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2015 Washington State Energy Code: Residential Impact Assessment

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TABLE OF CONTENTS

LIST OF TABLES

Glossary of Acronyms

AFUE	Annual Fuel Utilization Efficiency
AHRI	American Heating and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
CFL	compact fluorescent lamp
Council	Northwest Power and Conservation Council
DHP	Ductless heat pump
ft	Foot
HVAC	Heating, Ventilation and Air Conditioning
ISO	International Organization for Standards
kWh	Kilowatt-hour
NEEA	Northwest Energy Efficiency Alliance
RBSA	Residential Building Stock Assessment
SEEM	Simplified Energy and Enthalpy Model
SqFt	Square feet
TMY	Typical Meteorological Year
UA	Building heat loss expressed as U-value times area
WSEC	Washington State Energy Code

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 quantify the energy use, energy savings, and incremental costs for residential codes in Washington. Ecotope compared the 2015 and 2012 residential energy code for single-family (including townhomes) and low-rise multifamily units; low-rise multifamily units are defined as 3-stories or less.

The study objectives included:

- Calculate average expected energy use per house (SF and MF) under the new Washington State Energy Code (WSEC). Heating systems included gas furnaces, gas furnaces with air conditioning, heat pumps, and electric resistance heat.
- Calculate the incremental savings due to each code improvement for each heating type and climate for both SF and MF cases.
- Estimate incremental new construction costs of the WSEC for both single-family and low-rise multifamily.

Comparison of 2012 and 2015 Code Provisions

The general structure and details of the 2012 and 2015 WSEC are very similar, with only a few changes in the options table, as detailed in Table 6 in the Appendix. The baseline requirements of the two codes are the same, except that detached one-family, detached two-family, and townhouses using zonal electric primary heating are required in 2015 to have a ductless heat pump installed.

The point requirement for the options table increased from 2012 to 2015. The quick summary is the points went from 1.5 points in 2012 to 3.5 points in 2015 for medium-sized units, which is the size of most new construction units. The requirements for small units (<1500 SqFt) increased from 0.5 points to 1.5 points, large homes (>5000 SqFt) units increased from 2.5 points to 4.5 points. Table 5 in the Appendix shows the points requirements in more detail.

Energy Impacts

The analysis estimated incremental energy savings and costs for the most recent round of the WSEC change from 2012 to 2015. Table ES1 gives the estimated savings of the new code on a per unit basis. The estimates are a weighted average of all construction types, heating system types, and climates in a given category. Further, the estimates consider both the electric and gas site savings separately. Single-family units in Washington have more incidence of gas heating compared to low-rise multifamily, where electric resistance heat is most common, which explains why, on a per dwelling basis, there is more electric savings for multifamily than single-family. Overall this represents 10.6% of the estimated energy use of the homes built to the 2012 WSEC.

Table ES1: Energy Savings by Fuel Type

2012 to 2015 Site Savings		WSEC
Single-Family	Electric kWh/yr	294
	Gas therm/yr	68
Multifamily (per dwelling unit)	Electric kWh/yr	542
	Gas therm/yr	2

Cost Impacts

Table ES2 provides estimates of weighted average incremental cost per unit. The costs in 2012 dollars include envelope measures, duct sealing, HVAC equipment upgrades, house sealing, and lighting upgrades. The numbers are the minimum first cost necessary to achieve the code changes pertaining to energy consumption in the building. These costs were derived from the analysis of the Washington State Department of Commerce and the standard cost tables use by the Regional Technical Forum (RTF).

Table ES2: Average Incremental Costs (per Unit)

2012 to 2015 Cost Increase		WSEC
Single-Family	2012 $s	$1,330
Multifamily	2012 $s	$268

1. Introduction

Ecotope estimated the site energy use and savings for units built under the 2015 Washington State Energy Code (WSEC) for residential buildings. The energy use is compared against the 2012 residential WSEC. The 2012 and 2015 WSEC use the same baseline specifications and require points based on various upgraded measures, with the 2015 code requiring more points than the 2012 code. Details about the 2012 and 2015 WSEC can be found in the Appendix tables. 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 each heating and cooling climate. The energy end-uses considered in the house were space heating, space cooling, ventilation, domestic water heating, and lighting. The analysis applies to site-built single-family houses and multifamily dwellings three stories or less constructed under the residential energy code.

