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PNNL-33917

Cost-Benefit Analysis of the 2021 Washington State Energy Code – Commercial Provisions

February 2023

M Tyler
D Maddox

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Prepared for
the Washington State Department of Enterprise Services

Pacific Northwest National Laboratory
Richland, Washington 99354

Contents

1.0 Introduction

The state of Washington is updating their current state commercial energy code. They will be moving from the 2018 Washington State Energy Code (2018 WSEC-C) to the 2021 WSEC-C. The Washington State Building Code Council (SBCC) requested that Pacific Northwest National Laboratory (PNNL) perform an independent analysis of the energy, economic, and emissions impacts of the code changes between the 2018 WSEC-C and 2021 WSEC-C. This report assesses the life cycle costs and savings and greenhouse gas emissions impacts of those code changes.

1.1 2021 WSEC-C Proposals

Table 1 lists the code changes included in this analysis. These code changes are a subset of all changes from 2018 WSEC-C to 2021 WSEC-C and focus on those with high costs and/or high energy savings. They represent most of the energy and cost impacts of the code changes.

Table 1. Code Changes Included in Analysis

Proposal ID or Code Location	Description
21-GP1-69	HVAC TSPR
21-GP1-78	On-Site Renewable Energy
21-GP1-103	Space Heating Proposal
21-GP1-136	Heat Pump Water Heating
21-GP1-138	Fan Power Allowance Tables
21-GP1-146	Additional Efficiency Credits
21-GP1-160	PTAC U-factors
21-GP1-159	Thermal bridging
21-GP1-190	DCV
21-GP1-198	Exterior Lighting
21-GP1-165	60% enthalpy ERV for DOAS except R1/R2
Table C405.3.2(2)	LPD
Table C402.1.4	Opaque Envelope
21-GP1-161	Fenestration
21-GP1-235	Data centers use 90.4-2019; same as 2024 IECC
C403.1.4	Special rules to limit electric resistance supplemental heat
21-GP1-166	Hydronic System flow rate: Limit pipe flow based on diameter
21-GP1-174	SWH storage tank insulation; Add R-2 for 140 F tank
21-GP1-176	SWH Pipe insulation; Add 1 inch to Table C403.10.3 values

2.0 Cost-Effectiveness Methodology

This analysis evaluates the cost-effectiveness of 2021 WSEC-C relative to 2018 WSEC-C. The analysis covers six commercial building types and two climate zones.

2.1 Cost-Effectiveness Analysis and Parameters

The methodology used for this analysis is consistent with the Washington State Office of Financial Management (OFM) Life Cycle Cost analysis. This includes using the OFM's Life Cycle Cost Analysis (LCCA) spreadsheet tool[1] version 2020-A along with the required inputs.[2]

This analysis includes incremental initial costs, repairs, maintenance, and replacements. The residual value of equipment and components that have remaining useful life at the end of the study period is also included.

This methodology accounts for the benefits of energy efficient building construction over a multi-year analysis period, balancing initial costs against longer term energy savings. The value of future savings and costs are discounted to a present value based on a discount rate. The discount rate may reflect the interest rate at which money can be borrowed for projects with the same level of risk or the interest rate that can be earned on other conventional investments with similar risk. The updated code edition is deemed cost-effective when the net present savings (present value of savings minus costs) is positive. The standard input values required by the OFM are shown below in Table 2.

Table 2. Analysis Input Values

Parameter	Value	Source
Analysis Period	50 years	OFM
Energy Price, kWh	$0.0856	OFM: EIA Electricity Annual, WA (2018)
Energy Price, therms	$0.818	OFM: EIR Natural Gas Database, WA (2017)
Inflation	3.01%	OFM
Discount Rate (nominal)	5%	OFM
Discount Rate (real)	1.93%	OFM

2.2 Building Prototypes and Energy Modeling

The cost-effectiveness analysis uses six building types represented by six prototype building energy models. This analysis represents most of the energy and cost impacts of the changes to the WSEC-C.

