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Final Cost-Benefit Analysis of Select 2021 WSEC Residential Provisions

January 2023

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Prepared for
the Washington State Department of Enterprise Services

Pacific Northwest National Laboratory
Richland, Washington 99354

Executive Summary

The State of Washington is in the process of updating their current state residential energy code. They will be moving from the 2018 Washington State Energy Code (2018 WSEC-R) to a 2021 WSEC-R. The Washington State Building Code Council (SBCC) requested PNNL to perform an independent analysis of the energy and economic impacts of a number of the proposed code changes to the 2018 WSEC-R. The specific request was to determine the energy and economic and emissions impact of select proposals included in the 2021 WSEC-R. The objective was to review submitted data in the proposals, supplement and revise the economic impact analyses included in those proposals as needed, and review life cycle cost analyses per state protocols or using alternative methods if necessary to provide improved and more accurate analysis.

PNNL reviewed the proposals listed in the following table. The team analyzed a subset of these proposals using building energy simulation with Washington-specific inputs and following the DOE established methodology for cost-effectiveness.[1] Table ES-1 illustrates all proposals requested for analysis. For this report, proposals 1-8 were selected for cost-effectiveness analysis by simulation. However, proposals 4 and 8 were removed from analysis due to the Washington State Building Code Council (SBCC) vote to disapprove. PNNL will review proposals 9 through 16 in a future study that considers the 2021 WSEC-R as a whole compared to the 2018 WSEC-R and the 2006 WSEC-R.

[1] https://www.energycodes.gov/methodology

Table ES-1. List of proposals for the 2021 WSEC-R analysis

Proposal	Section	Subject	Analysis
Proposal 1	R403.13, R405.2, R503.1.2	Heat Pump Space Heater	Cost-effectiveness
Proposal 2	R403.5, R405.2, R503.1.3	Heat Pump Water Heater	Cost-effectiveness
Proposal 1+2	R403.13, R405.2, R503.1.2, R403.5, R405.2, R503.1.3	Heat Pump Space Heating and Water Heating	Cost-effectiveness
Proposal 3	R202, R401.1	Definitions Scope	Cost-effectiveness
Proposal 4	Table R402.1.2	U-Factor Replacements	Disapproved by SBCC
Proposal 5	R405.3, R406, Chapter 6	Update Section R406	Cost-effectiveness
Proposal 6	R403.5.1	Allowed Leakage Rates	Cost-effectiveness
Proposal 7	R403.5.5	Water Heater Install Location	Cost-effectiveness
Proposal 8	R403.3.2.1	Sealed Air Handler	Disapproved by SBCC
Proposal 9	R502	Additions	Future Qualitative Review
Proposal 10	R402.4.1.2	Testing Agency Certification	Future Qualitative Review
Proposal 11	R403.5.1	SWH Circulation System	Future Qualitative Review
Proposal 12	Table 406.3	Energy Credit Options 3.1 & 3.2	Future Qualitative Review
Proposal 13	Table 406.3 Option 3.2	HSPF of 9.5	Future Cost-effectiveness
Proposal 14	Table 406.3 Option 3.5	HSPF of 11.0	Future Cost-effectiveness
Proposal 15	Table 406.3 Option 3.6	HSPF of 10.0	Future Qualitative Review
Proposal 16	R406 Option 3.2, 3.5	COP, HSPF	Future Qualitative Review

Cost-effectiveness results of the individual proposals are shown in Table ES-2 for various metrics. Details on the analysis for each proposal are in Section 3. When life cycle cost savings is positive, the proposal is considered cost-effective. As shown in Table ES-2, when considering only market rate utility costs, all code change proposals are determined to be cost-effective except for the proposal to reduce the maximum allowable air leakage rate. When the social cost of carbon (SCC) is also considered (as required by the State of Washington), all code change proposals are cost-effective. The code change proposal for moving low-rise multifamily buildings with interior access to the provisions of the commercial code showed negative SCC savings as the commercial code showed increased annual energy consumption. All remaining code change proposals showed positive life cycle SCC savings.

Table ES-2. Cost-Effectiveness Results of Select Proposals

Metric	Prop 1 HP Space Heating	Prop 2 HP Water Heating	Prop 1+2 Combo	Prop 3 MF Res to Com	Prop 5 Electric R406 Update	Prop 6 Reduce ACH50	Prop 7 SWH Cond Space
Annual energy cost savings ($)	-$27	$85	$56	-$44	$113	$26	$16
Life cycle cost savings ($)	$115	$426	$807	$404	$1,988	-$16	$454
SCC life cycle cost savings ($)	$577	$644	$1,365	-$87	$1,109	$129	$143
Total life cycle cost savings ($)	$692	$1,070	$2,172	$317	$3,097	$113	$597
Added construction cost ($)	-$1,015	$673	-$640	-$1,812	-$209	$813	$0
Simple payback period (yrs)	Immediate	7.9	Immediate	Immediate	Immediate	32	Immediate
Carbon savings (tons)	14.4	14.1	32.0	1.3	24.8	2.7	3.2
Electric savings (kWh/yr)	-1,599	-109	-2,306	-459	-678	102	-68
Natural gas savings (therms/yr)	119	90	237	0	168	15	21
Fuel oil savings (gallons/yr)	0.14	0.18	0.36	0	0.24	0.03	0.04

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1.0 Introduction

The State of Washington is in the process of updating their current state residential energy code. They will be moving from the 2018 Washington State Energy Code (2018 WSEC-R) to a 2021 WSEC-R. The Washington State Building Code Council (SBCC) requested PNNL to perform an independent analysis of the energy and economic impacts of a number of the proposed code changes to the 2018 WSEC-R. The specific request was to determine the energy and economic and emissions impact of select proposals included in the 2021 WSEC-R. The objective was to review submitted data in the proposals, supplement and revise the economic impact analyses included in those proposals as needed, and review life cycle cost analyses per state protocols or using alternative methods if necessary to provide improved and more accurate analysis.

1.1 2021 WSEC-R Proposals

PNNL reviewed the proposals listed in the following table. The team analyzed a subset of these proposals using large-scale simulation following the DOE established methodology for cost-effectiveness.[1] Table ES-1 illustrates all proposals requested for analysis. For this report, proposals 1-8 were selected for cost-effectiveness analysis by simulation. However, proposals 4 and 8 were removed from analysis due to the Washington State Building Code Council (SBCC) vote to disapprove. PNNL will review proposals 9 through 16 in a future study that considers the 2021 WSEC-R as a whole compared to the 2018 WSEC-R and the 2006 WSEC-R.

[1] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

Table 1. Proposal Summary for 2021 WSEC-R

Proposal	Section	Subject	Analysis
Proposal 1	R403.13, R405.2, R503.1.2	Heat Pump Space Heater	Cost-effectiveness
Proposal 2	R403.5, R405.2, R503.1.3	Heat Pump Water Heater	Cost-effectiveness
Proposal 1+2	R403.13, R405.2, R503.1.2, R403.5, R405.2, R503.1.3	Heat Pump Space Heating and Water Heating	Cost-effectiveness
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2.0 Cost-effectiveness Analysis

The PNNL analysis for the 2021 WSEC-R proposals followed the standard modeling and cost-effectiveness methodology as detailed in the DOE established methodology.[1] EnergyPlus simulations were run using the 2018 WSEC-R as the baseline across the Washington state climate zones (4C and 5B) to estimate energy use changes, energy cost changes, and carbon emissions based on the proposals. Single-family prototypes are 2,376 sq ft while multifamily dwelling units are 1,200 sq ft. The updated prototypes were simulated based on the new code language in each proposal.

The WSEC-R baseline and updated prototypes included additional energy efficiency credit requirements as required in Section R406. In both the baseline and updated prototype simulation, energy credit options from the 2021 WSEC-R were used to meet the updated R406 requirements. For the single-family prototype at 2,376 sq ft, 8.0 credits were required while the multifamily dwelling unit at 1,200 sq ft required 6.5 credits. When a proposal required the addition of more efficiency, the energy credits in the updated prototype were adjusted to account for the additional efficiency. The energy credits selected in the baseline and updated prototypes are listed in Section 3.0 where the details on the analysis for each proposal are presented.

2.1 Methodology

This section provides an overview of the methodology used in evaluating the cost-effectiveness of the proposals for the 2021 WSEC-R compared to the 2018 WSEC-R. Cost-effectiveness results for life cycle cost (LCC) savings, simple payback, and cash flow are calculated for each building type in each climate zone. The results are weighted to aggregate results to the climate zone level. Weighting factors for each of the prototype buildings were developed for all U.S. climate zones using 2019 new residential construction starts and residential construction details from the U.S. Census (Census 2010), the Residential Energy Consumption Survey (RECS 2013), and the National Association of Home Builders (NAHB 2009). The weights were fine-tuned by the revised county-to-climate zone map based on ASHRAE 169 climate zone changes.