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, 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 quantify the energy use, energy savings, and incremental costs for residential codes in Washington. Ecotope compared the 2015 and 2012 residential energy code for single-family units and low-rise multifamily units; low-rise multifamily units are defined as 3-stories or less.

Specifically, the study objectives included:

- Calculate average expected energy use per house (SF and MF) under the new WSEC.
- Calculate the incremental savings due to each code improvement for each heating type and climate for both SF and MF cases.
- Estimate incremental new construction costs of the WSEC for both single-family and low-rise multifamily.

Updated approaches include a new version of SEEM, the energy use modeling tool, which can now model interactive effects of the water heater, particularly heat pump water heaters. And SEEM has been updated to allow for faster modeling, allowing all combinations of the options table that meet the required total points requirements to be run (more than 11,000 unique SEEM runs, which does not include additional post-processing model iterations, such as solar). In total, there are 3,432 models used for the 2012 WSEC and 44,172 models used for the 2015 WSEC.

Ecotope evaluated all codes and standards within the same analytical context, updating older analyses as needed, so the results are internally consistent. The analysis of the 2015 is based on the 2015 code versus what would have happened had the 2015 code not been implemented, which would be the 2012 code as it would be applied in 2015; this has implications on the equipment efficiencies based on federal minimum equipment changes between 2012 and 2015, and for this analysis the federal minimums as of 2015 are used throughout this analysis. The analysis includes only regulated loads: space heating and cooling, water heating, lighting and ventilation. Loads not regulated by the code, including appliances and plug loads, are excluded.

All of the work in the report is based on paper-to-paper comparisons of building specifications. The energy use and savings estimates are based on simulations and engineering models that have been calibrated in previous field studies; no field work was conducted nor measurements made in this current study. 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, though, only a study on code compliance and realization rate will be able to determine that.

2. Methodology

The methodology for this code analysis follows previous code analyses with some updates in data sources and processes. Improvements in SEEM allows a full treatment of the options table, and RBSA datasets provide a source for updating some of the weights. 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 2012 and 2015 Code Provisions

The general structure and details of the 2012 and 2015 WSEC are very similar, with only a few changes in the options table, as detailed in Table 6 in the Appendix. The baseline requirements of the two codes are the same, except that detached one-family, detached two-family, and townhouses using zonal electric primary heating are required in 2015 to have a ductless heat pump installed.

The point requirement for the options table increased from 2012 to 2015. The quick summary is the points went from 1.5 points in 2012 to 3.5 points in 2015 for medium-sized units, which is the size of most new construction units. The requirements for small units (<1500 SqFt) increased from 0.5 points to 1.5 points, large (>5000 SqFt) increased from 2.5 points to 4.5 points. Table 5 in the Appendix shows the points requirements in more detail.

2.2. Savings Analysis

2.2.1. Modeling Approach

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 system type.

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 and water heating.

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), American 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. 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 2.2.5. The baseline and improved equipment efficiencies used in this analysis are listed in Table 7 of the Appendix. When working with the federal minimum efficiencies, the 2012 and 2015 WSEC use the same minimum standard. 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 1.85 hours per day throughout the year.

Water heating energy was calibrated to the equivalent of $[23 + 11(\#occ - 1)]$ gals per day per occupant (Larson et al. 2015). Single-family occupancy varies based on prototype (see Table 8) and is based on the RBSA Single-Family Report (Baylon et al. 2012). Multifamily occupancy is 1.7 people/house, taken from the RBSA Multifamily Report (Baylon et al. 2013). The loads not regulated by the code, including appliances and plug loads, are not included in the totals reported, although the SEEM model uses estimates of the heating impact of these uses in estimating the heating and cooling requirements of the dwelling.

2.2.3. 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. As the future distribution of new construction housing in the Northwest is not known, the geographic distribution of housing permit records reported by the US Census in 2013 has been used to represent future construction locations. Table 10 in the Appendix lists the climate zone weights and the breakdown of single-family and multifamily by climate zone.

2.2.4. Building Prototypes

Ten building prototypes were used in the SEEM simulations and all but one of these are standard analytical prototypes used by the Council to develop and evaluate energy forecasts and conservation plans for the region's utilities; the 5000b prototype is an extension of the 2688b prototype and is used to simulate the large building specifications in the WSEC. The prototypes and some selected prototype characteristics are listed in Table 8 of the Appendix.

