2021 WSEC-C – Third Party Cost Benefit Analysis

ECOTOPE

Final Report

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Washington Department of Enterprise Services

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EXECUTIVE SUMMARY

The focus of this study was to provide a third-party review of up to twenty code proposals, as approved by the energy Technical Advisory Group (TAG), for the 2021 Washington State Energy Code commercial (WSEC-C). The process began with validating the information provided by the proponent, verifying supplemental calculations, and confirming claimed net present savings in each proposal. In some cases, additional cost-benefit analyses and cost data research was conducted.

Ecotope focused on quantitative impacts (first year construction costs and utility cost savings) of the specific directives of the statute being implemented. However, the State's life cycle cost analysis (LCCA) tool accounts for carbon emissions savings as well, this is the extent of qualitative benefits accounted for in this analysis.

The table below summarizes proposals reviewed by this study and high-level summary of findings.

Table 1: Code Change Proposal Review Summary

Proposal Number	Subject	Proponent	Ecotope Review:
21-GP1-103	Space Heating Proposal	Jonny Kocher, RMI	**Review Findings:** Revise cost and energy values **Confidence in results:** Medium **Ecotope adjustment:** Added alternate system analysis
21-GP1-136	Heat Pump Water Heating	Jonny Kocher, RMI	**Review Findings:** Revise cost and energy values **Confidence in results:** Medium **Ecotope adjustment:** Revised analysis per final CR102
21-GP1-179	Electrical Receptacles at Gas Appliances	Duane Jonlin, City of Seattle	**Review Findings:** Revise cost values **Confidence in results:** High (no energy savings) **Ecotope adjustment:** N/A
21-GP1-193	Compressed Air	Mike Kennedy	**Review Findings:** References reliable sources **Confidence in results:** High **Ecotope adjustment:** N/A
21-GP1-138	Fan Power Allowance Tables	Nicholas O'Neil, Energy 350	**Review Findings:** References reliable sources **Confidence in results:** High **Ecotope adjustment:** N/A
21-GP1-95	Indoor Horticulture Dehumidification	Sean Denniston, NBI	**Review Findings:** References reliable sources **Confidence in results:** High **Ecotope adjustment:** N/A
21-GP1-99	DR Water Heaters	Sean Denniston, NBI	**Review Findings:** References reliable sources **Confidence in results:** High **Ecotope adjustment:** N/A
21-GP1-180	Reduce Threshold for LPA Compliance on Remodels	Duane Jonlin, City of Seattle	**Review Findings:** Revise cost and energy values **Confidence in results:** Low **Ecotope adjustment:** N/A
21-GP1-139	Boiler Controls	Nicholas O'Neil, Energy 350	**Review Findings:** References reliable sources **Confidence in results:** High **Ecotope adjustment:** N/A

Proposal Number	Subject	Proponent	Ecotope Review:
21-GP1-160	PTAC U-factors	Duane Jonlin, City of Seattle	**Review Findings:** Does not reference sources **Confidence in results:** High **Ecotope adjustment:** Validated HDD calcs
21-GP1-164	Include Split Systems in HP Requirement	Duane Jonlin, City of Seattle	**Review Findings:** References reliable sources **Confidence in results:** Medium – no cost or energy impacts **Ecotope adjustment:** N/A
21-GP1-133	High capacity space heating boiler	Mike Kennedy	**Review Findings:** References reliable sources **Confidence in results:** High **Ecotope adjustment:** N/A
21-GP1-165	60% enthalpy ERV req'd DOAS, except R1/R2	Duane Jonlin, City of Seattle	**Review Findings:** Revise cost numbers **Confidence in results:** Medium **Ecotope adjustment:** N/A
21-GP1-97	DR Thermostats	Sean Denniston, NBI	**Review Findings:** References reliable sources **Confidence in results:** High **Ecotope adjustment:** N/A
21-GP1-190	DCV	Mike Kennedy	**Review Findings:** References reliable sources **Confidence in results:** High **Ecotope adjustment:** N/A
21-GP1-204	Exterior Building Grounds Lighting	Michael Myer, PNNL	**Review Findings:** References reliable sources **Confidence in results:** High **Ecotope adjustment:** N/A
21-GP1-198	Exterior Lighting	Michael Myer, PNNL	**Review Findings:** References reliable sources **Confidence in results:** High **Ecotope adjustment:** N/A

INTRODUCTION

Ecotope reviewed the information provided by proponents for a set of proposals submitted for the 2021 Washington State Energy Code commercial (WSEC-C) adoption process. The intent was to provide a third-party review of up to twenty code proposals as approved by the energy Technical Advisory Group (TAG) and evaluate the data supporting the cost-benefit analyses submitted with each proposal. The results shown are intended to be viewed as another component to the overall set of information provided to the SBCC; and the analysis presented below should not be assumed to have aggregated all public comments, other cost/benefit analyses, or inclusion of all impacted building types.

Primary focus was to validate the proponent's identified cost and benefits of proposals by checking if adequate information was provided and if it was from a credible source. In some cases, additional cost-benefit analyses and cost data research was conducted. Final step (if needed) was determining if the provable benefits of the rule are greater than its probable costs.

The tool used to validate cost benefit is the Office of Financial Management Life Cycle Cost Analysis (LCCA) tool. This is financial tool is developed and maintained by the State to evaluate energy and cost savings over a 50-year time horizon with approved assumptions for details such as discount rates, inflation, fuel cost escalation rates, and the social cost of carbon. Cost benefit is measured by comparing the present values of capital, maintenance, and utility costs to verify if a measure shows net present savings to the building owner. The table below lists the standard assumptions uses by this tool.

Table 2: Summary of LCCA Assumptions (per OFM)

	Commercial (incl. Multifamily)	**Source**
Study Life	50 years	OFM
Energy Price, Electric	$0.0856	EIA Electricity Annual, WA (2018)
Energy Price, Gas	$0.818	EIR Natural Gas Database, WA (2017)
Inflation	3.01%	OFM
Discount Rate (nominal)	5%	
Discount Rate (real)	1.93%	

Ecotope focused on quantitative impacts (first year construction costs and utility cost savings) of the specific directives of the statute being implemented. However, the State's life cycle cost analysis (LCCA) tool accounts for carbon emissions savings, so qualitative benefits such as social cost of carbon have been addressed as well. Ecotope did not account for current supply chain issues, recent rise of inflation, or impacts to construction timeline. Equipment useful life assumptions were sourced from BOMA International guidebook.

Each code proposal was reviewed on a building-by-building basis. With roughly 18 different occupancy types within the commercial building stock, there are a multitude of unique energy end-use values, incremental cost impacts, and payback timelines. All these variables can make reviewing the cost effectiveness of a code proposal difficult without extensive research. This study is not intended to cover all impacted building types, nor capture each application in which these proposals effect the industry.

21-GP1-103: SPACE HEATING PROPOSAL

Summary of Findings

Code change proposal, budget requirements, and efficiency projections were based off a credible source, the California Cost Effectiveness Study (see TRC, EnergySoft, 2019). However, the energy and cost calculations the proponent references for the office building's proposed HVAC system references a system not compliant with the current code proposal. Also, it appears energy savings from unrelated efficient appliances are included in all savings. Ecotope's review is based off the proponent's baseline HVAC reference with data sourced from the Pacific Northwest National Laboratory's (PNNL) life cycle cost analysis of VRF (Thornton, 2011) and a published Elsevier report on the energy savings potential of VRF from VAV in the US (Kim, 2017).

The California Cost Effectiveness Study used by the proponent looked at three building types: medium office, medium retail, and small hotel. The proponent only used medium office and medium retail in their cost and energy analysis. Baseline HVAC system references are appropriate to the proposal; however, the medium office proposed heating system listed in the study appears to be a packaged DX + VAV with electric resistance heat, which is not in compliance with the new code proposal. The medium retail proposed heating system was a single zone packaged heat pump which does comply, comparing to a baseline single zone packaged DX with gas furnace. While this HVAC system is very common in: retail, warehouse, small office, restaurant, school (roughly 60% of commercial floor area in the state), the reference is not completely accurate because the baseline and proposed hot water energy consumption values are not the same.