DOE's cost-effectiveness methodology evaluates 32 residential prototypes comprising two building types (single-family and low-rise multifamily), four foundation types (slab, crawl, unheated basement, and heated basement), and four heating system types (gas furnace, oil furnace, electric furnace, and heat pump). These prototypes are simulated with TMY3 weather data from locations in Washington representing the two climate zones and two moisture regimes in this analysis.

Construction cost differences between the 2018 WSEC-R and the 2021 WSEC-R for each proposal were taken directly from DOE/PNNL reports on the cost-effectiveness of new code editions, Home Depot and Lowes stores, as well as conversations with heat pump manufacturers and sales representatives. National cost estimates were adjusted by a

[1] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

Washington-specific construction cost multiplier[1] and appropriate Consumer Price Index (CPI) multipliers[2] to bring costs into 2022 dollars.

Life Cycle Cost (LCC) savings is the primary measure used to assess the economic impact of building energy codes. LCC is the calculation of the present value of costs over a 30-year period including initial equipment and construction costs, energy savings, maintenance and replacement costs, and residual value of components at the end of the 30-year period. When the LCC of the updated code (e.g., the 2021 WSEC-R) is lower than that of the previous code (the 2018 WSEC-R), the updated code is considered cost-effective. In other words, when life cycle cost savings is positive, the proposal is considered cost-effective.

The energy savings from the simulation analysis are converted to energy cost savings using the electricity and gas prices established for analyzing Washington energy code proposals. In addition, the oil price is the most recent state-specific residential oil price from DOE's Energy Information Administration. Fuel prices used in this analysis can be found in Table 2. Fuel prices are escalated over the analysis period based on EIA's year-by-year projections in the 2021 Annual Energy Outlook,[3] Reference Case Table 3.[4]

Table 2. Fuel Prices used in the Analysis

Electricity ($/kWh)	Gas ($/Therm)	Oil ($/MBtu)
0.0966	1.062	2.52

Per the established methodology, DOE calculates three metrics from the perspective of the homeowner—LCC, simple payback, and cash flow. LCC is the primary metric used by DOE for determining the cost-effectiveness of an overall code or individual code change. The economic parameters used in the current cost-effectiveness analysis are summarized in Table 3. The economic parameters are recently updated following the established methodology to account for changing economic conditions.

[1] https://www.energycodes.gov/sites/default/files/2021-11/Location_Factors_Report.pdf

[2] https://www.usinflationcalculator.com/inflation/consumer-price-index-and-annual-percent-changes-from-1913-to-2008/

[3] https://www.eia.gov/outlooks/aeo/

[4] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2021&sourcekey=0

Table 3. Summary of Economic Parameters Used in Cost-Effectiveness Analysis

Parameter	Value
Mortgage Interest Rate	5%
Loan Term	30 years
Down-Payment Rate	10% of home price
Points and Loan Fees	0.6% of mortgage amount
Analysis Period	30 years
Property Tax Rate	1.1% of home price/value
Income Tax Rate	15% federal
Inflation Rate	3.0% annual
Home Price Escalation Rate	Equal to inflation rate

An additional analysis metric required for all Washington energy code proposals is the life cycle cost savings when including the social cost of carbon (SCC). Emission factors used in the calculation of carbon emissions and SCC are extracted from the Carbon Externality spreadsheet as part of the Washington Life Cycle Cost Analysis Tool – version 2020-A provided by the Washington Office of Financial Management. Carbon emissions are based on annual fuel consumption derived from the simulation of the baseline and updated prototypes. Carbon emission factors used in the analysis are shown in Table 4.

Table 4. Carbon Emission Factors by Fuel Type

Energy Source	Carbon Emission Factor[1]
Electricity	4.12×10^{-4} metric tons CO_2/kWh (0 after 2030)
Natural Gas	0.00531 metric tons CO_2/therm
Oil	9.62 x 10-3 metric tons CO2/gallon

The life cycle savings of SCC is determined based on a net present value (NPV) calculation of annual savings in the SCC over a 30-year period. The social cost of carbon is based on estimates from the U.S. Government Interagency Working Group on SCC.[1] The annual social cost of carbon for the years 2010 to 2118 is contained in the Washington Life Cycle Cost Analysis Tool. The annual social cost of carbon is multiplied by the annual carbon emissions over a 30-year period to calculate the total dollar value of the carbon emissions. The NPV of SCC is calculated with a discount rate of 5% over the 30 years of carbon emissions. The difference in the NPV of SCC for the baseline case and updated case based on each proposal is the NPV savings for SCC.

2.2 Cost-Effectiveness Results of Proposals

Cost-effectiveness results of the individual proposals are shown in Table 5. Details on the analysis for each proposal are in Section 3.

[1] https://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

Table 5. Cost-Effectiveness Results of Analyzed Proposals

Metric	Prop 1 HP Space Heating	Prop 2 HP Water Heating	Prop 1+2 Combo	Prop 3 MF Res to Com	Prop 5 Electric R406 Update	Prop 6 Reduce ACH50	Prop 7 SWH Cond Space
Annual energy cost savings ($)	-$27	$85	$56	-$44	$113	$26	$16
Life cycle cost savings ($)	$115	$426	$807	$404	$1,988	-$16	$454
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Carbon savings (tons)	14.4	14.1	32.0	1.3	24.8	2.7	3.2
Electric savings (kWh/yr)	-1,599	-109	-2,306	-459	-678	102	-68
Natural gas savings (therms/yr)	119	90	237	0	168	15	21
Fuel oil savings (gallons/yr)	0.14	0.18	0.36	0	0.24	0.03	0.04

3.0 Individual Proposal Analyses

In this section, each proposal is either analyzed by EnergyPlus simulation for a cost-effectiveness assessment or by qualitative review. The qualitative review is for proposals that cannot by analyzed by simulation as they fit outside the normal operation of the PNNL prototypes. For each proposal with a cost-effectiveness analysis, the energy credit options used in the simulations are detailed for the baseline case and the updated case. For all proposals except proposal 5, baseline and updated cases have a total of 8 credits and 6.5 credits for single-family and multifamily homes, respectively, from section R406. For proposal 5, the baseline cases have a total of 6 credits and 4.5 credits for single-family and multifamily homes, respectively, while the updated cases have a total of 8 credits and 6.5 credits for single-family and multifamily homes, respectively. For all single-family prototypes that use a heat pump water heater, the storage tank was sized up to 80 gallons to meet a minimum first hour rating of 86 gallons/hr at 125°F outlet temperature.

3.1 Proposal 1: Heat pump space heating (21-GP2-065)

Code change proposal 21-GP2-065 adds a new section (R403.13) requiring that space heating be provided by heat pump equipment. The new heat pump requirement allows electric resistance heating for low load homes such as Passive House. The proposal also added a new exception to Section R503.1.2 for heating and cooling systems in alterations that space heating systems must comply with the new R403.13. This proposal is an effort to align with Washington State policy to increase energy efficiency by 70% and achieve the broader goal of building zero fossil-fuel greenhouse gas emission homes and buildings by the year 2031.

3.1.1 Heat Pump Space Heating Proposed Code Language

R403.13 Heat pump space heating. Space heating shall be provided by a heat pump system.

Exceptions:

1. Detached one- and two-family dwellings and multiple single-family dwellings (townhouses) up to three stories in height above grade having an installed HVAC heating capacity no greater than 1.5 W of electric resistance heating per square foot of dwelling unit conditioned floor area, or up to 500 W, whichever is greater.
2. Group R-2 dwelling or sleeping units having an installed HVAC heating capacity no greater than 750 watts in Climate Zone 4, and 1000 watts in Climate Zone 5, in any separate habitable room with exterior fenestration are permitted to be heated using electric resistance appliances. For buildings in locations with exterior design conditions below 4°F, an additional 250 watts above that allowed for Climate Zone 5 is permitted.

   2.1 A room within a dwelling or sleeping unit that has two primary walls facing different cardinal directions, each with exterior fenestration, is permitted to have an installed HVAC heating capacity no greater than 1000 watts in Climate Zone 4, and 1300 watts in Climate Zone 5. Bay windows and other minor offsets are not considered primary walls. For buildings in locations with exterior design conditions below 4°F, an additional 250 watts above that allowed for Climate Zone 5 is permitted.
3. Resistance heating elements integrated into unitary heat pump equipment.
4. Solar thermal systems.
5. Waste heat, radiant heat exchanger, and energy recovery systems.
6. Supplementary heat in accordance with Section R403.1.2.

