0.95	HVAC inside	0.91 gas DHW	ES Appl+ ventless Dryer
Med	hp	5% UA reduc	3 ACH , fan eff	9.5 HSPF HP #	HVAC Inside	Tier III HPWH	
Multifamily	zonal	U-.24 Glaze	2 ACH, HRV			Tier III HPWH	

* Renewable Electric Energy options were not determined to be part of a least-cost pathway
# Certain equipment options include fuel normalization credits – see Table 10

†Required credits listed in Table 9

Prototype, Heating System, Climate Zone, and Option Path Weights

The weights were developed from a combination of the RLW reports (RLW 2007a, RLW 2007b), the RBSA phone survey, the RBSA field study (Baylon 2012, Baylon 2013), and normalized to the selected residential prototypes used in this analysis. Final prototype weights along with some general characteristics about the prototypes can be found in Table 14.

Table 14. A Selection of Residential Prototype Characteristics

2018 WSEC Classification (Section R406)	Small Dwelling Unit		Medium Dwelling Unit			Multifamily (Group R-2)
Prototypes	1344c	1344s	2200c	2200s	2688b	2460c
Building Type Single-family Detached (SF) or Multifamily (MF)	SF	SF	SF	SF	SF	*MF – Garden Style*
Heated Area (ft^2)	1,344	1,344	2,200	2,200	2,688	820 sqft/unit
# of Units	1	1	1	1	1	12
Foundation Type	Crawl	Slab	Crawl	Slab	Bsmt	Crawl
Floors	1	1	2	2	2	3
Occupants/ Unit	2.0	2.0	2.7	2.7	3.5	1.9
Prototype Weight*	0.13	0.02	0.62	0.11	0.11	1.0

* Single-family and multifamily each sum to 100%

Each single-family prototype was run with four base heating systems based on the standard methodology used for the Council analysis. The four base heating systems are gas furnace with no central air conditioning, gas furnace with central air conditioning, central heat pump, and electric zonal. Weights for the base heating systems in the single-family prototypes were developed using the RLW single-family report (RLW 2007a).

The final base heating systems and weights by building type are shown in Table 15. Each column adds to one; to renormalize across the whole population of residential construction (so the whole table adds to one), multiply these weights by the corresponding single-family or multifamily weight in Table 17.

Table 15. Base Heating System Weights by Building Type

System Type	Description	Single-family (SF)	Multifamily Group R-2 (MF)
GFNC	Central gas furnace with distribution ductwork; no air conditioning	53%	0%
GFAC	Central gas furnace and air-conditioning	30%	0%
ASHP	Central heat pump with distribution ductwork and electric resistance backup	12%	0%
ZONAL	Electric zonal baseboard heating. For WSEC-R 2015-2018 analysis, houses with electric zonal required to have Ductless Heat Pump in main living area	5%	100%

The weather files used in all savings simulations are composite typical meteorological year (TMY) weather files corresponding to the heating and cooling climate zones used by the Council. For this analysis, only Seattle and Spokane climates were used, and weights re-normalized. Table 16 and Table 17 lists the climate zone weights and the breakdown of single-family and multifamily.

Table 16. Climate Zone Weights[11]

Heating Zone	Cooling Zone	IECC Climate Zone	Single- and Multifamily
1	1	4C (Seattle)	91%
2	2	5B (Spokane)	9%

Table 17. Single-family and Multifamily Weighting by Total Residential Floor Area

Occupancy Type	Weighting
Single-family	82%
Low-rise Multifamily	18%

[11] Climate zones as defined by the Northwest Power and Conservation Council