From the proponents referenced study (Table 10 in TRC, 2019), the cost for the baseline HVAC system for a medium office is $24/sf. According to PNNL's research and modeling VRF Life Cycle Cost Analysis, variable refrigerant flow (VRF) systems has an upfront cost of ~$24/ft^2. For a medium office, a research study comparing energy savings potential of VRF from VAV in the US found VRF heating energy is shown to be 33% more efficient than VAV in Seattle's climate and 31% more in Spokane's climate. (Kim, 2017) Ecotope's third party analysis combined these three sources of information into the LCCA tool. See Figure 2 and Figure 3 in Appendix A for summary of results and energy consumption values used.

While the supporting research provided by the proponent is inaccurate, the findings are likely correct. The cost burden of this proposal is expected to be minimal due to the fact that most commercial buildings already utilize cooling systems, which drive equipment sizing. Requiring the cooling compressor to work in heating would not add upfront capacity increases to the HVAC system. Utility costs between gas and heat pumps usually balance out at a heat pump COP of 2.0, so any efficiency above that would lead to utility cost savings (a relevant cost benefit analysis should be completed to show this). For heat pump systems, an upsize of electrical panels and/or transformer may need to be accounted for but otherwise it is assumed that supporting mechanical systems (ducts, pipes, etc) are the same between a gas and heat pump system. This study only focused on the first cost impacts of two HVAC systems on the medium office prototype.

Cost Analysis

Comments on Proponent's Cost Analysis

1. Detailed cost analysis from California Cost Effectiveness Study. Cost calculations for retail building type use a system that complies with code proposal but does not have the same

baseline and proposed building characteristics and thus the heating systems cannot be compared equally.
2. Cost calculations for office building type appear to be based off an electric resistance VAV system, not a heat pump system, which does not comply with the current code proposal.
3. The California Cost Effectiveness Study the Proponent uses rightly considers the cost of natural gas and electric infrastructure. For both scenarios it considers the upfront cost of equipment. For the electrical infrastructure it considers electrical paneling and wiring, electrical line lengths and cost per linear foot. For natural gas it considers metering, service extension, and distribution.

Recommended Cost Adjustments (→ Ecotope Updates)

1. Update calculations to be based on compliant source for office analysis.

   → See PNNL's research and modeling of VRF Life Cycle Cost Analysis.

2. Consider inflation, maintenance, repair, and equipment replacement costs.

Energy Analysis

Comments on Proponent's Energy Analysis

1. Detailed energy analysis from California Cost Effectiveness Study. Energy calculations for retail building type use a system that complies with code proposal and is considered reliable.
2. Energy calculations for office building type appears to be based off an electric resistance VAV system which does not comply with current code proposal.

Recommended Energy Projection Adjustments (→ Ecotope Updates)

1. Update calculations to be based on compliant source.

   → See PNNL's research and modeling of VRF Life Cycle Cost Analysis and Dongsu Kim, S. J., 2017 report on energy savings potential of VRF.

21-GP1-136: HEAT PUMP WATER HEATING

Summary of Findings

Ecotope performed an independent LCCA calculation using Washington State's LCCA tool, updated results, energy, and equipment cost data can be found in Appendices A, B, C respectively. The only building type included in this study is a multifamily prototype. This is the occupancy type with the highest relative DHW energy use (compared to other end-uses), as well as the most complex system design requirements. It should be noted that these systems are already required in King County and Seattle, which represents over 50% of the expected new construction across the state.

<u>Per final updates to the HPWH proposal, in which the required tonnage of the heat pump water heaters dropped to 50% and allows supplemental gas backup across the state, LCCA results show incremental first cost of $900 per dwelling unit when compared to a gas baseline system. When accounting for the social cost of carbon, the revised HPWH system shows to be better than the gas baseline system.</u>

Ecotope ran independent cost and energy analyses that incorporate several changes to the theoretical systems referenced as a basis for the proponent's cost and energy analyses. Ecotope's energy analysis further considered factors including power draws associated with electric resistance temperature maintenance and low-temperature supplemental heating, and the effect of annual air temperature fluctuations on HPWH efficiency. While HPWH plants generally require more building floor area, these plants can be located on the roof or in unusable portions of the garage. Instances exist where the plant takes over extra leasable floor area but scenarios such as those depend on building layout and project team decisions. Cost impacts of a larger water heating plant (cost per square foot of floor area), when compared to traditional gas or electric systems, was not considered in this analysis.

Cost Analysis

Comments on Proponent's Cost Analysis

1. The proponent's HPWH case does not satisfy the code proposal for the following reasons (Ecotope revised analysis assumes a code-compliant CO2 system):
    a. If accounting for coil defrost, two Colmac CxA-15's and one CxA-10 will not satisfy the 275,000 BTU/h capacity requirement associated with the 173-unit example building at 40°F.
2. Partial electric or gas redundancy should be included in the HPWH cost analysis because the code proposal allows supplementary electric heating below 40°F air temperatures, which occur in all parts of Washington. CO2 system evaluated below does not have the same low temperature limitations as the proponent's system choice.
3. External controls are not required for a code compliant HPWH or gas water heating system. Most water heaters utilize on-board controls with factory-provided sensors.
4. Temperature maintenance tank and heater should be added, which are required by the majority of HPWH systems on the market that are compliant to this code.
5. HPWH storage capacity can be decreased to 1,500 gallons for 173-unit apartment case.
6. Gas water heater costing assumes 2,000 gallons of storage, but typical gas water heater sizing would consist of greater heating capacity and less storage to minimize capital cost. ASHRAE Ch. 51: Service Water Heating, Figure 21. Apartments, illustrates a required increase in heating capacity of approximately 30% if storage is decreased from 12 gal/Apt to 6 gal/Apt, which would result in a lower costing gas heating system that consists of a 360,000 BTU/h gas water heater and 1,000 gallons of storage.

Cost Adjustments (→ considerations in Ecotope's updated cost analysis)

Ecotope costed a CO2 HPWH system that satisfies all the adjustments below, which resulted in a cost estimate of $148,750. Ecotope also costed a gas water heating system that satisfies all the comments adjustments below, which resulted in a cost estimate of $58,400 – about 55% lower than the proponent's cost estimate. The updated costs were included in the revised LCCA. Ecotope believed these to be a conservative cost estimate based on today's emerging market.

1. Base cost analysis off code compliant HPWH
    ➔ Ecotope used a price estimate provided by a CO2 HPWH sales representative.
2. Incorporate supplementary gas boiler and temperature maintenance heater into HPWH costing
    ➔ Ecotope added cost for instantaneous heater with basic controls, electric resistance tank, and pump.
3. Utilize onboard controls in HPWH and boiler cases
    ➔ Ecotope eliminated "controls" line item in cost analysis
4. Adjust storage and recovery capabilities to align with technology-specific design practices.

- ➔ Ecotope decreased HPWH storage to 1,500 gallons per Ecosizer sizing.
- ➔ Ecotope decreased gas water heater storage to 1,000 gallons and increased boiler capacity 30% per ASHRAE Ch. 51: Service Water Heating, Figure 21. Apartments

Energy Analysis

Comments on Proponent's Energy Analysis

1. Proponent uses a HPWH system not compliant with code proposal
2. Proponent only looked at energy usage of a multifamily building. Consider energy usage in different building types with varying occupancy schedules and domestic hot water demand.
3. Proponent used a single COP rating for the entire year.

Recommended Energy Analysis Adjustments (→ Ecotope Updates)

1. Consider electric resistance and gas energy usage when HPWH capacity cannot meet demand.
2. Consider energy consumption from temperature maintenance electric resistance element.
3. Use HPWH that is compliant with code proposal
4. Consider annual temperature fluctuations when calculating HPWH energy usage.