7. Where there is no electric utility service available at the building site.
8. Heating systems that rely primarily on biomass are allowed in Climate Zone 5.

Modify Table R405.2 as follows:

Systems	
R403.1	Controls
R403.1.2	Heat pump supplemental heat
R403.3.2	Sealing
R403.3.1	Equipment and system sizing
R403.3.3	Duct testing
R403.3.4	Duct leakage
R403.3.5	Building cavities
R403.4	Mechanical system piping insulation
R403.5.1	Heated water circulation and temperature maintenance system
R403.6	Mechanical ventilation
R403.7	Equipment sizing and efficiency rating
R403.8	Systems serving multiple dwelling units
R403.9	Snow melt system controls
R403.10	Pool and permanent spa energy consumption
R403.11	Portable spas
R403.13	Heat pump space heating

R503.1.2 Heating and cooling systems. New heating, cooling and duct systems that are part of the alteration shall comply with Section R403.

Exceptions:

1. Where ducts from an existing heating and cooling system are extended, duct systems with less than 40 linear feet in unconditioned spaces shall not be required to be tested in accordance with Section R403.2.2.
2. Existing duct systems constructed, insulated, or sealed with asbestos.
3. Replacements of space heating equipment shall not be required to comply with Section R403.13 where the rated capacity of the new equipment does not exceed the rated capacity of the existing equipment.

3.1.2 Analysis

The PNNL analysis for the heat pump heating installs an 8.2 HSPF/14 SEER electric heat pump (federal minimum efficiency) in a residential prototype instead of a fossil fuel furnace (95 AFUE) or an electric resistance furnace (COP = 1) combined with a 13 SEER air conditioner. The additional efficiency options used in the heat pump analysis for the baseline case and updated case are shown in Table 6 and Table 7. Both the baseline and updated cases include all four foundation types. The baseline models use all four HVAC system types while the updated models use only heat pump systems. The energy credit options and corresponding credits values listed in the tables correspond to Table R406.3—Energy credits in the 2021 WSEC-R.

Table 6. Baseline model descriptions for Proposal 1

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0	0.0	2.0
1.6 (30% UA Reduction)	2.5	1.5	2.0	2.0
2.1 (2.0 ACH50 + HRV)	1.0	0.5	1.0	1.0
3.1 (95 AFUE Furnace)	1.0		1.0	
4.2 (Ducts in Conditioned Space)	1.5	1.0		
5.4 (NEEA Tier III HPWH)	2.0	2.0	2.5	2.5
Total Credits	**8.0**	**8.0**	**6.5**	**7.5**

Table 7. Updated model descriptions for Proposal 1

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table		3.0		2.0
1.6 (30% UA Reduction)		1.5		2.0
2.1 (2.0 ACH50 + HRV)		0.5		1.0
3.1 (95 AFUE Furnace)				
4.2 (Ducts in Conditioned Space)		1.0		
5.4 (NEEA Tier III HPWH)		2.0		2.5
Total Credits		**8.0**		**7.5**

3.1.3 Cost-effectiveness Results

The analysis for the heat pump space heating proposal shows that installing an 8.2 HSPF/14 SEER electric heat pump in a newly constructed home instead of a fossil fuel furnace (95 AFUE) or an electric resistance furnace (COP = 1) combined with a 13 SEER air conditioner will show an aggregated average annual energy cost increase of $27 based on Washington utility rates. The increase in annual energy cost is due to the increase in electric energy use by the heat pump for space heating with energy savings in the cooling mode.

For this analysis, the incremental costs for installing a heat pump include the avoided cost of installing the gas infrastructure in the fossil fuel prototypes. The prototypes with electric heating and credits for HPWH are fully electric and do not have any gas infrastructure as part of the model. As a result, construction costs for the electric heating systems do not include the avoided cost of installing the gas infrastructure since the baseline is already fully electric.

Single-Family Construction Costs:

- Install Heat Pump: $4,240
- Remove Furnace: $(3,128)
- Remove Air Conditioner: $(1,133)

- Avoided Gas Infrastructure: $(2,300)[1]
- Upgrade Electric Service: $700[1]
- **Fossil Fuel Prototype Construction Costs: $(1,621)**
- **Electric Prototype Construction Costs: $(21)**

Multifamily Construction Costs:

- Install Heat Pump: $3,151
- Remove Furnace: $(1,891)
- Remove Air Conditioner: $(1,065)
- Avoided Gas Infrastructure: $(2,300)
- Upgrade Electric Service: $700
- **Fossil Fuel Prototype Construction Costs: $(1,405)**
- **Electric Prototype Construction Costs: $195**

These costs show that installing the heat pump instead of a fossil fuel furnace shows significant construction cost savings when accounting for removal of the gas infrastructure. The electric furnace prototypes are considered fully electric and do not have any gas infrastructure in place. Table 8 shows the life cycle cost results for Proposal 1 heat pump analysis. The construction cost of -$1,015 shown in Table 8 is a weighted average of all construction costs across the building types, foundation types, and system types and will not exactly match the costs shown above. Annual electric consumption increased by 1,599 kWh, gas consumption decreased by 119 therms, and oil savings is 0.14 gallons.

The analysis shows that the reduced construction costs combined with a small annual energy cost increase is cost-effective with a life cycle cost savings of $115 and life cycle cost savings of the social cost of carbon at $577 for a total life cycle cost savings of $692.

Table 8. Proposal 1 for heat pump space heating cost-effectiveness results

Metric	Compared to the 2018 WSEC-R
Annual (first year) energy cost savings ($)	-$27
Life cycle cost savings ($)	$115
Social cost of carbon (SCC) life cycle cost savings ($)	$577
Total life cycle savings ($)	$692
Added construction cost ($)	-$1,015
First year carbon emissions savings (tons)	14.4
Simple payback period (yrs)	Immediate
Annual electric savings (kWh)	-1,599
Annual gas savings (therms)	119
Annual fuel oil savings (gallons)	0.14

[1] https://www.swenergy.org/pubs/heat-pump-study-2022

3.2 Proposal 2: Heat pump water heating (21-GP2-066)

Code change proposal 21-GP2-066 adds a new section that requires 100% of the water heating be provided by electric heat pump equipment for low-rise multifamily buildings. There are exceptions for various systems such as electric water heaters less than 20 gallons, dwelling units less than 1,000 sq ft, solar hot water systems, and supplemental water heating systems. The proposal adds a new section for supplementary water heating that is modeled on the existing section for supplementary space heating for heat pumps in the model IECC and adapted for the specifics of heat pumps used for water heating. This proposal is an effort to align with Washington State policy to increase energy efficiency by 70% and achieve the broader goal of building zero fossil-fuel greenhouse gas emission homes and buildings by the year 2031.

3.2.1 Heat Pump Water Heating Proposed Code Language

<u>**R403.5.4 Heat pump water heating.** Service hot water in one- and two-family dwellings and multiple single- family dwellings (townhouses) shall be provided by a heat pump system. The heat pump water heating system shall be sized to provide 100 percent of peak hot water demand. Where the heat pump is located in unconditioned space, the heat pump water heating system shall be sized to provide 100 percent of peak hot water demand at an entering source dry bulb (or wet bulb if rated for wet bulb temperatures) air temperature of 40°F (4°C).</u>

<u>**Exceptions:**</u>

- <u>Resistance heating elements integrated into heat pump equipment.</u>
- <u>Electric water heaters with a rated water storage volume of no greater than 20 gallons.</u>
- <u>Dwelling units with no more than 1,000 square feet of conditioned floor area.</u>
- <u>Supplementary water heating systems in accordance with R403.5.4.1, provided the system capacity does not exceed the capacity of the heat pump water heating system.</u>
- <u>Solar water heating systems</u>
- <u>Waste heat and energy recovery systems</u>
- <u>Heat trace freeze protection systems.</u>
- <u>Snow and ice melt systems.</u>

<u>**R403.5.4.1 Supplementary heat for heat pump water heating systems.** Heat pumps used for water heating and having supplementary water heating equipment shall have controls that limit supplemental supplementary water heating equipment operation to only those times when one of the following applies:</u>

1. <u>The heat pump water heater cannot meet hot water demand.</u>
2. <u>For heat pumps located in unconditioned space, the outside air temperature is below 40°F (4°C).</u>
3. <u>The heat pump is operating in defrost mode.</u>
4. <u>The vapor compression cycle malfunctions or loses power.</u>

<u>**Exception:** Heat trace temperature maintenance systems, provided the system capacity does not exceed the capacity of the heat pump water heating system.</u>

3.2.2 Analysis

The PNNL analysis for heat pump water heaters replaced all water heaters in the prototypes with heat pump water heaters (2.0 UEF) in single-family homes only. This level of heat pump water heater efficiency is equal to the level of efficiency for high performance service water heating option of R408 in the 2021 IECC. The PNNL prototypes use the same fuel for space heating and water heating. As a result, the electric systems use an electric resistance storage water heater, while the gas and oil systems use the same fuel respectively for storage water heaters. Instantaneous water heaters were not analyzed as part of this proposal. The prototype water heaters were all at the federal minimum efficiency level by fuel type. For the EnergyPlus simulations, heat pump water heaters were installed in conditioned space without venting so the chilled exhaust air was delivered to the conditioned space. This is a conservative approach, as Washington State homes are dominated by heating and many heat pump water installations will not be in the conditioned space.