The six prototype models selected for the analysis are shown below in bold font in Table 3. These six prototypes were chosen because they do the following:

- Provide a good representation of the overall code cost-effectiveness without requiring simulation of all 16 prototype models

1 https://ofm.wa.gov/sites/default/files/public/budget/forms/LifeCycleCostTool.xlsb

2 https://sbcc.wa.gov/sites/default/files/2021-04/Methodology%20_Cost%20_Benefits%20_NRGCodeChanges_1_22_19.pdf

- Represent most of the energy and cost impacts of the code changes
- Match almost identically with prior energy savings results from others during a validation exercise comparing 2018 to 2006 WSEC-C
- Include all the lighting systems and most of the heating, ventilating, and air conditioning (HVAC) systems represented in the prototypes
- Represent the energy impact of five of the eight commercial principal building activities that account for 79% of the state's new construction by floor area covered by the full suite of 16 prototypes.

Table 3. Prototype Buildings

Principal Building Activity	Building Prototype	Included in Analysis
Office	**Small Office**	**Yes**
	Medium Office	No
	Large Office	**Yes**
Mercantile	**Standalone Retail**	**Yes**
	Strip Mall	No
Education	**Primary School**	**Yes**
	Secondary School	No
Healthcare	*Outpatient Healthcare*	No
	Hospital	No
Lodging	**Small Hotel**	**Yes**
	Large Hotel	No
Warehouse	*Warehouse (non-refrigerated)*	No
Food Service	*Quick-service Restaurant*	No
	Full-service Restaurant	No
Apartment	**Midrise Apartment**	**Yes**
	High-rise Apartment	No

The prototypes represent common construction practices and an overview is provided below in Table 4. The baseline models include the primary conventional HVAC systems commonly used in commercial buildings under the 2018 WSEC-C.

Each prototype building is analyzed for each of the two primary climate zones found within the state. Using EnergyPlus software, the six building prototypes are simulated with characteristics meeting the requirements of the 2018 WSEC-C and then modified to meet the requirements of the 2021 WSEC-C. The energy use and energy cost are then compared between the two sets of models.

Table 4. Overview of Selected Prototypes

Building Prototype	Floor area (ft²)	Number of Floors	Baseline HVAC System		
			Heating	Cooling	Main System
Small Office	5,502	1	Heat pump	Unitary direct expansion (DX)	Packaged constant air volume (CAV)
Large Office	498,588	12	Gas boiler	Chiller, cooling tower	Variable air volume (VAV) with hydronic reheat
Standalone Retail	24,692	1	Gas furnace	Unitary DX	Packaged CAV
Primary School	73,959	1	Boiler/Gas furnace	Unitary DX	Packaged VAV with hydronic reheat
Small Hotel	43,202	4	Electric resistance	DX	Packaged terminal air conditioner
Midrise Apartment	33,741	4	Gas furnace	DX	Split DX system

The following table shows the additional efficiency credits required in WSEC-C Section C406 as selected for the simulations.

Table 5. Additional Efficiency Credits Selected for Simulations

Measure	Section	Hotel	Apartment	Office	School	Retail
Improve cooling and fan efficiency	C406.2.2.2	2				
Improve heating efficiency	C406.2.2.3	2		3	10	16
High performance DOAS: 80% eff	C406.2.2.6	31	31	21	39	40
10% reduced lighting power	C406.2.3.1	7	4	18		20
Lamp Efficacy Improvement 90 lm/W	C406.2.3.3	5	6			
Onsite renewable energy	C406.2.5	7				
Selected points		**54**	**41**	**42**	**49**	**76**
Target points		54	41	42	48	74
Difference		*0*	*0*	*0*	*1*	*2*

2.3 Climate Zones

Climate zones are defined in ASHRAE Standard 169 and include eight primary climate zones in the United States, the hottest being climate zone 1 and the coldest being climate zone 8. Letters A, B, and C are applied in some cases to denote the level of moisture, with A indicating humid, B indicating dry, and C indicating marine.

Two climate zones cover nearly all the populated area of Washington state. Climate zone 4C is west of the Cascades and climate zone 5B is east of the Cascades. Savings are analyzed using weather data from a representative city within each climate zone, namely Seattle and Spokane.

2.4 Incremental Construction Costs

Estimates were obtained or developed for the incremental construction costs between 2018 WSEC-C and 2021 WSEC-C as implemented in the six prototype models and two climate zones. Costs for the initial construction include materials, labor, commissioning, construction equipment, overhead and profit. Costs were obtained from a variety of sources, including prior cost-effectiveness analysis by Pacific Northwest National Laboratory (PNNL), WSEC-C proposals, and preliminary cost benefit analysis by Ecotope.