Each 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. Heating system weights and details about the mechanics of developing the weights can be found in the Appendix starting on page 20.

2.2.5. WSEC Options Tables

The WSEC provides a challenge for the analysis compared to other state energy codes. In the past three WSEC code cycles (2009, 2012, 2015), the code specifies a set of prescriptive building baseline requirements and a list of additional measures. The builder must select one or several items from the additional measure list to meet the total point requirement. Table 5 in the Appendix lists the total points required by code year and by building type, and Table 6 lists all of the possible options available to meet the point requirement.

For this analysis, the prototypes were each assigned a target point total based on code year, building type, and floor area. All valid combinations of options meeting those point totals were then generated, totally 44,172 unique iterations for the 2015 code and 3,432 iterations for the 2012 code. Some of the options, such as solar PV, are engineering calculations calculated after the SEEM models are run, so the total number of SEEM models used in the analysis is 11,058.

Three methods were used to weight these models: least first cost, adoption-weighted, and adoption-weighted without solar PV. The least first cost path is used in the analysis for this memo and involves calculating the total upgrade cost of each iteration and selecting the least first cost iteration for each prototype. The other two weighting schemes are discussed in the weighting section of the Appendix starting on page 20.

2.3. Cost Analysis

Ecotope assembled cost estimates for the changes in the WSEC. These included envelope measures, duct sealing, HVAC equipment upgrades, house sealing, and lighting upgrades. The costs are developed for a given set of prototype houses built up from individual measures. For example, the individual measures can include items like ceiling and wall insulation. The cost of upgrading the envelope then is calculated by multiplying the prototypical roof area by the insulation upgrade cost per unit area and so on for each construction component. The component costs are summed to create a full cost for the prototype. The individual measure cost estimates were based on a number of sources which primarily include the Council's 7th Northwest Power Plan workbooks and various measure analyses from the RTF (Council 2016; RTF 2011-2016). Cost summaries are weighted in the same manner as energy summaries.

The costs are presented separately for electric and gas to allow for cost-effectiveness calculations of electric and gas savings. Some costs, such as those associated with lighting, apply to the electric savings for all prototypes. For envelope improvements that reduce both gas heating and electric cooling, 90% of the envelope upgrade cost is applied to gas heating and 10% to electric cooling (where applicable). This split roughly reflects the energy use and savings split between heating and cooling across the Northwest. For heat pump or zonal resistance houses, there is no ambiguity, and all costs are assigned to electric savings.

3. Savings Estimates

Table 1 presents the estimated savings of the new code on a per unit basis. Single-family units in Washington have more incidence of gas heating compared to low-rise multifamily, which explains the difference in savings by fuel. The estimates are weighted averages of all construction types, heating system types, and climates in a given category. Single-family units in Washington have more incidence of gas heating compared to low-rise multifamily, where electric resistance heat is most common, which explains why, on a per dwelling basis, there is more electric savings for multifamily than single-family.

Table 1: Average per Unit Savings by Fuel Type (2015 vs. 2012 Code)

2012 to 2015 Site Savings		WSEC
Single-Family	Electric kWh/yr	294
	Gas therm/yr	68
Multifamily (per dwelling unit)	Electric kWh/yr	542
	Gas therm/yr	2

Table 2 presents the single-family and multifamily estimates broken out by the four heating systems most prevalent in Northwest building stock. The tables were constructed using a weighted average of the prototypes used in the simulation analysis. These tables provide more granularity on the range of savings potential depending on heating system type. Table 1 is then a weighted average of Table 2 using the weights from Table 9 in the Appendix. The electric zonal case for single-family units have high savings because of the 2015 provision that all homes with electric zonal primary heating must also install a ductless heat pump. However, zonal electric heat only accounts for 5% of new single-family homes, so the large savings for this heating type do not account for a large savings across all homes. The new 2015 provision for DHPs may even cause the zonal electric incidence to decrease as central heat pumps become more financially competitive (previously, electric zonal was a far less expensive option than central heat pumps, but with the inclusion of DHPs, that is not the case anymore). Overall this represents 10.6% of the estimated energy use of the homes built to the 2012 WSEC.