- ➔ See updated energy savings calculations in Appendix B: 21-GP1-136 Heat Pump Water Heating – Energy Calculations and Results

21-GP1-179: ELECTRIC RECEPTACLES AT GAS APPLIANCES

Summary of Findings

Current cost estimate does not align with RSMeans cost estimate and should be updated from $0.33 / sf to $0.90 / sf, assuming the range is the only non-electric appliance in a typical apartment.

Cost Analysis

Comments on Proponent's Cost Analysis:

1. Cost per receptacle does not list sourcing.
2. Price of range receptacle Per RSMeans 2022: 50 A breaker, 40' of (4) #6, 50 A receptacle = $677
3. Assuming 750 sf apartment: $0.90 / sf

Recommended Cost Adjustments

1. Adjust cost estimate to $0.90 / sf

Energy Analysis

There is no expected change in energy usage related to this proposal.

21-GP1-193: COMPRESSED AIR SYSTEMS

Summary of Findings

The code proposal references legitimate CASE reports regarding cost and energy savings. Costs referenced from the 2013 CASE reports should be updated to reflect current costs, but the order of magnitude of cost savings compared to the incremental cost from 2013 gives confidence that overall cost savings will still be realized.

Cost Analysis

Comments on Proponent’s Cost Analysis

1. Auto-shut down timer is cited in the cost analysis but is not mentioned anywhere in the code proposal. This will be referred to as “Smart Controls”
2. Smart Controls and Trim Compressor estimated costs reference a CASE report from 2013.
3. Pipe sizing, leak monitoring, and leak testing reference 2020 CASE Report.
4. LCCA shows cost savings associated with every proposed code change.

Recommended Cost Adjustments

1. Change “Auto-shut down timer” to “Smart Controls” in cost and energy analysis.
2. Current costs for trim compressor and smart controls.

Energy Analysis

Comments on Proponent’s Energy Analysis

1. Trim compressor, leak monitoring, leak testing, and pipe sizing reference most conservative estimates of cost effectiveness in CASE Reports.
2. The proposal states the least cost-effective prototype in the CASE report was referenced. Prototype 3 is referenced when stating smart controls costs, but Prototype 2 is least cost-effective.

Recommended Energy Projection Adjustments

1. Reference least cost-effective approach to smart controls, or remove statement that claims data from least cost-effective approach was used. Otherwise this is not the most conservative estimate

21-GP1-138: UPDATE FAN ALLOWANCE TABLES

Summary of Findings

Code change proposal, budget requirements, and efficiency projections were based off a credible source: the 2022 CASE report for air distribution systems.

Cost Analysis

Comments on Proponent’s Cost Analysis

1. Detailed cost analysis from a reliable source - 2022 CASE report - was referenced.

Recommended Cost Adjustments

No recommended adjustments

Energy Analysis

Comments on Proponent’s Energy Analysis

1. Detailed energy analysis from a reliable source – 2022 CASE report – was referenced

21-GP1-95: INDOOR HORTICULTURE DEHUMIDIFICATION

Summary of Findings

Code change proposal, budget requirements, and efficiency projections were based off a credible source, the 2022 CASE report for controlled environment horticulture.

Cost Analysis

Comments on Proponent's Cost Analysis

1. Detailed cost analysis from a reliable source - 2022 CASE report - was referenced.

Recommended Cost Adjustments

No recommended adjustments

Energy Analysis

Comments on Proponent's Energy Analysis

1. Detailed energy analysis from a reliable source – 2022 CASE report – was referenced
2. Should be noted that savings of 80 kBTU/sf/yr is referencing the square footage of indoor plant canopy, not the entire building area.

Recommended Energy Projection Adjustments

No recommended adjustments

21-GP1-99: ELECTRIC WATER HEATER DEMAND RESPONSE

Summary of Findings

Proposal is missing cost and energy savings analysis. Cost of equipment is expected to increase because the proposal requires demand response controls. Energy use will not decrease but may provide capability to be used at a different time of day which could lead to reduced grid carbon emissions.

Cost Analysis

Comments on Proponent's Cost Analysis

1. Proponent does not include cost analysis.

Recommended Cost Adjustments

No cost analysis provided.

Energy Analysis

Comments on Proponent's Energy Analysis

1. Proponent does not include energy analysis. Demand response capabilities will not decrease energy usage, but may reduce grid carbon emissions by targeting water heaters to run when renewable energy generation is high.

Recommended Energy Projection Adjustments

1. Effects on grid carbon emissions not accounted for in energy code savings analyses

21-GP1-180: REDUCE THRESHOLD FOR LPA COMPLIANCE ON REMODELS

Summary of Findings

Sources are not cited and incremental energy savings calculation is likely incorrect. Inputs of the proponent's energy savings and cost calculations are not well defined.

Cost Analysis

Comments on Proponent's Cost Analysis

1. No sources referenced for cost.
2. Fixture per sf estimate is reasonable based off Ecotope's experience with lighting retrofits.
3. Logic around "60% of fixtures added to project" is not clearly explained.

Recommended Cost Adjustments:

1. Reference sources for cost estimate.
2. Provide clear explanation to explain percentage of fixtures added to project.

Energy Analysis

Comments on Proponent's Energy Analysis

1. Units do not align with calculation
2. Incremental energy savings is accounted for twice in the equation.
3. Sources are not referenced.

Recommended Energy Projection Adjustments

1. Cite sources and re-calculate energy savings to account for incremental cost once.

21-GP1-139: BOILER CONTROLS

Summary of Findings

Analysis is thorough, but sources for the cost references should also be specified. Standard OFM inputs should be used for the life cycle cost analysis tool, however the overridden assumptions produce a lower net present savings than the default OFM values. Both assumptions for the inflation and discount rate show this proposal to be cost effective.

Cost Analysis

Comments on Proponent's Cost Analysis

1. Inflation is accounted for in cost estimate, but original source is not specified.
2. Custom LCCA inputs were used.

Recommended Cost Adjustments

1. Cite source for cost estimate.
2. Use OFM-assigned LCCA inputs (this would still show positive net present savings)

Energy Analysis

Comments on Proponent's Energy Analysis

1. 2022 CASE report was referenced – credible source.
2. Energy Plus software was used to project energy savings – credible source.

Recommended Energy Projection Adjustments

No recommendations.

21-GP1-160: PTAC U-FACTORS

Summary of Findings

The code change is anticipated to reduce heating and cooling energy use in buildings, but the cost and energy calculations listed in this code change proposal are simple and missing references. The cost and energy analysis of the example building uses a simplified industry standard heating degree day (HDD) calculation but does not provide references for U-value or HDD values used. The analysis seems to be a fair, but likely overestimation of the cost and energy savings. Therefore, the savings listed is a ballpark estimation and should be viewed as a maximum savings without taking into account internal gains, temperature setpoints, and other assumptions that can affect estimated energy savings.

Cost Analysis

Comments on Proponent's Cost Analysis

1. Cost analysis is missing references.
2. Proponents' simple payback is 16.5 years ($1,565 cost increase, $95/yr energy savings). Showing payback well within expected lifespan of envelope (50+ yrs).
3. Using the proponent's methodology with ASHRAE Fundamentals 2017 Seattle and Spokane HDD at base temperature of 65F, Ecotope estimates a maximum annual energy cost savings of $102 for Seattle and $143 for Spokane. Proponent's analysis showing $95/yr energy savings seems reasonable.

Recommended Cost Adjustments

1. No recommended adjustments

Energy Analysis

Comments on Proponent's Energy Analysis

1. Energy analysis is missing references.
2. Energy analysis uses a simplified heating degree day (HDD) calculation (industry standard) but does not specify base temperature. These calculations can be useful; however, they ignore internal gains, thermostat setpoints, and other assumptions that can affect estimated energy savings. HDD calculation usually overestimate savings.

Recommended Energy Projection Adjustments

1. No recommended adjustments

21-GP1-164: INCLUDE SPLIT SYSTEMS IN HP REQUIREMENT

Summary of Findings

Code change proposal adds split system equipment to the equipment required to be a heat pump. Cost and energy calculations are simple and missing references; however, this proposal increases options to comply with existing code and does not necessarily add additional cost or reduce energy consumption. The code change is in alignment with Washington State 2031 goals and is anticipated to reduce energy use in buildings as heat pumps are proved to consume less energy, however the calculations should be improved to demonstrate this more credibly.