The additional efficiency options used in the heat pump water heater analysis for the baseline case and updated case are shown in Table 9 and Table 10. Both the baseline and updated cases include all four foundation types. The baseline models use all four HVAC system types while the updated models use only heat pump systems. The energy credits listed in the tables correspond to Table R406.3—Energy credits in the 2021 WSEC-R. Note that given the efficiency of the heat pump water heater used in the analysis, no extra credit is allowed from R406, thus the same energy credit options are used in the baseline case and updated case.

Table 9. Baseline model descriptions for Proposal 2

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0		
1.6 (30% UA Reduction)	2.5	1.5		
2.1 (2.0 ACH50 + HRV)	1.0	0.5		
3.1 (95 AFUE Furnace)	1.0			
4.2 (Ducts in Conditioned Space)	1.5	1.0		
6.1 (2.4 kW PV System)	2.0	2.0		
Total Credits	**8.0**	**8.0**		

Table 10. Updated model descriptions for Proposal 2

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0		
1.6 (30% UA Reduction)	2.5	1.5		
2.1 (2.0 ACH50 + HRV)	1.0	0.5		
3.1 (95 AFUE Furnace)	1.0			
4.2 (Ducts in Conditioned Space)	1.5	1.0		
6.1 (2.4 kW PV System)	2.0	2.0		
Total Credits	**8.0**	**8.0**		

3.2.3 Cost-effectiveness Results

The PNNL analysis for the heat pump water heating proposal shows that installing a 2.0 UEF heat pump water heater in a newly constructed home instead of federal minimum efficiency gas and electric water heaters will show aggregated annual energy cost savings of $85 based on Washington utility rates. Aggregated annual electric energy consumption increased by 109 kWh but aggregated annual natural gas savings of 90 therms and oil savings of 0.18 gallons help show overall annual energy cost savings.

For this analysis, the incremental costs for installing a heat pump water heater and associated avoided costs of the gas infrastructure are shown below. Cost for the electric systems did not include the removal of gas infrastructure.

Single-Family Construction Costs:

- Incremental Cost of HPWH: $975
- Avoided Gas Infrastructure: $(451)
- **Fossil Fuel Prototype Construction Costs: $524**
- **Electric Prototype Construction Costs: $975**

These costs show that installing a heat pump water heater instead of a fossil fuel water heater can show reduced construction costs when accounting for removal of the gas piping for the gas water heater. The electric furnace prototypes are considered fully electric and do not have any gas infrastructure in place. Table 11 shows the life cycle cost results for Proposal 2 heat pump water heater analysis. The lower aggregated construction cost shown in Table 11 is higher because the electric system prototypes do not account for the removal of the gas infrastructure since they are already considered fully electric.

The analysis shows that installing a heat pump water heater with a 2.0 UEF instead of the federal minimum efficiency gas and electric water heaters can be cost-effective based on the added construction costs and annual energy savings. Life cycle cost savings are $426 and the life cycle cost savings of the social cost of carbon emission reduction is $644 for a total life cycle cost savings of $1,070.

Table 11. Proposal 2 - Heat pump water heater cost-effectiveness results

Metric	Compared to the 2018 WSEC-R
Annual (first year) energy cost savings ($)	$85
Life cycle cost savings ($)	$426
Social cost of carbon (SCC) life cycle cost savings ($)	$644
Total life cycle cost savings ($)	$1,070
Added construction cost ($)	$673
First year carbon emissions savings (tons)	14.1
Simple payback period (yrs)	7.9
Annual electric savings (kWh)	-109
Annual gas savings (therms)	90
Annual fuel oil savings (gallons)	0.18

3.3 Proposals 1 & 2 Combined (21-GP2-065 and 21-GP2-066)

To determine the cost-effectiveness of a fully electric home, a simulation analysis was performed on the combination of code change proposals 21-GP2-065 for heat pump space heating and 21-GP2-066 for heat pump water heating.

3.3.1 Analysis

This analysis combined code change proposals 21-GP2-065 for heat pump space heating and 21-GP2-066 for heat pump water heating. The specifications for these proposals described in the two prior sections are matched in this cost-effectiveness analysis. Given that heat pump water heater requirements from Proposal 2 are only for single-family buildings, this analysis considers only the single-family prototypes. The result of the analysis is a fully electric prototype, so the avoided costs of the unnecessary gas infrastructure are accounted for.

The additional efficiency options used in the combined proposal analysis for heat pump space heating and heat pump water heater for the baseline case and updated case are shown in

Table 12 and Table 13. Both the baseline and updated cases include all four foundation types. The baseline models use all four HVAC system types while the updated models use only heat pump space heating and heat pump water heating systems. The energy credits listed in the tables correspond to Table R406.3—Energy credits in the 2021 WSEC-R.

Table 12. Baseline model descriptions for Proposal 1 & 2 Combined

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0		
1.6 (30% UA Reduction)	2.5	1.5		
2.1 (2.0 ACH50 + HRV)	1.0	0.5		
3.1 (95 AFUE Furnace)	1.0			
4.2 (Ducts in Conditioned Space)	1.5	1.0		
6.1 (2.4 kW PV System)	2.0	2.0		
Total Credits	**8.0**	**8.0**		

Table 13. Updated model descriptions for Proposal 1 & 2 Combined

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table		3.0		
1.6 (30% UA Reduction)		1.5		
2.1 (2.0 ACH50 + HRV)		0.5		
3.1 (95 AFUE Furnace)				
4.2 (Ducts in Conditioned Space)		1.0		
6.1 (2.4 kW PV System)		2.0		
Total Credits		**8.0**		

3.3.2 Cost-effectiveness Results

The PNNL analysis for the combined heat pump space heating and heat pump water heating proposal shows that installing these systems in a newly constructed home instead of federal minimum efficiency gas and electric HVAC and water heating equipment have aggregated annual energy cost savings of $56 based on Washington utility rates. Aggregated annual electric energy consumption increased by 2,306 kWh but aggregated annual natural gas savings of 237 therms and oil savings of 0.36 gallons help show overall annual energy cost savings.

For this analysis, the incremental construction costs for installing a minimum federal efficiency heat pump for space heating and the 2.0 UEF heat pump water heater and associated costs for removal of the gas infrastructure are shown below.

Single-Family Construction Costs:

- Install Heat Pump: $4,240
- Remove Furnace: $(3,128)
- Remove Air Conditioner: $(1,133)
- Avoided Gas Infrastructure: $(2,300)
- Upgrade Electric Service: $700
- Incremental Cost of HPWH $975
- **Fossil Fuel Prototype Construction Costs: $(646)**
- **Electric Prototype Construction Costs: $(625)**

The construction costs show that installing a heat pump and heat pump water heater for all system types while accounting for removal of gas piping show an aggregated construction cost increase of $640. The aggregated construction cost considers all prototype heating system types. Table 14 shows the life cycle cost results for the combined heat pump space heating and heat pump water heating code change proposals.

The analysis shows that installing a minimum efficiency central heat pump system in combination with a heat pump water heater with a 2.0 UEF instead of the federal minimum efficiency HVAC and SWH systems are cost-effective based on the added construction costs and annual energy savings. Life cycle cost savings are $807 and the life cycle cost savings of the social cost of carbon emission reduction is $1,365 for a total life cycle cost savings of $2,172

Table 14. Combined heat pump and heat pump water heating cost-effectiveness results

Metric	Compared to the 2018 WSEC-R
Annual (first year) energy cost savings ($)	$56
Life cycle cost savings ($)	$807
Social cost of carbon (SCC) life cycle cost savings ($)	$1,365
Total life cycle cost savings ($)	$2,172
Added construction cost ($)	-$640
First year carbon emissions savings (tons)	32.0
Simple payback period (yrs)	Immediate
Annual electric savings (kWh)	-2,306
Annual gas savings (therms)	237
Annual fuel oil savings (gallons)	0.36

3.4 Proposal 3: Definitions Scope (21-GP2-084)

Code change proposal 21-GP2-084 would require low-rise multifamily (Group R-2) buildings accessed from interior corridors or other interior spaces to comply with the commercial provisions of the 2021 WSEC-C. Motivation for the proposed code change is that low-rise hotel/motel buildings are already being built to the commercial code and there is no reason for 3-story and 4-story residential buildings to be built under different code requirements. The inclusion of low-rise multifamily buildings into the commercial code would result in similar annual energy use. The proposed code change will provide a uniform set of code requirements for all multifamily buildings except for buildings that have exterior access to the dwelling units.

