MEMORANDUM

Pacific Northwest NATIONAL LABORATORY

Date: **2/25/2022**

To: **Stoyan Bumbalov**

From: **Matthew Tyler**

Subject: **Preliminary Cost-Effectiveness of Renewable Energy Proposal for the Washington State Energy Code**

Information Release # **PNNL-SA-170654**

Washington State is considering adopting a proposed commercial provision to the Washington State Energy Code that requires on-site renewable energy generation for commercial buildings over 10,000 square feet (Proposal 21-GP1-078). PNNL analyzed the cost-effectiveness of this proposal and found it would be cost-effective.

The analysis covered six building types represented by six prototype building energy models: small office, large office, standalone retail, primary school, small hotel, and mid-rise apartment.

Climate zones are defined in ASHRAE Standard 169, with the hottest being climate zone 0 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 moist or humid, B indicating dry, and C indicating marine. Climate zones 4C, 5B, 5C, and 6B are in Washington.

The electricity price used in the analysis is $0.092/kWh. This price is the state average commercial energy cost for December 2020 through November 2021, which is the most recently available 12 months of data. This is a weighted average by monthly retail sales of electricity for commercial buildings in Washington. The prices and sales data are from the United States Energy Information Administration (EIA) *Electricity Power Monthly.*[1]

PNNL estimated the annual electricity generation and energy cost savings by running EnergyPlus building energy simulations for the six prototype building models in the four Washington climate zones. The simulations rely on the PVWatts generator model developed by NREL and built into EnergyPlus. The PV system size (kW required) is based on the floor area of each prototype building model and the 0.50 W/sf proposed requirement. The PV module type is input as a typical poly- or mono-crystalline silicon module with rated efficiency of 15% and operating efficiency of 14.4%. Additional losses are modeled with an inverter efficiency of 96% and system losses of 14%, which represent losses in a real system that are not explicitly calculated by the PVWatts model equations.

These results are presented below in Table 1. There is likely no net generation at the installed capacity as the buildings would use all available generated electricity. The annual electricity generation per installed watt of power depends on the climate zone but not building type. These values are shown below in Table 2.

[1] https://www.eia.gov/electricity/monthly/

Table 1. PV System Size and Annual Generation [2]

	Floor Area	kW required	Annual kWh Generation			
			4C	5B	5C	6B
Large Office	498,588	249	303,739	389,915	276,871	336,934
Small Office	5,502	2.75	3,352	4,303	3,055	3,718
Standalone Retail	24,692	12.3	15,042	19,310	13,712	16,686
Primary School	73,959	37.0	45,056	57,839	41,070	49,980
Mid-rise Apartment	33,741	16.9	20,555	26,387	18,737	22,801
Small Hotel	43,202	21.6	26,319	33,786	23,991	29,195

Table 2. Annual Electricity Generation per Installed Watt

Annual kWh Generation per Installed Watt			
4C	5B	5C	6B
1.22	1.56	1.11	1.35

The added construction cost is $1.72/Wdc, which is the same installed cost listed on the proposal's Economic Impact Data Sheet and reported by NREL.[3]

Life Cycle Cost (LCC) savings is the primary measure DOE uses to assess the economic impact of building energy codes. Net LCC savings is the calculation of the present value of energy savings minus the present value of non-energy incremental installed costs over a 30-year period. The proposal is considered cost-effective when net LCC is positive.

Two LCC scenarios[4] are analyzed with the inputs shown in Table 3 and the differences are outlined here:

- Scenario 1: represents publicly-owned buildings, considers initial costs, energy costs, maintenance costs, and replacement costs without borrowing or taxes. These LCC results per square foot are shown in Table 4 by building type and climate zone. The proposal is considered cost-effective as all values are positive in this scenario.
- Scenario 2: represents privately-owned buildings, adds borrowing costs (financing of the incremental first costs) and tax impacts (such as loan interest and depreciation deductions using corporate tax rates). These LCC results per square foot are shown in Table 5 by building type and climate zone. The proposal is considered cost-effective as all values are positive in this scenario.

Table 6 below shows the annual energy cost savings in dollars per square foot by building type and climate zone. Table 7 shows the simple payback period.

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[2] Small office is included for completeness although the floor area is below the proposed 10,000 square foot limit.
[3] https://www.nrel.gov/docs/fy21osti/77324.pdf
[4] https://www.energycodes.gov/commercial-energy-and-cost-analysis-methodology

Table 3. Economic Analysis Parameters

Economic Parameter	Scenario 1	Scenario 2
Study Period, years	30	30
Nominal Discount Rate	3.10%	5.25%
Real Discount Rate	3.00%	3.34%
Effective Inflation Rate	0.10%	1.85%
Electricity Prices, per kWh	$0.092	$0.092
Loan Interest Rate	NA	5.25%
Federal Corporate Tax Rate	NA	21.00%
State Corporate Tax Rate	NA	0.00%
Combined Income Tax Impact	NA	21.00%
State and Average Local Sales Tax	9.23%	9.23%

Table 4. Net LCC Savings, Scenario 1 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment
4C	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21
5B	$0.52	$0.52	$0.52	$0.52	$0.52	$0.52
5C	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12
6B	$0.33	$0.33	$0.33	$0.33	$0.33	$0.33

Table 5. Net LCC Savings, Scenario 2 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment
4C	$0.31	$0.31	$0.31	$0.31	$0.31	$0.31
5B	$0.59	$0.59	$0.59	$0.59	$0.59	$0.59
5C	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22
6B	$0.42	$0.42	$0.42	$0.42	$0.42	$0.42

Table 6. Annual Energy Cost Savings ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment
4C	$0.056	$0.056	$0.056	$0.056	$0.056	$0.056
5B	$0.072	$0.072	$0.072	$0.072	$0.072	$0.072
5C	$0.051	$0.051	$0.051	$0.051	$0.051	$0.051
6B	$0.062	$0.062	$0.062	$0.062	$0.062	$0.062

Table 7. Simple Payback (years)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment
4C	15.3	15.3	15.3	15.3	15.3	15.3
5B	12.0	12.0	12.0	12.0	12.0	12.0
5C	16.8	16.8	16.8	16.8	16.8	16.8
6B	13.8	13.8	13.8	13.8	13.8	13.8