Cost Analysis

Comments on Proponent's Cost Analysis

Cost analysis is missing references. Calculations are simple and without backing. But since this proposal increases options over the existing language, a new cost benefit is not necessarily required.

Recommended Cost Adjustments

1. Cost of split system equipment compared to packaged would provide more insight, but not necessary

Energy Analysis

Comments on Proponent's Energy Analysis

Energy analysis is missing references. Calculations are simple and without backing. Calculations show heat pumps are a 2/3 reduction in energy use with no reference to the baseline system being references.

Recommended Energy Projection Adjustments

1. Add which baseline system this proposal is being compared against.

21-GP1-133: HIGH-CAPACITY SPACE HEATING BOILER

Summary of Findings

Code change proposal, budget requirements, and efficiency projections were based off a credible source, ANSI/ASHRAE/IES Standard 90.1-2019 Addendum bc.

Cost Analysis

Comments on Proponent's Cost Analysis

1. Detailed cost analysis from a reliable source – ANSI/ASHRAE/IES Standard 90.1-2019 Addendum bc – was referenced.

Recommended Cost Adjustments

No recommended adjustments

Energy Analysis

Comments on Proponent's Energy Analysis

1. Detailed energy analysis from a reliable source – ANSI/ASHRAE/IES Standard 90.1-2019 Addendum bc – was referenced.

Recommended Energy Projection Adjustments

No recommended adjustments

21-GP1-165: 60% ENTHALPY ERV REQUIRED FOR DOAS, EXCEPT R1/R2

Summary of Findings

Proposal's cost and energy analysis is minimal and does not contain references. Upfront costs expected to increase however, the order of magnitude of the upfront cost increases compared to annual cost savings is not anticipated to be significant enough to reduce confidence that overall energy savings will still be realized. However, to confirm this, calculations and references should be improved.

Cost Analysis

Comments on Proponent's Cost Analysis

Cost analysis is missing references.

Recommended Cost Adjustments

1. Most major ERV manufacturers currently list ERVs that will meet this code proposal. However, this is not guaranteed to be the case for all ERV manufacturers so upfront cost could increase with higher energy recovery effectiveness on ERV, depending on manufacturer offerings.

Energy Analysis

Comments on Proponent's Energy Analysis

1. Energy analysis is missing references. Calculations are simple and without backing.
2. Proposal assumes 2% HVAC energy savings. Proponent then multiplies that 2% to the total building EUI to produce energy savings. Unclear on the validity of this calculation without clearer assumptions listed.
3. Specify the building type used to establish 50 EUI baseline.

Recommended Energy Projection Adjustments

1. Validate 2% HVAC energy savings assumption with reference studies.

21-GP1-97: DR THERMOSTATS

Summary of Findings

Code change proposal, budget requirements, and efficiency projections were based off a credible source, the 2013 CASE report for upgradeable setback thermostats. Costs referenced from the 2013 CASE reports should be updated to reflect current costs, but the order of magnitude of cost savings compared to the incremental cost from 2013 gives confidence that overall cost savings will still be realized.

Cost Analysis

Comments on Proponent's Cost Analysis

1. Detailed cost analysis from a reliable source - 2013 CASE report - was referenced.

Recommended Cost Adjustments

No recommended adjustments

Energy Analysis

Comments on Proponent's Energy Analysis

1. Detailed energy analysis from a reliable source – 2013 CASE report – was referenced

Recommended Energy Projection Adjustments

No recommended adjustments

21-GP1-190: DEMAND CONTROLLED VENTILATION

Summary of Findings

Code change proposal, budget requirements, and efficiency projections were based off a credible source, ANSI/ASHRAE/IES Standard 90.1-2019 Addendum b.

Cost Analysis

Comments on Proponent's Cost Analysis

1. Detailed cost analysis from a reliable source – ANSI/ASHRAE/IES Standard 90.1-2019 Addendum b - was referenced.

Recommended Cost Adjustments

No recommended adjustments

Energy Analysis

Comments on Proponent's Energy Analysis

1. Detailed energy analysis from a reliable source – ANSI/ASHRAE/IES Standard 90.1-2019 Addendum b – was referenced.

Recommended Energy Projection Adjustments

No recommended adjustments

21-GP1-204: EXTERIOR BUILDING GROUNDS LIGHTING

Summary of Findings

Code change proposal, budget requirements, and efficiency projections appear consistent with the original intent of the code requirement. Sensible updates to stay consistent with updates in lighting technology. Removing exception for solar powered lamps seems reasonable under the understanding that these fixtures fall outside of the scope of the energy code since they would not be connected to the building's electrical service.

Cost Analysis

Comments on Proponent's Cost Analysis

1. No cost impacts on removing and/or modifying redundant code language.
2. The updated lighting power densities and associated cost analysis reasoning, or lack thereof, needs a proper link to cost data, but Ecotope does not expect the savings to fall short of those projected in the proposal.

Recommended Cost Adjustments

No recommended adjustments

Energy Analysis

Comments on Proponent's Energy Analysis

1. No energy impacts on removing and/or modifying redundant code language.
2. Energy calculations are reasonable for 50% reduction in lighting power density. Note, proposal is assuming 4,380 annual hours of nighttime when light fixtures would operate – this is in line with weather file data for Seattle and Spokane.

Recommended Energy Projection Adjustments

No recommended adjustments

21-GP1-198: EXTERIOR LIGHTING

Summary of Findings

Code change proposal, budget requirements, and efficiency projections were based off a credible source, the California's Title 24 and ANSI/ASHRAE/IES Standard 90.1. The updated lighting power densities and cost analysis needs a proper link to the codes and standards referenced, but Ecotope does not expect the savings to fall short of those projected in this proposal.

Cost Analysis

Comments on Proponent's Cost Analysis

1. Detailed cost analysis from a reliable source – BC Hydro funded cost analysis of 90.1 - was referenced.

Recommended Cost Adjustments

No recommended adjustments

Energy Analysis

Comments on Proponent's Energy Analysis

1. Detailed energy analysis in direct correlation with updated lighting power reductions.

Recommended Energy Projection Adjustments

No recommended adjustments

REFERENCES

Dongsu Kim, S. J. (2017). *Evaluation of energy savings potential of variable refrigerant flow (VRF) from variable air volume (VAV) in the U.S. climate locations.*

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TRC, EnergySoft. (2019). *2019 Nonresidential New Construction Reach Code Cost Effectiveness Study.* California Energy Codes & Standards.

APPENDIX A: UPDATED LIFE CYCLE COST ANALYSES

Figure 1: 21-GP1-136 – LCCA Summary (Revised – 50% HPWH Capacity with Gas Supplemental)

Office of Financial Management
Olympia, Washington - Version: 2020-A
Life Cycle Cost Analysis Tool

Executive Report

Project Information	
Project:	
Address:	
Company:	
Contact:	
Contact Phone:	
Contact Email:	

Key Analysis Variables		Building Characteristics	
Study Period (years)	50	Gross (Sq.Ft)	0
Nominal Discount Rate	5.00%	Useable (Sq.Ft)	0
Maintenance Escalation	1.00%	Space Efficiency	
Zero Year (Current Year)	2020	Project Phase	0
Construction Years	0	Building Type	0

Life Cycle Cost Analysis		BEST	
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intenstity (kBtu/sq.ft)			
1st Construction Costs	$ 148,734	$ 58,367	$ -
PV of Capital Costs	$ 313,221	$ 106,636	$ -
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 532,636	$ 583,700	$ -
Total Life Cycle Cost (LCC)	**$ 845,857**	**$ 690,336**	**$ -**
Net Present Savings (NPS)	**N/A**	**$ 155,521**	**$ -**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost	BEST		
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	2,065	4,584	-
% CO2e Reduction vs. Baseline	N/A	-122%	45%
Present Social Cost of Carbon (SCC)	$ 134,544	$ 290,936	$ -
Total LCC with SCC	**$ 980,401**	**$ 981,272**	**$ -**
NPS with SCC	**N/A**	**$ (871)**	**$ -**