3.4.1 Definitions Scope Proposed Code Language

RESIDENTIAL BUILDING. For this code, the following building types are residential buildings:

1. Detached one- and two-family dwellings
2. Multiple single-family dwellings (townhouses)
3. Group R-3 and R-4 buildings three stories or less in height above grade plane
4. Group R-2 buildings three stories or less in height above grade plane whose dwelling units are accessed directly from the exterior
5. Accessory structures to residential buildings

Group R-2 buildings with dwelling units accessed from interior corridors or other interior spaces are not residential buildings.

R401.1 Scope. This chapter applies to residential buildings. Group R-2 buildings with dwelling units accessed from interior corridors or other interior spaces must comply with the WSEC--Commercial Provisions.

3.4.2 Analysis

As mentioned earlier, Proposal 21-GP2-084 would require low-rise multifamily buildings accessed from interior corridors or spaces to be built to the commercial provisions of the code. To run a cost-effectiveness analysis for this proposal, the PNNL multifamily prototype building would need to be configured to the residential provisions in the baseline case and the commercial provisions in the updated case. Each prototype would require the appropriate additional efficiency credits from the residential and commercial codes respectively. The team thus determined a set of 2021 WSEC-C commercial code specifications for the low-rise multifamily building. Table 15 shows the low-rise multifamily building specifications for the residential baseline case and the updated commercial prototype. Both residential and commercial specifications include the additional efficiency options required for each code. All unmentioned specifications are matched between the residential and commercial codes.

Table 15. Residential and Commercial Specifications for Low-Rise Multifamily

Multifamily Prototype	2021 WSEC-R Residential Baseline	2021 WSEC-C Commercial Update
Fenestration U-factor	0.20*	0.26
Fenestration SHGC	0.40	0.38
Skylight U-factor	0.5	0.5
Ceiling Insulation R-Value	R-60	R-49
Wood Frame Wall R-Value	R-20+5	R-20+3.8
Frame Floor R-Value	R-30	R-30
Below Grade Wall R-Value	R-21+5	R-20+3.8
Slab R-Value and Depth	R-10 at 4 ft	R-10 at 2 ft
Infiltration	2.0 ACH50*	0.25 @ 75 Pa (4.0 ACH50)
Ventilation	HRV 65% SRE*	HRV 60% SRE
Heat Pump System	8.2 HSPF/14 SEER	8.2 HSPF/14 SEER
Service Water Heating System	NEEA Tier III HPWH*	NEEA Tier III HPWH*
Hot Water Consumption (gal/day)	25.5+8.5xNbr	25.5+8.5xNbr
Interior Lighting (W)	100% High Efficacy	0.41 W/sq ft
Exterior Lighting (W)	306 W	306 W
Duct Leakage	4 CFM25/100 sq ft	8 CFM25/100 sq ft
Duct Location	Conditioned Space*	Conditioned Space

*Denotes a change to the prescriptive requirements of WSEC-R/WSEC-C 2021 based on the credit options selected below in Table 16 and Table 17.

The additional efficiency options used in the low-rise multifamily commercial code analysis for the baseline case and updated case are shown in Table 16 and Table 17. Both the baseline and updated cases include all four foundation types but are run only for the heat pump systems given the new requirement for heat pump systems. The energy credits listed in the tables correspond to Table R406.3—Energy credits in the 2021 WSEC-R and Table C406.2—Efficiency Measure Credits in the 2021 WSEC-C.

Table 16. Baseline model descriptions for Proposal 3

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table				2.0
1.2 (Window U-Factor of 0.20)				1.0
2.1 (2.0 ACH50 + HRV)				1.0
5.4 (NEEA Tier III HPWH)				2.5
Total Credits				**6.5**

Table 17. Updated model descriptions for Proposal 3

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
C406.2.6.3 (Heat Pump Water Heating)				261
Total Credits				**261**

3.4.3 Cost-effectiveness Results

The PNNL analysis for the low-rise multifamily building commercial code requirement shows that constructing a low-rise multifamily building to the commercial provisions of the WSEC-C instead of the WSEC-R has aggregated annual energy cost increase of $44 based on Washington utility rates. Aggregated annual electric energy consumption increased by 459 kWh. A low-rise multifamily building built under the commercial code shows slightly higher energy use and energy use costs than being built to the residential code as suggested in the code change proposal reasoning.

For this analysis, the incremental construction costs for building the low-rise multifamily building prototype to the commercial provisions of WSEC-C are shown below. The cost changes are based on the code changes as well as additional efficiency options for residential and commercial provisions. The prices below represent dwelling unit costs and not building level costs.

Multifamily Construction Costs:

- Window change (U-factor 0.2 to 0.26: $(100)
- Ceiling R-Value change (R-60 to R-49): $(612)
- Wood Frame Wall R-Value change (R-20+5 to R-20+3.8): $(264)
- Below Grade Wall R-Value change (R21+5 to R-20+3.8): $(160)
- Slab Insulation Depth change (4ft to 2 ft): $(76)
- Infiltration Change (2 ACH50 to 4 ACH50): $(439)
- Duct leakage change (4 CFM25/100 sq ft to 8 CFM25/100 sq ft): $(161)
- **Total construction cost due to changes: $(1,812)**

The construction costs show that moving a low-rise multifamily building access from interior corridors or spaces from the residential code to the commercial code show an aggregated construction cost savings of $1,812. Table 18 shows the life cycle cost results for the code change proposal to move low-rise multifamily buildings to the commercial code.

The analysis shows that this proposal can be cost-effective based on the reduced construction costs with higher annual energy savings. Life cycle cost savings are $404 but the life cycle cost savings of the social cost of carbon emission increased by $87 due to the increase in electric energy consumption of 459 kWh. Thus, the total life cycle cost savings including social cost of carbon is $317.

Table 18. Proposal 3 – Definitions Scope Cost-Effectiveness Results

Metric	Compared to the 2021 WSEC-R
Annual (first year) energy cost savings ($)	-$44
Life cycle cost savings ($)	$404
Social cost of carbon (SCC) life cycle cost savings ($)	-$87
Total life cycle cost savings ($)	$317
Added construction cost ($)	-$1,812
Simple payback period (yrs)	Immediate
Annual electric savings (kWh)	-459
Annual gas savings (therms)	0
Annual fuel oil savings (gallons)	0

3.5 Proposal 5: Updated R406 measures (21-GP2-073)

Code change proposal 21-GP2-073 changes two sections of the WSEC-R. Code changes to Section R405.3 increase the stringency of the performance-based carbon emissions requirements compared to the standard reference design. Code changes to Section R406 update the requirements for additional energy efficiency options. The energy credit requirements have increased for all dwelling unit sizes while the energy credit values in Tables R406.2 and R406.3 have been reassigned based on simulation analysis. Envelope credits were reassigned based on more stringent prescriptive requirements. All credits were broken out between two space heating system categories. The R406 code change proposal is expected to result in a 10% energy reduction over a 2006 WSEC-R compliant home. These savings are primarily attributed to the credits required to comply with the 2021 WSEC-R in Section R406.3, along with prescriptive envelope upgrades.

3.5.1 Updated R406 Measures Proposed Code Language

R405.3 Performance-based compliance. Compliance based on simulated energy performance requires:

1. The requirements of the sections indicated within Table R405.2
2. For structures less than 1,500 square feet of conditioned floor area, the annual carbon emissions shall be less than or equal to 64 percent of the annual carbon emissions of the standard reference design.
3. For structures 1,500 to 5,000 square feet of conditioned floor area, the annual carbon emissions shall be no more than 47 percent of the standard reference design.
4. For structures over 5,000 square feet of conditioned floor area, the annual carbon emissions shall be no more than 41 percent of the standard reference design.
5. For structures serving Group R-2 occupancies, the annual carbon emissions shall be less than or equal to 61 percent of the annual carbon emissions of the standard reference design.

ADDITIONAL ENERGY EFFICIENCY REQUIREMENTS

R406.1 Scope. This section establishes additional energy efficiency requirements for all new construction covered by this code, including additions subject to Section R502 and change of occupancy or use subject to Section R505 unless specifically exempted in Section R406. Credit from both Sections R406.2 and R406.3 are required.

R406.2 Carbon emission equalization. This section establishes a base equalization between fuels used to define the equivalent carbon emissions of the options specified. The permit shall define the base fuel selection to be used and the points specified in Table R406.2 shall be used to modify the requirements in Section R406.3.