Table 2: WSEC Savings by Building Type and Base Heating System

Building Type	Base Heating System	Electricity Savings (kWh/year)	Gas Savings (therms/year)
Single-Family	Gas Furnace with Central AC	-64	83
	Gas Furnace without Central AC	-78	82
	Central Heat Pump	1,222	0
	Electric Zonal	4,032	0
Multifamily (per dwelling unit)	Gas Furnace with Central AC	-45	22
	Gas Furnace without Central AC	-51	22
	Central Heat Pump	252	0
	Electric Zonal	618	0

The negative electric savings for gas furnaces is caused by Option 2c being used to meet the low-cost paths for the 2015, but not being used in the 2012 code. Option 2c is a tighter air sealing measure, but also requires an HRV. The HRV saves heating energy because of the 85% heat recovery (which would apply to the gas savings), but the electric fan energy for an HRV is higher than the base ventilation. This increase in ventilation energy exists in the heat pump and zonal cases as well, but both the energy penalty and energy savings are in the electricity column for those base systems.

4. Costs Estimates

Table 3 provides estimates of weighted average incremental cost per unit. Table 4 breaks out the incremental costs by heating system type. The costs in 2012 dollars, consistent with the 7th Plan (Northwest Power and Conservation Council 2016), include envelope measures, duct sealing, HVAC equipment upgrades, house air sealing, and lighting upgrades (but there were no additional upgrades in lighting from 2012 to 2015). The numbers are the minimum cost necessary to achieve the code changes pertaining to energy consumption in the building.

Table 3: Average Incremental Costs per Unit

2012 to 2015 Cost Increase		WSEC
Single-Family	2012 $s	$1,330
Multifamily	2012 $s	$268

In Table 4, the item that jumps out is the electric zonal upgrade cost for single-family. As with the savings estimate for this item, the jump in cost is due to the ductless heat pump provision for electric zonal homes in the 2015 code.

Table 4: Average Incremental Costs per Unit by Heating System Type

Building Type	Base Heating System	Upgrade Cost Assigned to Electricity	Upgrade Cost Assigned to Gas	Total Upgrade Cost
Single-Family	Gas Furnace with Central AC	$63	$1,100	$1,163
	Gas Furnace without Central AC	$0	$1,163	$1,163
	Central Heat Pump	$1,165	$0	$1,165
	Electric Zonal	$4,347	$0	$4,347
Multifamily	Gas Furnace with Central AC	$14	$128	$142
	Gas Furnace without Central AC	$0	$142	$142
	Central Heat Pump	$142	$0	$142
	Electric Zonal	$287	$0	$287

5. References

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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.

2012 vs 2015 WSEC Specifications

The following tables describe the WSEC for 2012 and 2015, along with assumptions related to the code specifications. Table 5 shows the total points necessary to meet the code for various building types in 2012 and 2015. Table 6 is the combined options table for 2012 and 2015. Unless specified as 2012 or 2015, the items in the table are for both code years. Table 7 shows the baseline assumptions for each item mentioned in the code, along with possible upgrade paths and the cost of the upgrade. These are the costs that are used to build up the 2012 and 2015 total costs, which are then subtracted to get the 2015 upgrade cost over the 2012 code.

Table 5. Required Points for 2012 and 2015 WSEC

Building Size and Type	Points Requirement	
	2012	2015
Small Unit (less than 1500 SqFt)	0.5	1.5
Medium Unit (1500–5000 SqFt)	1.5	3.5
Large Unit (greater than 5000 SqFt)	2.5	4.5
R-2 Unit (Multifamily three stories and less)	—	2.5
Small Additions (less than 750 SqFt for 2012, less than 500 SqFt for 2015)	0.5	0.5
Medium Additions (500–1500 SqFt)	—	1.5
Large Additions (greater than 1500 SqFt)	—	—