*Baseline is a HPWH plant – 50% HPWH capacity with gas supplemental heating

*Alt 1 is a central gas water heating system

Baseline Input Page

Total Building Annual Utility Analysis	$ 15,038	Water (CCF)	Electricity (KWH)	Natural Gas (Therms)
Annual Utility Bill [$]			$ 10,012	$ 5,026
Annual Utility Consumption Not Entered Below			116,965	6,144
Sum of Annual Utility Consumption Below		-	-	-
Total Annual Utility Consumption		-	116,965	6,144
Annual Utility Bill ÷ Total Utility Consumption		$ -	$ 0.09	$ 0.82

SHOW	Uniformat II Elemental Classification for Buildings (Building Component List)		REF	# of Units	Useful Life (Yrs.)	Installed Cost ($/Unit)	1st Year Maintenance Cost ($/Unit)	Total Component Installed Cost ($'s)	Annual Water (CCF/Unit)	Annual Electricity (KWH/Unit)	Annual Natural Gas (Therm/Unit)
	Primary Entries Below: # of Units must be > 0 to be counted; Useful Life must be >= 2							$ 148,734	Entries Below for Component Specific Utility Ana		
	A	Substructure									
	B	Shell									
	C	Interiors									
	D	Services									
x	D20	Plumbing									
x	D201098	Gas Water Heating Plant									
x	D201097	Gas Boiler		1	15	$14,508.00		$ 14,508			
x	D202098	Storage Tanks									
x	D202097	Gas Line									
x	D203098	Central Heat Pump Water Heater									
x	D203097	Heat Pump Water Heater		1	15	$69,426.00		$ 69,426			
x	D204098	Storage Tanks		3	25	$21,600.00		$ 64,800			
x	D204097	Backup Electric Tanks									
x	D209098	Electrical Systems									

*Baseline is a HPWH plant – 50% HPWH capacity with gas supplemental heating

Alternative 1 Input Page

Total Building Annual Utility Analysis	$ 14,118	Water (CCF)	Electricity (KWH)	Natural Gas (Therms)
Annual Utility Bill [$]			$ -	$ 14,118
Annual Utility Consumption Not Entered Below				17,259
Sum of Annual Utility Consumption Below		-	-	-
Total Annual Utility Consumption		-	-	17,259
Annual Utility Bill ÷ Total Utility Consumption		$ -	$ -	$ 0.82

SHOW	Uniformat II Elemental Classification for Buildings (Building Component List)		REF	# of Units	Useful Life (Yrs.)	Installed Cost ($/Unit)	1st Year Maintenance Cost ($/Unit)	Total Component Installed Cost ($'s)	Annual Water (CCF/Unit)	Annual Electricity (KWH/Unit)	Annual Natural Gas (Therm/Unit)
	Primary Entries Below: # of Units must be > 0 to be counted; Useful Life must be >= 2								Entries Below for Component Specific Utility Ana		
	Match Baseline: Filter to Select All & Drag Copy O14:S14 & U14:AG14							$ 58,367			
	A	Substructure									
	B	Shell									
	C	Interiors									
	D	Services									
	D20	Plumbing									
	D201098	Gas Water Heating Plant									
	D201097	Gas Boiler		1	15	$14,508.00		$ 14,508			
	D202098	Storage Tanks		2	25	$21,600.00		$ 43,200			
	D202097	Gas Line		1	51	$659.00		$ 659			
	D203098	Central Heat Pump Water Heater									
	D203097	Heat Pump Water Heater									

*Alt 1 is a central gas water heating system

Figure 2: 21-GP1-103 Space Heating Proposal – LCCA Summary (Medium Office)

Office of Financial Management
Olympia, Washington - Version: 2020-A
Life Cycle Cost Analysis Tool

Executive Report

Project Information	
Project:	
Address:	
Company:	
Contact:	
Contact Phone:	
Contact Email:	

Key Analysis Variables		**Building Characteristics**	
Study Period (years)	50	Gross (Sq.Ft)	0
Nominal Discount Rate	5.00%	Useable (Sq.Ft)	0
Maintenance Escalation	1.00%	Space Efficiency	
Zero Year (Current Year)	2020	Project Phase	0
Construction Years	0	Building Type	0

Life Cycle Cost Analysis	**BEST**		
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intenstity (kBtu/sq.ft)			
1st Construction Costs	$ 1,287,072	$ 1,287,072	$ -
PV of Capital Costs	$ 2,516,899	$ 2,516,899	$ -
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 277,729	$ 384,896	$ -
Total Life Cycle Cost (LCC)	**$ 2,794,628**	**$ 2,901,796**	**$ -**
Net Present Savings (NPS)	**N/A**	**$ (107,168)**	**$ -**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost	**BEST**		
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	371	793	-
% CO2e Reduction vs. Baseline	N/A	-114%	47%
Present Social Cost of Carbon (SCC)	$ 26,482	$ 53,732	$ -
Total LCC with SCC	**$ 2,821,110**	**$ 2,955,528**	**$ -**
NPS with SCC	**N/A**	**$ (134,418)**	**$ -**

Office of Financial Management
Olympia, Washington - Version: 2020-A
Life Cycle Cost Analysis Tool

Baseline Input Page

☑ Show All Entered Units (Requires Re-Filter)

Total Building Annual Utility Analysis	$ 8,560	Water (CCF)	Electricity (KWH)
Annual Utility Bill [$]			$ 8,560
Annual Utility Consumption Not Entered Below			100,000
Sum of Annual Utility Consumption Below		-	-
Total Annual Utility Consumption		-	100,000
Annual Utility Bill ÷ Total Utility Consumption		$ -	$ 0.09

SHOW	Uniformat II Elemental Classification for Buildings (Building Component List)		REF	# of Units	Useful Life (Yrs.)	Installed Cost ($/Unit)	1st Year Maintenance Cost ($/Unit)	Total Component Installed Cost ($'s)	Annual Water (CCF/Unit)	Annual Electricity (KWH/Unit)
	Primary Entries Below: # of Units must be > 0 to be counted; Useful Life must be >= 2							$ 1,287,072	Entries Below for Component S	
	A	Substructure								
	B	Shell								
	C	Interiors								
	D	Services								
x	D20	Plumbing								
x	D201098	Electric + gas VAV - Medium Office								
x	D202098	VRF - Medium office		53628	20	$24.00		$ 1,287,072		
	E	Equipment & Furnishings								
	F	Special Construction & Demolition								
	G	Building Sitework								
	Z	Other Project Costs								
	Z10	One Time - Upfront Costs		1	50					
	Z30	Re-Occurring Annual Cost (Track Inflation)		1	1					

<- Primary Filter (Requires Level 1)

Office of Financial Management
Olympia, Washington - Version: 2020-A
Life Cycle Cost Analysis Tool