R406.3 Additional energy efficiency requirements. Each dwelling unit in a residential building shall comply with sufficient options from Table R406.2 and R406.3 so as to achieve the following minimum number of credits:

1. Small Dwelling Unit: .... 5.0 credits
   Dwelling units less than 1500 square feet in conditioned floor area with less than 300 square feet of fenestration area. Additions to existing building greater than 500 square feet of heated floor area but less than 1500 square feet.
2. Medium Dwelling Unit: .... 8.0 credits
   All dwelling units that are not included in #1, #3 or #4.
3. Large Dwelling Unit: .... 9.0 credits
   Dwelling units exceeding 5000 square feet of conditioned floor area.
4. Dwelling units serving R-2 occupancies: .... 6.5 credits
5. Additions less than or equal to 100 to 500 square feet: .... 2.0 credits

3.5.2 Analysis

There are multiple paths for buildings to comply with section R406 that yield varying cost-effectiveness results. Since there are so many possible combinations of credits to meet the code requirements, only one needs to be confirmed to show the code change proposal is cost-effective. The analysis compared the levels of credit requirements for single-family and multifamily prototypes in the 2018 WSEC-R and those required by the code change proposal for 2021 WSEC-R. For this proposal, three different prototype configurations were considered for compliance with section R406. Option 1 utilizes mixed-fuel prototypes in both the baseline and updated cases. Options 2 and 3 both utilize fully electric prototypes with varying combinations of credit options to determine cost-effectiveness.

3.5.2.1 Option 1

The additional efficiency options used for Option 1 of the R406 update proposal analysis for the baseline case and updated case are shown in Table 19 and Table 20. Both the baseline and updated cases include all four system types and foundation types. The energy credits listed in the tables correspond to Table R406.3—Energy credits in the 2021 WSEC-R.

Table 19. Baseline model descriptions for Proposal 5 (Option 1)

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0	0.0	2.0
1.6 (30% UA Reduction)	2.5	1.5		
2.1 (2.0 ACH50 + HRV)	1.0	0.5		
3.1 (95 AFUE Furnace)	1.0		1.0	
4.2 (Ducts in Conditioned Space)	1.5	1.0		
5.4 (NEEA Tier III HPWH)			2.5	2.5
6.1 (1.2 kW PV System)			1.0	
Total Credits	**6.0**	**6.0**	**4.5**	**4.5**

Table 20. Updated model descriptions for Proposal 5 (Option 1)

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0	0.0	2.0
1.2 (Window U-Factor at 0.20)			1.0	1.0
1.6 (30% UA Reduction)	2.5	1.5		
2.1 (2.0 ACH50 + HRV)	1.0	0.5	1.0	1.0
3.1 (95 AFUE Furnace)	1.0		1.0	
4.2 (Ducts in Conditioned Space)	1.5	1.0		
5.4 (NEEA Tier III HPWH)	2.0	2.0	2.5	2.5
6.1 (1.2 kW PV System)			1.0	
Total Credits	**8.0**	**8.0**	**6.5**	**6.5**

3.5.2.2 Option 2

The additional efficiency options used for Option 2 of the R406 update proposal analysis for the baseline case and updated case are shown in Table 21 and Table 22. Both the baseline and updated cases include all four system types and foundation types.

Table 21. Baseline model descriptions for Proposal 5 (Option 2)

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0	0.0	2.0
1.2 (Window U-Factor at 0.20)			1.0	
1.6 (30% UA Reduction)	2.5	1.5		
2.1 (2.0 ACH50 + HRV)	1.0	0.5	1.0	
3.1 (95 AFUE Furnace)	1.0		1.0	
4.2 (Ducts in Conditioned Space)	1.5	1.0		
5.4 (NEEA Tier III HPWH)			2.5	2.5
Total Credits	**6.0**	**6.0**	**5.5**	**4.5**

Table 22. Updated model descriptions for Proposal 5 (Option 2)

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table		3.0		2.0
1.2 (Window U-Factor at 0.20)				1.0
1.6 (30% UA Reduction)		1.5		
2.1 (2.0 ACH50 + HRV)		0.5		1.0
3.1 (95 AFUE Furnace)				
4.2 (Ducts in Conditioned Space)		1.0		
5.4 (NEEA Tier III HPWH)		2.0		2.5
Total Credits		**8.0**		**6.5**

3.5.2.3 Option 3

The additional efficiency options used for Option 3 of the R406 update proposal analysis for the baseline case and updated case are shown in Table 23 and Table 24. Both the baseline and updated cases include all four system types and foundation types.

Table 23. Baseline model descriptions for Proposal 5 (Option 3)

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0	0.0	2.0
1.2 (Window U-Factor at 0.20)			1.0	
1.6 (30% UA Reduction)	2.5	1.5		
2.1 (2.0 ACH50 + HRV)	1.0	0.5	1.0	
3.1 (95 AFUE Furnace)	1.0		1.0	
4.2 (Ducts in Conditioned Space)	1.5	1.0		
5.4 (NEEA Tier III HPWH)			2.5	2.5
Total Credits	**6.0**	**6.0**	**5.5**	**4.5**

Table 24. Updated model descriptions for Proposal 5 (Option 3)

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table		3.0		2.0
1.1 (Window U-Factor at 0.24)				0.5
1.6 (30% UA Reduction)		1.5		
2.1 (2.0 ACH50 + HRV)		0.5		
4.2 (Ducts in Conditioned Space)		1.0		
5.4 (NEEA Tier III HPWH)		2.0		2.5
7.1 (ENERGY STAR Appliances)				1.5
Total Credits		**8.0**		**6.5**

3.5.3 Cost-effectiveness Results

3.5.3.1 Option 1

The PNNL analysis for Option 1 configuration of the code change proposal to update the additional energy credits requirement shows aggregated annual energy cost savings of $95 based on Washington utility rates.

For this analysis, the incremental construction costs for the Option 1 configuration of additional efficiency credits are shown below. The cost changes are based purely on the additional efficiency credit requirements for the 2018 WSEC-R and those required in the code change proposal. In the baseline case, single-family credits totaled 6.5 credits and 4.5 credits for multifamily dwelling units. In the updated case, single-family credits totaled 8 credits and 6 credits for the multifamily dwelling units. The prices below represent dwelling unit costs and not building level costs.

Single-Family Construction Costs:

- Install NEEA Tier III HPWH – 80 gallons: $1,900
- **Total Construction Cost: $1,900**

Multifamily Construction Costs:

- Upgrade Window U-Factor 0.3 to 0.2: $100
- Reduce infiltration to 2.0 ACH50 $440
- Add HRV at 65% SRE $1,040
- **Total Construction Cost: $1,580**

Table 25 shows the life cycle cost results for the R406 code change proposal to update the additional efficiency credit requirements. The results show that Option 1 of the R406 updated additional energy credits produce an aggregated construction cost increase of $1,851.

The analysis shows that this proposal is not quite cost-effective even with life cycle cost savings of the social cost of carbon. Life cycle cost savings are -$970 while life cycle cost savings of the social cost of carbon are $566 for a total life cycle cost savings of -$404. It appears that the energy savings for Option 1 are not quite high enough for positive life cycle cost savings given the large added construction costs.

Table 25. Proposal 5 – Updated R406 measures cost-effectiveness results (Option 1)

Metric	Compared to the 2018 WSEC-R
Annual (first year) energy cost savings ($)	$95
Life cycle cost savings ($)	-$970
Social cost of carbon (SCC) life cycle cost savings ($)	$566
Total life cycle cost savings	-$404
Added construction cost ($)	$1,851
First year carbon emissions savings (tons)	11.8
Simple payback period (yrs)	20
Annual electric savings (kWh)	337
Annual gas savings (therms)	68
Annual fuel oil savings (gallons)	0.15

3.5.3.2 Option 2

The PNNL analysis for Option 2 configuration of the code change proposal to update the additional energy credits requirement shows aggregated annual energy cost savings of $53 based on Washington utility rates.

The incremental construction costs for the Option 2 configuration of additional efficiency credits are shown below. The cost changes are based on the additional efficiency credit requirements for the 2018 WSEC-R and those required in the code change proposal. Since all system types will move to electric, cost savings from the gas infrastructure and added costs for electric service upgrades are included. In the baseline case, single-family credits totaled

6.5 credits and 4.5 credits for multifamily dwelling units. In the updated case, single-family credits totaled 8 credits and 6 credits for the multifamily dwelling units. The prices below represent dwelling unit costs and not building level costs.

The construction costs for the fossil fuel prototypes with the updated energy credits include the avoided cost of installing the gas infrastructure. The prototypes with electric heating are considered fully electric and do not have any gas infrastructure as part of the model. As a result, construction costs for the electric heating systems do not include the avoided cost of installing the gas infrastructure since the baseline is already considered fully electric.