3.0 Cost-Effectiveness Results for 2021 WSEC-C

This section summarizes the cost-effectiveness analysis results for 2021 WSEC-C compared with 2018 WSEC-C. Results are shown by building type and climate zone. Statewide weighted averages based on new construction weights are also shown. The code is considered cost-effective if the weighted statewide net present savings is positive, which is the case.

3.1 Construction Weighting of Results

Energy and economic impacts were determined and reported separately for each building type and climate zone. Cost-effectiveness results are also reported as averages for all prototypes and climate zones. To determine these averages, results were combined across the different building types and climate zones using weighting factors shown below in Table 6. These weighting factors are based on the floor area of new construction and major renovations in Washington for the six analyzed building prototypes and two climate zones. The weighting factors were developed from Washington construction start data from 2003 to 2018 (Dodge Data & Analytics)[3] based on an approach documented in Lei, et al.[4]

Table 6. Construction Weights

	Small office	Large office	Standalone retail	Primary school	Small hotel	Midrise apartment	**All Building Types**
4C Seattle	5.1%	17.8%	14.0%	7.1%	1.0%	45.2%	**90.3%**
5B Spokane	1.1%	0.2%	3.7%	2.1%	0.8%	1.8%	**9.7%**
State Average	**6.2%**	**18.0%**	**17.8%**	**9.2%**	**1.8%**	**47.0%**	**100.0%**

3.2 Incremental Construction Cost

Table 7 below shows the incremental initial construction costs for individual building types by climate zone and weighted average costs by climate zone and building type for moving to 2021 WSEC-C from 2018 WSEC-C.

Table 7. Incremental Construction Cost ($/ft^2)

	Small office	Large office	Standalone retail	Primary school	Small hotel	Midrise apartment	**All Building Types**
4C Seattle	0.96	0.87	1.52	1.32	1.82	4.22	**2.70**
5B Spokane	1.08	1.02	1.64	1.44	1.94	4.34	**2.04**
State Average	**0.98**	**0.87**	**1.53**	**1.35**	**1.87**	**4.22**	**2.63**

[3] Dodge Data & Analytics. 2020. Construction Research web page. Available: https://www.construction.com/products/construction-research

[4] https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29787.pdf

3.3 Energy Savings

Table 8 shows the whole building energy savings of 2021 WSEC-C relative to 2018 WSEC-C. These results are from the building energy simulations.

Table 8. Annual Energy Savings

	Small office	Large office	Standalone retail	Primary school	Small hotel	Midrise apartment	**All Building Types**
4C Seattle	13.0%	8.8%	19.4%	13.1%	31.6%	34.4%	**24.1%**
5B Spokane	11.5%	9.0%	18.9%	14.6%	33.6%	41.1%	**22.2%**
State Average	**12.7%**	**8.8%**	**19.2%**	**13.4%**	**32.5%**	**34.7%**	**23.9%**

3.4 Energy Cost Savings

Table 9 shows the economic impact of upgrading to 2021 WSEC-C by building type and climate zone in terms of the annual energy cost savings in dollars per square foot. These results are from the building energy simulations.

Table 9. Annual Energy Cost Savings ($/ft^2)

	Small office	Large office	Standalone retail	Primary school	Small hotel	Midrise apartment	**All Building Types**
4C Seattle	0.07	0.09	0.11	0.08	0.26	0.29	**0.19**
5B Spokane	0.07	0.09	0.12	0.10	0.31	0.30	**0.16**
State Average	**0.07**	**0.09**	**0.11**	**0.08**	**0.28**	**0.29**	**0.19**

3.5 Net Present Savings

Table 10 shows the net present savings (NPS) over the analysis period. These results are from the OFM's Life Cycle Cost Analysis (LCCA) spreadsheet tool. When the NPS is positive, the updated code edition is considered cost-effective, which is the case for all scenarios.

Table 10. Net Present Savings (NPS) ($/ft^2)

	Small office	Large office	Standalone retail	Primary school	Small hotel	Midrise apartment	**All Building Types**
4C Seattle	0.66	1.69	1.26	0.69	6.72	2.92	**2.16**
5B Spokane	0.57	1.66	1.59	1.30	8.11	3.87	**2.37**
State Average	**0.64**	**1.69**	**1.32**	**0.83**	**7.34**	**2.96**	**2.18**

Table 11 shows the present social cost of carbon over the analysis period. These results are from the OFM's LCCA spreadsheet tool.