Table 6. Combined Option Table for 2012 and 2015 WSEC

Label	Details	Credits
opt1a	Fenestration U .= 0.28 Floor R-38 Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab	0.5
opt1b	Fenestration U .= 0.25 Wall R-21 plus R-4 Floor R-38 Basement wall R-21 int plus R-5 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab	1.0
opt1c	Fenestration U .= 0.22 Ceiling and single-rafter or joist-vaulted R-49 advanced Wood frame wall R-21 int plus R-12 ci Floor R-38 Basement wall R-21 int plus R-12 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab	2.0
opt1d	**2012:** Not Available **2015:** Vertical fenestration U = 0.24	0.5
opt2a	**2012:** Reduce the tested air leakage to 4.0 air changes per hour maximum **2015:** Reduce the tested air leakage to 3.0 air changes per hour maximum and All whole house ventilation requirements as determined by Section M1507.3 of the International Residential Code shall be met with a high efficiency fan (maximum 0.35 watts/cfm), not interlocked with the furnace fan. Ventilation systems using a furnace including an ECM motor are allowed, provided that they are controlled to operate at low speed in ventilation only mode.	0.5
opt2b	Reduce the tested air leakage to 2.0 air changes per hour maximum and All whole house ventilation requirements as determined by Section M1507.3 of the International Residential Code shall be met with a heat recovery ventilation system with minimum sensible heat recovery efficiency of 0.70.	1.0
opt2c	Reduce the tested air leakage to 1.5 air changes per hour maximum and All whole house ventilation requirements as determined by Section M1507.3 of the International Residential Code shall be met with a heat recovery ventilation system with minimum sensible heat recovery efficiency of 0.85.	1.5
opt3a	**2012:** Gas, propane or oil-fired furnace with minimum AFUE of 95% **2015:** Gas, propane or oil-fired furnace with minimum AFUE of 94%, or Gas, propane or oil-fired boiler with minimum AFUE of 92%	**2012:** 0.5 **2015:** 1.0
opt3b	**2012:** Air-source heat pump with minimum HSPF of 8.5 **2015:** Air-source heat pump with minimum HSPF of 9.0	1.0

opt3c	Closed-loop ground source heat pump; with a minimum COP of 3.3 or Open loop water source heat pump with a maximum pumping hydraulic head of 150 feet and minimum COP of 3.6	**2012:** 2.0 **2015:** 1.5
opt3d	In homes where the primary space heating system is zonal electric heating, a ductless heat pump system shall be installed and provide heating to at least one zone of the housing unit.	1.0
opt4a	All heating and cooling system components installed inside the conditioned space. All combustion equipment shall be direct vent or sealed combustion. Locating system components in conditioned crawl spaces is not permitted under this option. Direct combustion heating equipment with AFUE less than 80% is not permitted under this option. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and shall show the location of the heating and cooling equipment and all the ductwork. And… **2012:** Electric resistance heat is not permitted under this option. **2015:** This includes all equipment and distribution system components such as forced air ducts, hydronic piping, hydronic floor heating loop, convectors and radiators. For forced air ducts: A maximum of 10 linear feet of return ducts and 5 linear feet of supply ducts may be located outside the conditioned space. All metallic ducts located outside the conditioned space must have both transverse and longitudinal joints sealed with mastic. If flex ducts are used, they cannot contain splices. Flex duct connections must be made with nylon straps and installed using a plastic strapping tensioning tool. Ducts located outside the conditioned space must be insulated to a minimum of R-8. Electric resistance heat and ductless heat pumps are not permitted under this option.	1.0
opt5a	**2012:** NA (no separate low flow water fixture option in 2012 so we have relabeled option 5a for 2012 as option 5b, which includes low flow; 5b from 2012 is now 5c) **2015:** All showerhead and kitchen sink faucets installed in the house shall be rated at 1.75 GPM or less. All other lavatory faucets shall be rated at 1.0 GPM or less.	0.5
opt5b	**2012:** Gas, propane or oil water heater with a minimum EF of 0.62 or Electric water heater with a minimum EF of 0.93. For both cases all showerhead and kitchen sink faucets installed in the house shall be rated at 1.75 GPM or less. All other lavatory faucets shall be rated at 1.0 GPM or less. **2015:** Gas, propane or oil water heater with a minimum EF of 0.74 or water heater heated by ground source heat pump meeting the requirements of Option 3c. For R-2 occupancy, a central heat pump water heater with an EF greater than 2.0 that would supply DHW to all the units through a central water loop insulated with R-8 minimum pipe insulation.	**2012:** 0.5 **2015:** 1.0