Single-Family Construction Costs:

- Install NEEA Tier III HPWH – 80 gallons: $1,900
- Install Federal Minimum Efficiency Heat Pump: $4,240
- Remove 95 AFUE Furnace: $(3,633)
- Remove 13 SEER Air Conditioner: $(1,133)
- Remove Gas Infrastructure: $(2,300)
- Upgrade Electric Service: $700
- **Fossil Fuel Prototype Construction Costs: $(226)**
- **Electric Prototype Construction Costs: $1,375**

Multifamily Construction Costs:

- Install Federal Minimum Efficiency Heat Pump: $3,151
- Add HRV at 65% SRE $1,040
- Remove 95 AFUE Furnace: $(1,891)
- Remove 13 SEER Air Conditioner: $(1,065)
- Remove Gas Infrastructure: $(2,300)
- Upgrade Electric Service: $700
- **Fossil Fuel Prototype Construction Costs: $(365)**
- **Electric Prototype Construction Costs: $1,775**

Table 26 shows the life cycle cost results for the R406 code change proposal to update the additional efficiency credit requirements. The results show that Option 2 of the R406 updated additional energy credits produce a weighted average construction cost increase of $411. The higher costs for the electric prototypes are due to the fact that these prototypes are considered fully electric in the baseline case.

The analysis shows that this proposal is cost-effective. Life cycle cost savings are -$529 while life cycle cost savings of the social cost of carbon are $991 for a total life cycle cost savings of $462.

Table 26. Proposal 5 – Updated R406 measures cost-effectiveness results (Option 2)

Metric	Compared to the 2018 WSEC-R
Annual (first year) energy cost savings ($)	$53
Life cycle cost savings ($)	-$529
Social cost of carbon (SCC) life cycle cost savings ($)	$991
Total life cycle cost savings	$462
Added construction cost ($)	$411
First year carbon emissions savings (tons)	23.0
Simple payback period (yrs)	8
Annual electric savings (kWh)	-1,298
Annual gas savings (therms)	168
Annual fuel oil savings (gallons)	0.24

3.5.3.3 Option 3

The PNNL analysis for Option 3 configuration of the code change proposal to update the additional energy credits requirement shows aggregated annual energy cost savings of $113 based on Washington utility rates. Aggregated annual electric energy consumption increased by 678 kWh but with natural gas savings of 168 therms and fuel oil savings of 0.24 gallons.

The incremental construction costs for the Option 3 configuration of additional efficiency credits are shown below. The cost changes are based on the additional efficiency credit requirements for the 2018 WSEC-R and those required in the code change proposal. Since all system types will move to electric, cost savings from the gas infrastructure and added costs for electric service upgrades are included. In the baseline case, single-family credits totaled 6.5 credits and 4.5 credits for multifamily dwelling units. In the updated case, single-family credits totaled 8 credits and 6 credits for the multifamily dwelling units. The construction costs for the fossil fuel prototypes with the updated energy credits include the avoided cost of installing the gas infrastructure. The prototypes with electric heating are considered fully electric and do not have any gas infrastructure as part of the model. As a result, construction costs for the electric heating systems do not include the avoided cost of installing the gas infrastructure since the baseline is already considered fully electric.

Single-Family Construction Costs:

- Install NEEA Tier III HPWH – 80 gallons: $1,900
- Install Federal Minimum Efficiency Heat Pump: $4,240
- Remove 95 AFUE Furnace: $(3,633)
- Remove 13 SEER Air Conditioner: $(1,133)
- Remove Gas Infrastructure: $(2,300)
- Upgrade Electric Service: $700
- **Fossil Fuel Prototype Construction Costs: $(226)**
- **Electric Prototype Construction Costs: $1,375**

Multifamily Construction Costs:

- Install Federal Minimum Efficiency Heat Pump: $3,151
- Add HRV at 65% SRE $1,040
- Remove 95 AFUE Furnace: $(1,891)
- Remove 13 SEER Air Conditioner: $(1,065)
- Remove Gas Infrastructure: $(2,300)
- Upgrade Electric Service: $700
- **Fossil Fuel Prototype Construction Costs: $(1,588)**
- **Electric Prototype Construction Costs: $357**

Table 27 shows the life cycle cost results of the R406 code change proposal to update the additional efficiency credit requirements. The results show that Option 3 of the R406 updated additional energy credits produce an aggregated construction cost decrease of $209. The final construction costs shown in Table 27 and used in the cost-effectiveness analysis are based on the weighted average of all system types. The prototypes with electric systems are considered fully electric and do not have the removal of the gas infrastructure costs.

The analysis shows that based on Option 3 energy credit configuration, the energy credits code change proposal can be cost-effective. As with any energy credit structure, there are configurations that will be cost-effective and configurations that are not. If there is one configuration of energy credits that is shown to be cost-effective, the proposal overall is cost-effective. Life cycle cost savings are $1,988 with life cycle cost savings of the social cost of carbon are $1,109 for a total life cycle cost savings of $3,097.

Table 27. Proposal 5 – Updated R406 measures cost-effectiveness results (Option 3)

Metric	Compared to the 2018 WSEC-R
Annual (first year) energy cost savings ($)	$113
Life cycle cost savings ($)	$1,988
Social cost of carbon (SCC) life cycle cost savings ($)	$1,109
Total life cycle cost savings	$3,097
Added construction cost ($)	-$209
First year carbon emissions savings (tons)	24.8
Simple payback period (yrs)	Immediate
Annual electric savings (kWh)	-678
Annual gas savings (therms)	168
Annual fuel oil savings (gallons)	0.24

3.6 Proposal 6: Reduced infiltration (21-GP2-089)

The code change proposal 21-GP2-089 aligns the maximum allowed leakage rate for prescriptive and performance compliance paths per R401.2 to 3.0 ACH50 or 0.25 CFM25/sq ft of dwelling unit enclosure area. This proposal also requires multifamily buildings with dwelling units accessed from the outdoors to comply with the commercial provisions for air leakage in the WSEC-C.

Prior to any analysis conducted for code change proposal 21-GP2-089, the SBCC voted to adjust the maximum allowed leakage rate from 3.0 ACH50 to 4.0 ACH50. Air leakage for the multifamily dwelling units remained at 0.25 CFM25/sq ft of dwelling unit enclosure area. The PNNL cost-effectiveness simulation analysis was modified to account for the updated approved air leakage rates of 4.0 ACH50 and 0.25 CFM50/100 sq ft of dwelling unit enclosure area.

3.6.1 Reduced Infiltration Proposed Code Language

R402.4.1 Building thermal envelope. The building thermal envelope shall comply with Sections R402.4.1.1 through R402.4.1.3. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.

> **R402.4.1.1 Installation.** The components of the building thermal envelope as listed in Table R402.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table R402.4.1.1, as applicable to the method of construction. Where required by the code official, an approved third party shall inspect all components and verify compliance.
>
> **R402.4.1.2 Testing.** The building or dwelling unit shall be tested for air leakage. The maximum air leakage rate for any building or dwelling unit under any compliance path shall not exceed <u>4.0</u> air changes per hour. Testing shall be conducted with a blower door at a pressure of 0.2 inches w.g. (50 Pascals). Where required by the code official, testing shall be conducted by an approved third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the code official. Testing shall be performed at any time after creation of all penetrations of the building thermal envelope. Once visual inspection has confirmed sealing (see Table R402.4.1.1), operable windows and doors manufactured by small business shall be permitted to be sealed off at the frame prior to the test.
>
> **Exception**: For dwelling units that are accessed directly from the outdoors, other than detached one family dwellings and townhouses, an air leakage rate not exceeding <u>0.25</u> cfm per square foot of the dwelling unit enclosure area shall be an allowable alternative. Testing shall be conducted with a blower door at a pressure of 0.2 inches w.g. (50 Pascals) in accordance with RESNET/ICC 380, ASTM E779 or ASTM E1827. Doors and windows of adjacent dwelling units (including top and bottom units) shall be open to the outside during the test. This exception is not permitted for dwelling units that are accessed from corridors or other enclosed common areas.

<u>Group R-2 multifamily buildings where dwelling units are accessed from a central corridor or other enclosed common area shall comply with Section C402.5.3.</u>

3.6.2 Analysis

The PNNL analysis for the code change proposal to reduce the maximum air leakage rates simply reduced the air leakage in the prototypes to 4.0 ACH50 for single-family and 0.25 CFM50/100 sq ft of enclosure area for the multifamily dwelling units.