Table 11. Present Social Cost of Carbon (SCC) ($/ft²)

	Small office	Large office	Standalone retail	Primary school	Small hotel	Midrise apartment	**All Building Types**
4C Seattle	0.15	0.35	0.51	0.39	2.72	0.89	**0.66**
5B Spokane	0.15	0.39	0.53	0.43	3.02	2.21	**0.98**
State Average	**0.15**	**0.35**	**0.51**	**0.40**	**2.85**	**0.94**	**0.69**

Table 12 shows the net present savings including present social cost of carbon over the analysis period. These results are from the OFM's LCCA spreadsheet tool. These values are a simple addition of the net present savings and present social cost of carbon.

Table 12. Net Present Savings with Social Cost of Carbon ($/ft²)

	Small office	Large office	Standalone retail	Primary school	Small hotel	Midrise apartment	**All Building Types**
4C Seattle	0.81	2.04	1.77	1.08	9.44	3.81	**2.82**
5B Spokane	0.72	2.06	2.12	1.72	11.13	6.08	**3.35**
State Average	**0.79**	**2.04**	**1.83**	**1.23**	**10.19**	**3.89**	**2.87**

4.0 Societal Benefits

4.1 Benefits of Energy Codes

It is estimated that by 2060, the world will add 2.5 trillion square feet of buildings, an area equal to the current building stock. As a building's operation and environmental impact is largely determined by upfront decisions, energy codes present a unique opportunity to assure savings through efficient building design, technologies, and construction practices. Once a building is constructed, it is significantly more expensive to achieve higher efficiency levels through later modifications and retrofits. Energy codes ensure that a building's energy use is included as a fundamental part of the design and construction process. Making this early investment in energy efficiency will pay dividends to Washington residents for years into the future.

4.2 Greenhouse Gas Emissions

The urban built environment is responsible for 75% of annual global greenhouse gas (GHG) emissions while buildings alone account for 39%.[5] While carbon dioxide emissions represent the largest share of greenhouse gas emissions, on-site fossil fuel consumption also contributes to other emissions, two of which, methane (CH_4) and nitrous oxide (N_2O), are also significant greenhouse gases. Carbon dioxide equivalent (CO_2e) is used here to represent the effect of all greenhouse gases. Table 13 summarizes the carbon emission factors available from 2021 WSEC-C Table C407.3(1) that were used in this analysis.

Table 13. Carbon Emissions Factors by Fuel Type

GHG	Electricity lb/kWh	Natural Gas (lb/therm)
CO_2e	0.44	11.7

The 2021 WSEC-C will result in statewide societal benefits such as energy cost savings, reduced greenhouse gas emissions, and job creation. Table 14 shows the first year and projected 30-year carbon dioxide equivalent emissions reduction of 11,200,000 metric tons. This is equivalent to the annual CO_2e emissions of 2,440,000 cars on the road (1 MMT CO_2e = 217,480 cars driven/year).

Table 14. Societal Benefits from Reduced Greenhouse Gas Emissions

Statewide Impact	First Year	30 Years Cumulative
CO_2e emissions reduction, Metric tons	22,800	11,200,000

[5] Architecture 2030, https://architecture2030.org/2030_challenges/2030-challenge

4.3 Jobs Creation through Energy Efficiency

Energy-efficient building codes impact job creation through two primary value streams:

1. Dollars returned to the economy through reduction in utility bills and resulting increase in disposable income, and;
2. An increase in construction-related activities associated with the incremental cost of construction that is required to produce a more energy efficient building.

When a building is built to a more stringent energy code, there is the long-term benefit of the ratepayer paying lower utility bills.

- This is partially offset by the increased cost of that efficiency, establishing a relationship between increased building energy efficiency and additional investments in construction activity.
- Since building codes are cost-effective, (i.e., the savings outweigh the investment), a real and permanent increase in wealth occurs that can be spent on other goods and services in the economy, just like any other income, generating economic benefits and creating additional employment opportunities.