opt5c	**2012:** Gas, propane or oil water heater with a minimum EF of 0.82 **2015:** Gas, propane or oil water heater with a minimum EF of 0.91 or Solar water heating supplementing a minimum standard water heater. Solar water heating will provide a rated minimum savings of 85 therms or 2000 kWh based on the Solar Rating and Certification Corporation (SRCC) Annual Performance of OG-300 Certified Solar Water Heating Systems or Electric heat pump water heater with a minimum EF of 2.0 and meeting the standards of NEEA's Northern Climate Specifications for Heat Pump Water Heaters or **2012:** Water heater heated by ground source heat pump meeting the requirements of Option 3c.	1.5
opt5d	**2012:** Not Available **2015:** A drain water heat recovery unit(s) shall be installed, which captures waste water heat from all the showers, and has a minimum efficiency of 40% if installed for equal flow or a minimum efficiency of 52% if installed for unequal flow. Such units shall be rated in accordance with CSA B55.1 and be so labeled.	0.5
opt6a	For each 1200 kWh of electrical generation **[2015:** per housing unit**]** provided annually by on-site wind or solar equipment a 0.5 credit shall be allowed, up to 3 credits. Generation shall be calculated as follows: For solar electric systems, the design shall be demonstrated to meet this requirement using the National Renewable Energy Laboratory calculator PVWATTs. Documentation noting solar access shall be included on the plans. For wind generation projects designs shall document annual power generation based on the following factors: The wind turbine power curve; average annual wind speed at the site; frequency distribution of the wind speed at the site and height of the tower. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall show the photovoltaic or wind turbine equipment type, provide documentation of solar and wind access, and include a calculation of the minimum annual energy power production.	0.5
opt6b		1.0
opt6c		1.5
opt6d		2.0
opt6e		2.5
opt6f		3.0
	2015 Option Combination Restrictions: Projects using option 1d may not use Option 1a, 1b or 1c. Projects may only include credit from one space heating option, 3a, 3b, 3c or 3d. When a housing unit has two pieces of equipment (i.e., two furnaces) both must meet the standard to receive the credit.	

Table 7. Baseline and Upgrade Assumptions for Individual Technologies

Category	Base	Upgrade	Upgrade Cost	Cost Unit
HVAC	ZONL	DHP2	$3,887.85	per unit
	FHCA 0.80	FHCA 0.94/0.95	$545.03	per unit
	FUR 0.80	FUR 0.94/0.95	$545.03	per unit
	HSPF_8.2_SEER_14.0	HSPF_8.5_SEER_14.0	$597.20	per unit
	HSPF_8.2_SEER_14.0	HSPF_9.0_SEER_14.0	$710.00	per unit
	HSPF_8.2_SEER_14.0	GSHP COP 3.3	$3,267.00	per ton
	Baseline ducts	Ducts inside envelope	$350.00	per unit
Insulation	Floor R-30	Floor R-38	$0.45	per sqft exposed floor
	Wall R-21	Wall R-21+4	$0.96	per sqft wall
	Wall R-21	Wall R-21+12	$1.46	per sqft wall
	Bsmt Wall R-21	Bsmt Wall R21+5	$0.71	per sqft wall
	Bsmt Wall R-21	Bsmt Wall R21+12	$1.21	per sqft wall
	Ceiling R-49	Ceiling R-49 adv	$0.20	per sqft ceiling
	Window 0.30	Window 0.28	$2.68	per sqft window
	Window 0.30	Window 0.25	$6.71	per sqft window
	Window 0.30	Window 0.24	$8.05	per sqft window
	Window 0.30	Window 0.22	$10.73	per sqft window
	Slab R-0 under	Slab R-10 under	$0.90	per sqft slab
	5 ACH50	4 ACH50	$0.10	per sqft home
	5 ACH50	3 ACH50	$0.20	per sqft home
	5 ACH50	2 ACH50	$0.30	per sqft home
	5 ACH50	1.5 ACH50	$0.35	per sqft home
Ventilation	standard vent	better fan	$80.64	per unit
	standard vent	hrv 0.7 (single zone)	$1,000.00	per unit
	standard vent	hrv 0.85 (ducted multizone)	$2.00	per sqft home
DHW	0.93 EF	2.0 EF HPWH	$1,118.43	SF
	0.93 EF	2.0 EF HPWH	$790.65	MF
	0.93 EF	solar wh	$4,500.00	per unit
	0.93 EF	GSHP wh	$1,000.00	per unit
	0.62 gas	0.74 gas	$586.00	per unit
	0.62 gas	0.91 gas	$923.00	per unit
	standard practice	low flow fixtures	$47.31	per unit
	no drain recov	drain recovery	$475.00	per unit
Solar PV	none	~1kW–6kW	$7–$3.40	per Watt

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, and the RBSA field study (Baylon 2012, Baylon 2013). Final prototype weights along with some general characteristics about the prototypes can be found in Table 8.