The additional efficiency options used in the reduced air leakage code change proposal analysis for the baseline case and updated case are shown in Table 28 and Table 29. Both the baseline and updated cases include all four foundation types and four system types. The energy credits listed in the tables correspond to Table R406.3—Energy credits in the 2021 WSEC-R. Given that an air leakage rate of 4.0 ACH50 does not qualify for any additional efficiency credit, the same credits are used for the baseline and updated case.

Table 28. Baseline model descriptions for Proposal 6

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0	0.0	2.0
1.6 (30% UA Reduction)	2.5	1.5	2.0	2.0
3.1 (95 AFUE Furnace)	1.0		1.0	
4.2 (Ducts in Conditioned Space)	1.5	1.0		
5.4 (NEEA Tier III HPWH)	2.0	2.0	2.5	2.5
Total Credits	**7.0**	**7.5**	**5.5**	**6.5**

Table 29. Updated model descriptions for Proposal 6

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0	0.0	2.0
1.6 (30% UA Reduction)	2.5	1.5	2.0	2.0
3.1 (95 AFUE Furnace)	1.0		1.0	
4.2 (Ducts in Conditioned Space)	1.5	1.0		
5.4 (NEEA Tier III HPWH)	2.0	2.0	2.5	2.5
Total Credits	**7.0**	**7.5**	**5.5**	**6.5**

3.6.3 Cost-effectiveness Results

The PNNL analysis for the reduced air leakage code change proposal shows aggregated annual energy cost savings of $26 based on Washington utility rates. Aggregated annual electric energy consumption decreased by 102 kWh with natural gas savings of 15 therms and fuel oil savings of 0.03 gallons.

For this analysis, the construction costs for the reduced air leakage are shown below for single-family and multifamily prototypes. The cost changes are based purely on the additional efficiency credit requirements for the 2018 WSEC-R and those required in the code change proposal. In the baseline case, single-family credits totaled 6.5 credits and 4.5 credits for multifamily dwelling units. In the updated case, single-family credits totaled 8 credits and 6 credits for the multifamily dwelling units.

Single-Family Construction Costs per Home:

- Reduce air leakage 5 ACH50 to 4 ACH50: $1,267

Multifamily Construction Costs per Dwelling Unit:

- Reduce air leakage to 0.25 CFM50/100 sq ft $315

Table 30 shows the life cycle cost results for the code change proposal to reduce the maximum tested air leakage rate. The overall construction cost for this proposal was a weighted average of the single-family and multifamily prototypes in the state of Washington which totaled $813.

The analysis shows that the code change proposal for reduced air leakage is cost-effective considering the savings for the social cost of carbon. Life cycle cost savings are -$16 with life cycle cost savings of the social cost of carbon are $129 for a total life cycle cost savings of $113.

Table 30. Proposal 6 – Reduced infiltration cost-effectiveness results

Metric	Compared to the 2018 WSEC-R
Annual (first year) energy cost savings ($)	$26
Life cycle cost savings ($)	-$16
Social cost of carbon (SCC) life cycle cost savings ($)	$129
Total life cycle cost savings	$113
Added construction cost ($)	$813
First year carbon emissions savings (tons)	2.7
Simple payback period (yrs)	32
Annual electric savings (kWh)	102
Annual gas savings (therms)	15
Annual fuel oil savings (gallons)	0.03

3.7 Proposal 7: Water heaters in conditioned space (21-GP2-080)

Code change proposal 21-GP2-080 adds a requirement for water heaters to be installed within the building thermal envelope to alleviate standby losses to unconditioned spaces throughout the year. The requirement for water heater location inside conditioned space, similar to locating heating ducts inside conditioned space, minimizes standby losses as they are absorbed into the conditioned space. While manufacturers have increased tank insulation levels, water heaters still lose heat to the space throughout the year and provide an unnecessary source of wasted energy. An exception to the water heater location requirement is given for efficient water heaters that can operate in unconditioned spaces where the net benefit of standby losses is overcome by the efficiency of the unit performance. Standby losses from storage water heaters continue to be a source of wasted energy and occur year-round regardless of location.

3.7.1 Water Heaters in Conditioned Space Proposed Code Language

R403.5 Service hot water systems. Energy conservation measures for service hot water systems shall be in accordance with Sections R403.5.1 through R403.5.5. Service water-heating equipment shall meet the requirements of DOE 10 CFR Part 430 Uniform Energy Factor or the equipment shall meet the requirements of Section C404.2.

> **R403.5.5 Water heater installation location.** Service hot water systems shall be installed within the building thermal envelope.
>
> **Exceptions**: Where the hot water system efficiency is greater than or equal to 2.0 UEF.
>
> **R503.1.3 Service hot water systems.** New service hot water systems that are part of the alteration shall comply with Section R403.5.
>
> **Exception**: Replacement hot water heaters are not required to meet the requirements of Section R403.5.5.

3.7.2 Analysis

The PNNL prototypes for single-family and multifamily buildings have water heaters located inside conditioned space. The 2020 Residential Energy Consumption Survey (RECS) microdata for the state of Washington show that water heaters are equally split between the garage and conditioned space so there is a lot of potential for energy savings by moving them to conditioned space.[1] The PNNL multifamily prototypes all use individual water heaters located within each unit, which would always be located within the building thermal envelope, so this code change proposal was analyzed only for single-family prototypes. Only the unheated basement foundation type was simulated because that is the only single-family prototype with an unconditioned space outside of the building thermal envelope. The PNNL prototypes do not contain any garage space to look at water heaters in this location.

The cost-effectiveness analysis for the water heater location code change proposal analyzed the standard fossil fuel and electric water heaters within the PNNL prototypes in the unheated basement compared to locations in conditioned space. Heat pump water heaters are allowed to be located outside the thermal envelope due to their higher efficiency and were not analyzed for this proposal.

The analysis for the water heater location code change proposal simulated the standard fossil fuel and electric hot water heaters in two locations: an unheated basement and conditioned space. The additional efficiency options used in the analysis for the baseline case and updated case are shown in Table 31 and Table 32. Both the baseline and updated cases include all four foundation types and four system types. The energy credits listed in the tables correspond to Table R406.3—Energy credits in the 2021 WSEC-R. Since there is no energy credit benefit from locating water heaters in conditioned space, both the baseline and updated cases utilized the same energy credits.

[1] https://www.eia.gov/consumption/residential/data/2020/index.php?view=microdata

Table 31. Baseline model descriptions for Proposal 7

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0		
1.6 (30% UA Reduction)	2.5	1.5		
2.1 (2.0 ACH50 + HRV)	1.0	0.5		
3.1 (95 AFUE Furnace)	1.0			
4.2 (Ducts in Conditioned Space)	1.5	1.0		
6.1 (2.4 kW PV System)	2.0	2.0		
Total Credits	**8.0**	**8.0**		

Table 32. Updated model descriptions for Proposal 7

Credits	Single-Family Fossil Fuel	Single-Family Electric	Multifamily Fossil Fuel	Multifamily Electric
Fuel Normalization Table	0.0	3.0		
1.6 (30% UA Reduction)	2.5	1.5		
2.1 (2.0 ACH50 + HRV)	1.0	0.5		
3.1 (95 AFUE Furnace)	1.0			
4.2 (Ducts in Conditioned Space)	1.5	1.0		
6.1 (2.4 kW PV System)	2.0	2.0		
Total Credits	**8.0**	**8.0**		

3.7.3 Cost-effectiveness Results

The analysis for the water heater location code change proposal shows that moving water heaters into conditioned space shows aggregated annual energy cost savings of $16 based on Washington utility rates. Aggregated annual electric energy consumption increased by 68 kWh due to increases in cooling and cooling fan energy because of heat gains from the hot water heater in conditioned space. Natural gas energy decreased by 21 therms and fuel oil savings of 0.04 gallons.

For this analysis, the construction costs for the moving the water heater into conditioned space was assumed to be zero.

Table 35 shows the life cycle cost results for the code change proposal to require water heaters to be located in conditioned space. The analysis shows that the code change proposal for requiring water heaters installed in conditioned space is cost-effective considering the added construction costs are $0. Life cycle cost savings are $16 with life cycle cost savings of the social cost of carbon are $454 for a total life cycle cost savings of $597.

Table 33. Proposal 7 – Water heaters in conditioned space cost-effectiveness results

Metric	Compared to the 2018 WSEC-R
Annual (first year) energy cost savings ($)	$16
Life cycle cost savings ($)	$454
Social cost of carbon (SCC) life cycle cost savings ($)	$143
Total life cycle cost savings ($)	$597
Added construction cost ($)	$0
Simple payback period (yrs)	Immediate
First year carbon emissions savings (tons)	3.2
Annual electric savings (kWh)	-68
Annual gas savings (therms)	21
Annual fuel oil savings (gallons)	0.04

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