Alternative 1 Input Page

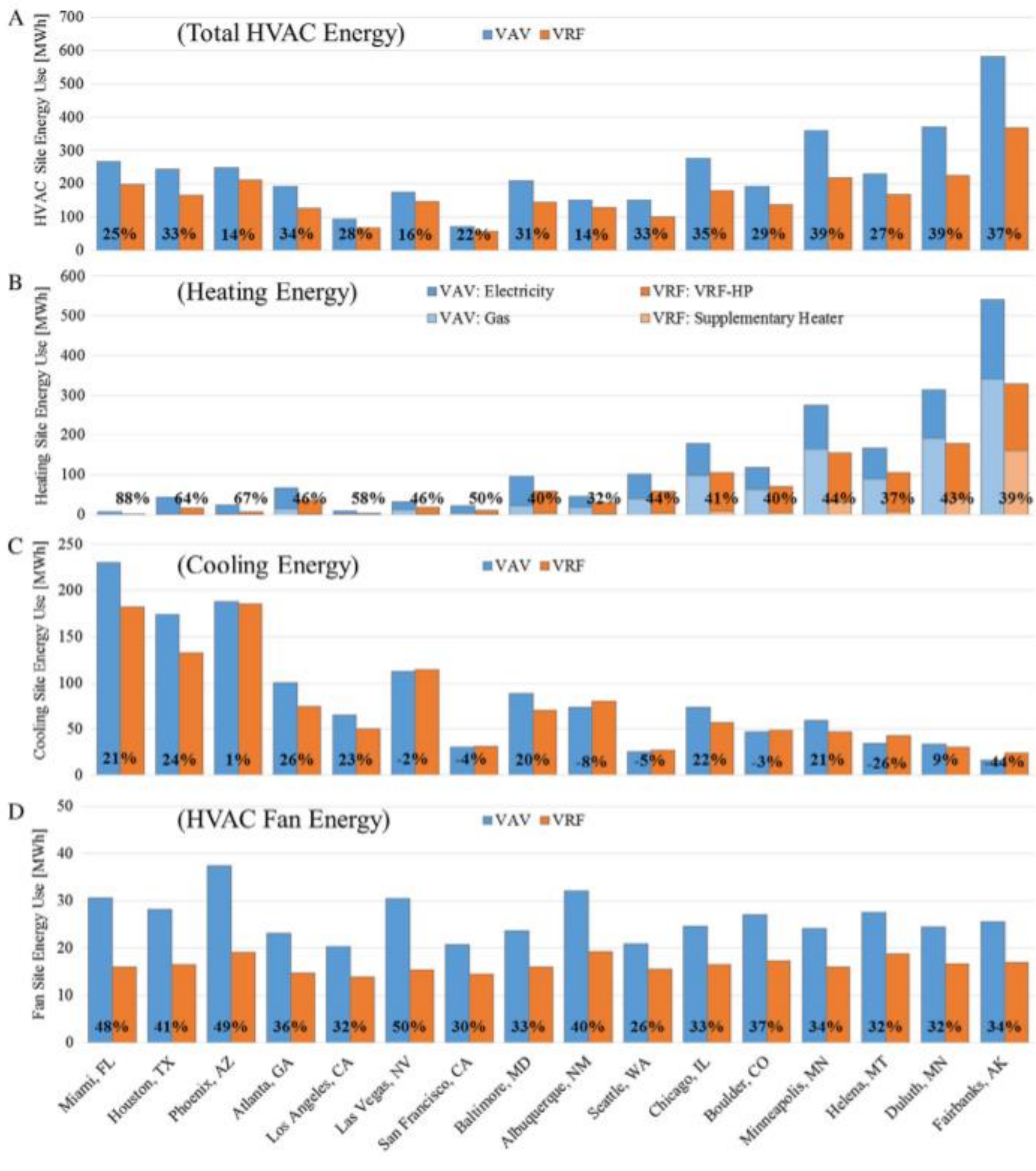
Open Primary Filter and Click OK to Re-filter

○ Manual Special Selection Only (Requires Refilter)
◉ Show Baseline Fields and Entered Units (Requires Refilter)
○ Show Differences Between Alternative and Baseline (Req. Refilter)

Total Building Annual Utility Analysis	$ 11,557	Water (CCF)	Electricity (KWH)	Natural Gas (Therms)
Annual Utility Bill [$]			$ 10,440	$ 1,117
Annual Utility Consumption Not Entered Below			116,000	1,365
Sum of Annual Utility Consumption Below		-	-	-
Total Annual Utility Consumption		-	116,000	1,365
Annual Utility Bill ÷ Total Utility Consumption		$ -	$ 0.09	$ 0.82

SHOW	Uniformat II Elemental Classification for Buildings (Building Component List)		REF	# of Units	Useful Life (Yrs.)	Installed Cost ($/Unit)	1st Year Maintenance Cost ($/Unit)	Total Component Installed Cost ($'s)	Annual Water (CCF/Unit)	Annual Electricity (KWH/Unit)	Annual Natural Gas (Therm/Unit)
	Primary Entries Below: # of Units must be > 0 to be counted; Useful Life must be >= 2								Entries Below for Component Specific Utility Ana		
	Match Baseline: Filter to Select All & Drag Copy O14:S14 & U14:AG14							$ 1,287,072			
.	A	Substructure									
	B	Shell									
	C	Interiors									
	D	Services									
	D20	Plumbing									
	D201098	Electric + gas VAV - Medium Office		53628	20	$24.00		$ 1,287,072			
	D202098	VRF - Medium office									
	E	Equipment & Furnishings									
	F	Special Construction & Demolition									
	G	Building Sitework									
	Z	Other Project Costs									
	Z10	One Time - Upfront Costs		1	50						
	Z30	Re-Occurring Annual Cost (Track Inflation)		1	1						

Figure 3: Modeled HVAC Energy Savings of Baseline (VAV) and Proposed (VRF) Systems (Kim, 2017)



APPENDIX B: 21-GP1-136 HEAT PUMP WATER HEATING – ENERGY CALCULATIONS AND RESULTS

Table 3: Water Heating Annual Energy Usage Results

Climate Zone	Building Type	Load	Annual Energy Consumption (kBtu/yr)			HPWH Savings	
			HPWH	Electric Water Heater	Gas Water Heater	% Savings over Electric	% Savings Over Gas
4C	**Office**	100 ppl	20,611	47,047	55,868	56%	63%
	Elementary	100 ppl	13,871	30,020	35,649	54%	61%
	Secondary	100 ppl	30,744	73,035	86,729	58%	65%
	Food Service	100 meals/hr	90,638	214,624	254,866	58%	64%
	Multifamily	173 units*	598,748	1,453,415	1,725,930	59%	65%
5B	**Office**	100 ppl	23,432	47,047	55,868	50%	58%
	Elementary	100 ppl	15,626	30,020	35,649	48%	56%
	Secondary	100 ppl	35,505	73,035	86,729	51%	59%
	Food Service	100 meals/hr	104,995	214,624	254,866	51%	59%
	Multifamily	173 units*	704,779	1,453,415	1,725,930	52%	59%

**using to Proponent's assumptions*

Table 4: Water Heating Energy Calculation Inputs

WATER HEATING CALCULATION INPUTS	
HP Capacity Required (Btu/h)	VARIES W/ BUILDING TYPE
Design Capacity Factor	16%
Entering Water Temp (°F)	50
Leaving Water Temp (°F)	120
Swing Tank Temp (°F)	125
Storage Temp (°F)	150
Ambient Air Temp (°F)	67.5
Electric Resistance COP	1
HPWH Min. Temp Limit (°F)	-15
Water Density (lbs/gal)	8.33
Electric Water Heater COP	0.95
Gas Heating Efficiency	0.8
RECIRC INPUTS - MULTIFAMILY ONLY	
Recirc Pipe Heat Loss (W/Unit)	80
Multifamily GPD/unit	37.5

Table 5: Heat Pump Water Heater Energy Calculation Results

Climate Zone	4C					5B				
Building Type	Office	Elementary	Secondary	Food Service	Multifamily	Office	Elementary	Secondary	Food Service	Multifamily
Total Annual Energy Usage (kBtu)	20,611	13,871	30,744	90,638	598,748	23,432	15,626	35,505	104,995	704,779
Total Annual Energy Usage (kWh)	6,041	4,065	9,010	26,564	175,483	6,867	4,580	10,406	30,772	206,559
Annual Heating Demand (kBtu)	53,891	34,388	83,660	245,847	1,735,883	53,891	34,388	83,660	245,847	1,735,883
Annual Average COP	**2.61**	**2.48**	**2.72**	**2.71**	**2.90**	**2.30**	**2.20**	**2.36**	**2.34**	**2.46**
Annual HPWH Energy Usage (kBtu)	15,648	9,332	25,025	74,793	572,166	18,292	10,811	29,330	87,899	672,308
Annual ER Energy Usage (kBtu)	4,963	4,538	5,719	15,845	26,582	5,140	4,814	6,174	17,096	32,472
Annual Temperature Maintenance Swing Tank ER (kBtu)	4,938	4,503	5,643	15,630	25,751	4,938	4,503	5,643	15,630	25,751
Annual Demand from Primary (kBtu)	48,954	29,884	78,017	230,217	1,710,132	48,954	29,884	78,017	230,217	1,710,132
Annual Demand Satisfied by HPWH (kBtu)	48,927	29,849	77,938	229,990	1,709,272	48,741	29,567	77,465	228,670	1,703,182
Annual Demand Satisfied by Primary ER (kBtu)	27	36	79	227	860	212	318	552	1,547	6,950