Table 8. A Selection of Prototype Characteristics

Characteristics	Prototypes									
	1344c	1344s	2200c	2200s	2688b	5000b	1904c	1904s	2856c	2856s
Building Type	SF	SF	SF	SF	SF	SF	MF	MF	MF	MF
Foundation	Crawl	Slab	Crawl	Slab	Bsmt	Bsmt	Crawl	Slab	Crawl	Slab
Units	1	1	1	1	1	1	2	2	3	3
Floors	1	1	1.5	1.5	1	2	2	2	3	3
Occupants per Unit	2.00	2.00	2.75	2.75	3.50	4.00	1.69	1.69	1.69	1.69
Prototype Weight	0.036	0.068	0.129	0.463	0.111	0.017	0.058	0.018	0.075	0.024

Each 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 multifamily heating system weights were developed from the RBSA phone survey.[1]

The final base heating system weights by building type are shown in Table 9. Each row adds to one; to renormalize across the whole population of residential construction (so the whole table adds to one), multiply the single-family row by 0.825 and the multifamily row by 0.175.

Table 9. Base Heating System Weights by Building Type

Building Type	Base Heating System			
	gfac	gfnc	hp	zonal
Single-Family	0.296	0.534	0.118	0.052
Multifamily	0.019	0.072	0.042	0.867

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. As the future distribution of new construction housing in the Northwest is not known, the geographic distribution of housing permit records reported by the US Census in 2013 has been used to represent future construction locations. Table 10 lists the climate zone weights and the breakdown of single-family and multifamily by climate zone.

[1] Note the RBSA phone survey was also summarized for single-family as well, but the RLW field survey was chosen as the better single-family dataset because of the difficulty in properly identifying heating equipment types in phone surveys.

Table 10. Climate Zone Weights[2]

Heating Zone	Cooling Zone	Climate Weight	Percent SF	Percent MF
1	1	0.820	82.1%	17.9%
1	2	0.012	90.7%	9.3%
1	3	0.072	88.3%	11.7%
2	1	0.017	83.8%	16.2%
2	2	0.079	79.8%	20.2%
3	1	0.001	85.9%	14.1%

For the option path weights, the prototypes were each assigned a target point total based on code year, building type, and floor area. All valid combinations of options meeting those point totals were then generated, totally 44,172 unique iterations for the 2015 code and 3,432 iterations for the 2012 code. Some of the options, such as solar PV, are engineering calculations calculated after the SEEM models are run, so the total number of SEEM models used in the analysis is 11,058.

Three methods were used to weight these models: least first cost for all cases, adoption-weighted, and adoption-weighted without solar PV. The least first cost path is used in the analysis for this memo and in no case did that include solar PV in the final runs.

The adoption-weighted scenarios use an "adoption curve" that seeks to capture a market transformation curve in which a small fraction are early adopters of high cost options (such as solar PV and ground source heat pumps) and a distribution of builders and buyers choose lower cost but not least cost options. In this context the adoption curve may be a more realistic method of portraying the market response to efficiency measures. Different assumptions about the uptake of the additional measures in the marketplace or about options selected will change the analysis. It should be noted when more option points are required in future WSEC code cycles, the path to meeting code will mostly certainly include PV in the least cost weighting scheme, especially with the continuing drop in PV cost.

The adoption-weighted path assigns a distribution to the costs within each prototype. The selected distribution for this analysis is the adoption curve distribution, with 16% of homes grouped as the least cost path, the next 34% grouped in the next cost level, then the next 34% at the next level of cost, then 14%, and finally the highest 2% of costs grouped together. The assumption is that there are many builders that will use low-cost options to meet the code, but there will always be builders that use higher-cost options to meet the code for various reasons (e.g., ground source heat pumps are appealing to some buyers and will provide a few points towards meeting the code requirements, but it is not a low-cost item).

The adoption-weighted without solar PV weighting scheme is identical to the previous weighting scheme, except all prototypes that includes solar PV are weighted as 0 and the remainder of the runs are grouped into the cost tiers.

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