Table 15 shows the number of jobs created because of efficiency gains in 2021 WSEC-C.

Table 15. Societal Benefits from Jobs Created

Statewide Impact	First Year	30 Years Cumulative
Jobs Created from Construction Related Activities and Reduction in Utility Bills	630	17,400

5.0 Energy Savings Compared to 2006 WSEC-C

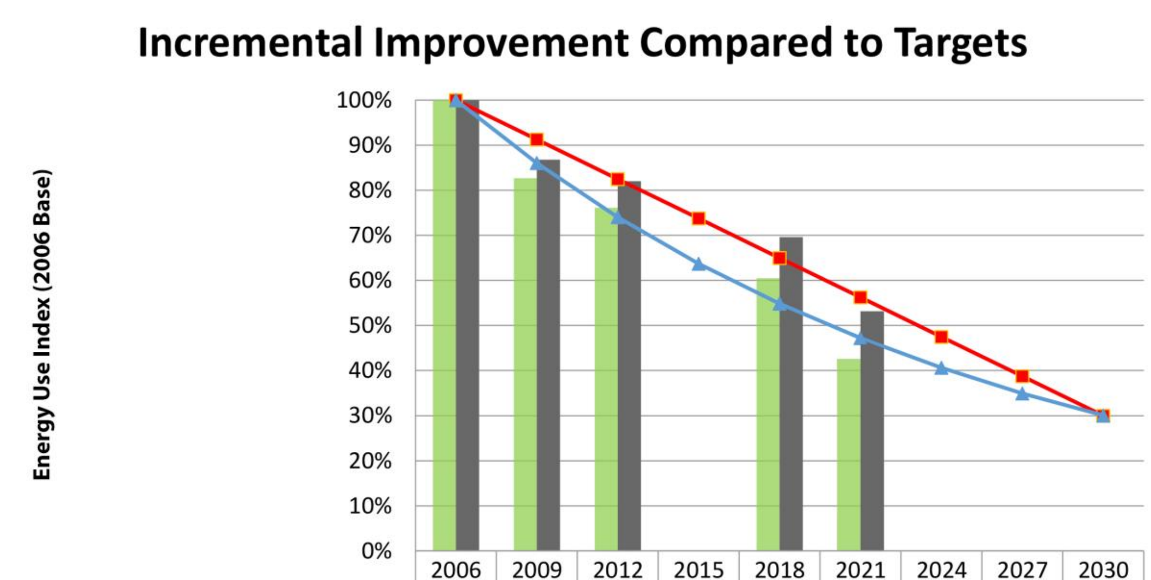
This section describes the energy savings analysis and results for the 2021 WSEC-C compared to the 2006 WSEC-C.

As shown in the table below, the energy use index is 69.6% for 2018 WSEC-C compared to the 2006 WSEC-C. This is based on prior analysis by others. Ecotope and O'Brien360 provided the 2006 and 2018 WSEC-C EnergyPlus input files to PNNL. PNNL used these files to verify the 69.6% value, which resulted in a value of 69.5% using the PNNL methodology.

As shown earlier in Table 8, the statewide weighted average whole building energy savings of 2021 WSEC relative to 2018 WSEC is 23.9%. Multiplying the 69.6% energy use index (2018 WSEC compared to 2006 WSEC) with the 23.9% savings (2021 WSEC relative to 2018 WSEC) yields a 16.6% reduction from the 2018 energy use index. The 2018 energy use index of 69.6% minus the 16.6% reduction yields the new 2021 energy use index of 53.0% relative to the 2006 WSEC.

In other words, a commercial new construction building that minimally complies with the 2021 WSEC-C is expected to have 53.0% energy use intensity compared to a building that minimally complies with the 2006 WSEC-C, assuming in this example the building's energy use matches the statewide weighted average energy use.

Table 16. Energy Use Index Relative to 2006 WSEC



	2006	2009	2012	2015	2018	2021	2024	2027	2030
Residential	100%	82.7%	76.1%		60.5%	42.4%			
Commercial	100%	86.8%	82.0%		69.6%	53.0%			
Target: 8.75 % savings compared to the 2006 WSEC	100%	91%	83%	74%	65%	56%	48%	39%	30%
Target: 14% savings compared to each previous code	100%	86%	74%	64%	55%	47%	41%	35%	30%

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Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

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