APPENDIX C: 21-GP1-136 REVISED WATER HEATING PLANT COSTS

Basis for HPWH Costing:
Load Breakdown:
173 Unit Apartment Building, 1.5 average occupants assumed per apartment.
25 GPD usage per occupant (market rate apartment best practice assumption)
100 Watts per apartment temperature maintenance (aka recirculation) loss, FOS = 1.5

Equipment Sizing:
HPWH plant was sized using the Ecosizer for a 173-unit apartment building, and modelled around a CO2 HPWH system with in-series temperature maintenance heating.
Electric Resistance plant was sized with the Ecosizer, but designed to satisfy the temperature maintenance load with the primary heating plant.
Gas water heating plant was sized per ASHRAE Ch. 51: Service Water Heating, Figure 21. Apartments

Equipment Costing:

Heat Pump Plant w/ Gas Supplementary	**QTY**	**Unit Price**	**Install and Markup***	**Total Cost**	**Reference**
CO2 HPWH	1	38570	80%	69,426	Equipment quote
500 Gal Storage Tank	3	12000	80%	64,800	Original cost analysis with updated sizing
Gas Boiler (360,000 BTUH)	1	8060	80%	14,508	Home Depot and Supply House (heater, pump, RIB, Aquastat)
				0	RSMeans 2022
				0	RSMeans 2022
				0	RSMeans 2022
Controls	included			0	
			Total:	148,734	

Electric Resistance Heating Plant

500 gal Tank w/ 35 kW ER Heater	3	73100	included	219,300	RSMeans (interpolated from existing options)
Electrical Panel Upgrade (400A)	1	12725	included	12,725	RSMeans 2022
Electrical Service/Distribution (400A), per lf	100	104.5	included	10,450	RSMeans 2022
			Total:	242,475	

Gas Water Heating Plant

Gas Boiler (360,000 BTUH)	1	8060	80%	14,508	Original cost analysis + 30% to account for boiler cap. Increase
500 Gal Storage Tank	2	12000	80%	43,200	Original cost analysis with updated sizing
gas line, 1", per lf	100	6.59	included	659	2013 RSMeans, ran through CPI inflation calculator: https://www.bls.gov/data/inflation_calculator.htm
Controls	included			0	
			Total:	58,367	

*Installation and markup percentage were adopted from RMI's original cost analysis when RSMeans data was not referenced.

Equipment Costing References:

Heat Pump Plant	**Reference**
CO2 HPWH	Equipment quote
500 Gal Storage Tank	Original cost analysis with updated sizing
Rheem Supplementary Electeric WH (36kW)	Home Depot and Supply House (heater, pump, RIB, Aquastat)
Temperature Maint. Heater - 120 gal, 26kW	RSMeans 2022
Electrical Panel Upgrade (400A)	RSMeans 2022
Electrical Service/Distribution (400A), per lf	RSMeans 2022

Electric Resistance Heating Plant	
500 gal Tank w/ 35 kW ER Heater	RSMeans (interpolated from existing options)
Electrical Panel Upgrade (400A)	RSMeans 2022
Electrical Service/Distribution (400A), per lf	RSMeans 2022

Gas Water Heating Plant	
Gas Boiler (360,000 BTUH)	Original cost analysis + 30% to account for boiler cap. Increase
500 Gal Storage Tank	Original cost analysis with updated sizing
gas line, 1", per lf	2013 RSMeans, ran through CPI inflation calculator: https://www.bls.gov/data/inflation_calculator.htm

MEMORANDUM

Pacific Northwest NATIONAL LABORATORY

Date:	**2/25/2022**		
To:	**Stoyan Bumbalov**	Information Release #	**PNNL-SA-170654**
From:	**Matthew Tyler**		
Subject:	**Preliminary Cost-Effectiveness of Renewable Energy Proposal for the Washington State Energy Code**		

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

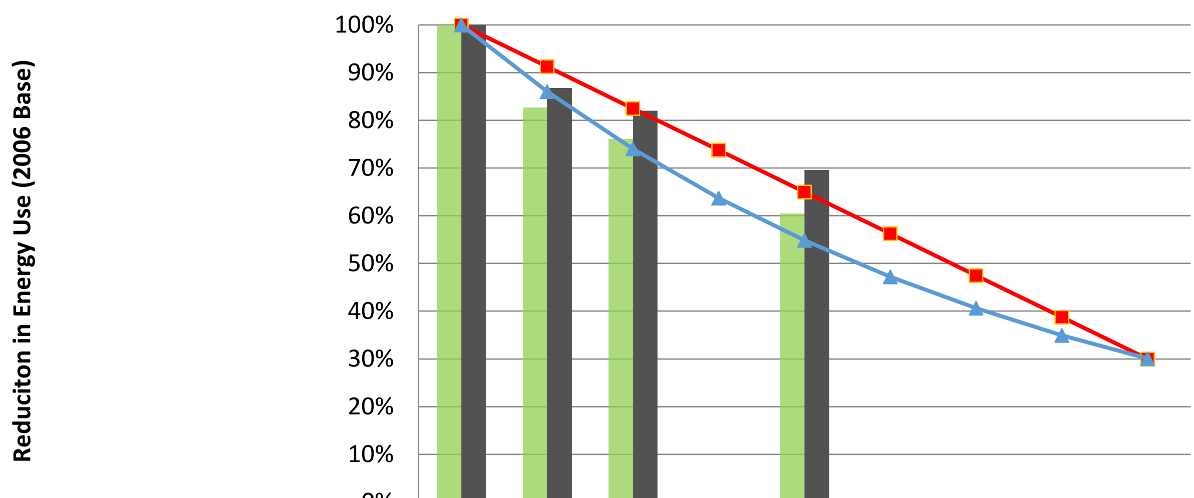
Table 7. Simple Payback (years)

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

Preliminary Cost Benefit Analysis for the 2021 Washington State Energy Code, Commercial Provisions

The legislature finds making homes, businesses, and public institutions more energy efficient will save money, create good local jobs, enhance energy security, reduce pollution that causes global warming, and speed economic recovery while reducing the need to invest in costly new generation. The State Energy Code Act, RCW 19.27A, sets forth the statutory authority and goals for the adoption and amendment of the Washington State Energy Code. The primary goals are to construct increasingly energy efficient homes and buildings that help achieve the broader goal of building zero fossil-fuel greenhouse gas emission homes and buildings by the year 2031 [*RCW 19.27A.020 (2)(a)*], any amendments must increase the energy efficiency of typical newly constructed nonresidential buildings [*RCW 19.27A.025(1)(a)*], and amendments shall incrementally move towards achieving a seventy percent reduction in annual net energy consumption by 2031 [*RCW 19.27A.160*]. To achieve the required seventy percent reduction, the Washington State Building Code Council (SBCC) established two models for measuring incremental change. One was to target an 8.75 percent reduction each three-year code cycle compared to the 2006 code. The other pathway is a 14 percent reduction over the previous code.

Incremental Improvement Compared to Targets



	2006	2009	2012	2015	2018	2021	2024	2027	2030
Residential	100%	82.7%	76.1%		60.5%				
Commercial	100%	86.8%	82.0%		69.6%				
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%

Based on the report of the progress made with the 2018 code towards the 70 percent reduction, a 19 percent reduction over the previous code was identified to place the commercial portions of the code back on track to attain the targeted reduction for the 2021 code. Stakeholders were asked to submit proposals to help attain this reduction goal.

Additionally, the Clean Buildings Act [*RCW 19.27A.210*] requires large nonresidential building owners in Washington state to demonstrate building performance in compliance with an established energy use intensity (EUI) target. Currently there are incentives for those buildings showing voluntary early compliance. However, compliance will be mandatory beginning in 2026. Several concerns were expressed that if the Washington State Energy Code did not meet the reduction goals, it could cause newer building stock to be out of compliance with the Clean Buildings Act, requiring retroactive upgrades to building systems.

The Residential Portion of the energy code covers residential buildings including single family homes, townhouses, and multi−family dwelling unit buildings that are three stories and less. The Commercial Portion of the energy code, which is the topic of this cost benefit analysis, covers all non−residential buildings, residential dwelling unit buildings that are four stories and more, and all residential sleeping unit buildings regardless of the number of stories.

The International Energy Conservation Code is the base document for the development of the Washington State Energy Code and this national model code is updated every three years. Those updates that further the statutory goals set forth in RCW 19.27A are integrated with the existing WAC 51-11C language and published as a basis for stakeholders to submit code change proposals.

The Washington State Building Code Council (SBCC) filed the Preproposal Statement of Inquiry to initiate the development of the 2021 Washington State Energy Code, Commercial Provisions, as adopted through WAC 51-11C, on March 23, 2021. In considering amendments to the state energy code, the Council established and consulted with a technical advisory group (TAG) including representatives of appropriate state agencies, local governments, general contractors, building owners and managers, design professionals, utilities, and other interested and affected. On April 1, 2021, the SBCC opened a 60-day submittal period for proposals for the 2021 Washington State Energy Code, Commercial provisions.

The Council has adopted a definition of cost−effectiveness based on RCW 39.35 as recommended by Department of Commerce. A guide on how to evaluate cost−effectiveness is therefore defined by the Council as a code change that has a net present savings over a 50−year life−cycle of a building utilizing the Life Cycle Cost Tool (LCCT) as developed by the Washington State Office of Financial Management (OFM). The methodology of the LCCT is based on the NIST Handbook 135 methodology and utilizes specific inputs as determined by the Council with guidance from the Washington State Department of Commerce[1]. The cost effectiveness analysis uses the average useful life years from Appendix 7 of the BOMA Preventive Maintenance Guidebook for all building components that are evaluated[2]. An alternate method of cost effectiveness analysis or determining average useful life years of building components may be applied. Each code change submitted that is not editorial or explanatory is required to include this analysis.

The TAG was also tasked with reviewing the proposals received, identifying pros and cons and whether it helped achieve the broader goals of energy savings and emission reduction. The TAG also discussed whether modifications were needed to ensure the provisions were correlated with other requirements,

[1] http://www.ofm.wa.gov/budget/facilities/costanalysis.asp
[2] https://icap.sustainability.illinois.edu/files/projectupdate/2289/Project% 20Lifespan%20Estimates.pdf

technically feasible, commercially available, and cost–effective to building owners and tenants, or if changes were necessary to mitigate any disproportionate impact on small business.

161 proposals were submitted during the two-month submittal period. After hundreds of hours of discussions, the TAG recommended that 118 proposals move forward into the rulemaking process. Most of these proposals are exempt from the cost benefit analysis requirement of 34.05.328 as they are editorial or provide additional clarity to existing rules. Additionally, changes coming from the national model code process (International Energy Conservation Code) are also exempt from the requirements of RCW 34.05.328 and not addressed here. Ultimately 23 proposals were identified as having more than a minimal cost impact. Thirty-seven proposals were editorial. The remaining 60 proposals were either clarifying requirements, correlating code requirements, or had minimal impact. Those with minimal impact are highlighted in Table 1.

TABLE 1
Code Change Proposals with Minimal Economic Impact

Code Change	Section/Description	Cost/Energy Savings
21-GP1-159	**C402.2.8/C402.2.9:** New requirement detailing control of thermal bridging at concrete balconies and fenestration frames to reduce heat loss.	Estimated construction cost of $1.33 per square foot or $1000 per dwelling unit for those apartments/dwellings with cantilevered concrete balconies. Estimated annual energy savings of 0.02 kBtu per square foot per balcony, or a savings of $11.79 per year per balcony in energy cost.
21-GP1-161	Table C402.4: Fenestration U-values are reduced, while allowing a slighter higher value for operable window for a greater range of choice. The fenestration U-values for increased allowable fenestration area is adjusted accordingly.	This proposal reduces heat loss through fenestration, the most significant heat loss for building envelopes. The higher-performance fenestration is moderately more expensive than conventional, a cost that is likely to moderate as the new standard becomes commonplace. The estimated construction cost is $0.09 per square foot, or $69 per dwelling unit, with estimated annual energy savings of 0.016 kBtu per square foot, or 12.4 kWh/kBtu per dwelling unit.
21-GP1-108	**C402.5.2:** Removes the exception allowing the air leakage rate to be exceeded with a report of corrective action taken.	Currently, if a building fails the envelope leakage test, corrective action is to be taken but verification is not required. Requiring retest and correction action measures be taken until the required air leakage rate is met encourages best practices to be implemented during construction. This proposal only economically impacts projects that fail to meet the required air leakage rate.
21-GP1-104	**C402.5.5**: Align combustion air duct insulation requirements with outside air requirements.	Initial capital costs will be more expensive for the insulation material and labor. Estimate of construction cost is less than $0.01 per square foot, with an estimated energy savings of 10.6 kBtu per square foot, based on a 50,000 square foot building.

Code Change	Section/Description	Cost/Energy Savings
21-GP1-163	**C403.2.4/C404.13**: Decrease the size threshold for requiring variable speed drive for fan and pump motors.	The estimated incremental construction cost is $0.04 per square foot. With an estimated 4 VFD motors in a 10,000 square foot building. Estimated energy savings of $0.10 kWh per square foot.
21-GP1-166	**C403.3.7:** A new section and table are added to incorporate requirements from ASHRAE 90.1 limiting the flow rate in critical circuits of hydronic systems to minimize flow resistance.	The requirements ensure hydronic system piping is designed appropriately and may result in larger pipe sizes for projects that would have otherwise had under-sized pipes. Pumping energy costs will be reduced. Estimated cost of construction is $0.02 per square foot based on a 100,000 sf building, with an estimated annual energy savings of 0.6 kBtu per square foot.
21-GP1-167	**C403.4.12**: Requires pressure independent control valves where the flow rate over coils is over 5 gallons per minute.	PICVs play an important role in reducing energy consumption while maintain building temperature at optimal setpoints, and are capable of reducing HVAC energy use more than 20%. Estimated construction cost is $0.01 per square foot, with an estimate of annual energy savings of 0.05 kWh per square foot based on a 100,000 sf building.
21-GP1-191	**C403.7.5**: Requires variable frequency drives on all motors over 5 hp in parking garage and loading dock ventilation systems.	There is an increased first cost for the VFD controller. ASHRAE 90.1 addendum d states that all VAV system fans are required to have VFD so no economic analysis is required. Title 24 reports that the estimated incremental cost is $2500 plus $600 in installation costs for each 10,000 cfm of garage exhaust. The average garage has 6 hp per 10,000 cfm. Annual energy saving is estimated at 2818 kWh per hp.
21-GP1-170	**C403.7.6.2:** Increases the enthalpy recovery ratio from 50 to 60 percent for other than R-2 occupancies.	There is a slight increase in cost of ERV, with a 20% increase in recovered energy. Estimated construction cost is $0.10 per square foot, with an estimated annual energy savings of 1 kWh per square foot.
21-GP1-174	C404.6.1: Requires thicker insulation for service water heating storage tanks designed for storage temperatures over 130 degrees.	The estimated incremental construction cost is $0.01 per square foot, with an estimated annual energy savings of 0.1 kBtu per square foot.
21-GP1-175	C404.7.1: Requires service water circulation systems with multiple risers or zones and variable flow circulation pumps to use self-actuating thermostatic balancing valve to	The estimated construction cost is $0.002 per square foot, based on a 100,000 square foot building. The estimated annual energy savings are 0.2 kWh per square foot.

Code Change	Section/Description	Cost/Energy Savings
	optimize flow of hot water to the different zones.	
21-GP1-182	C404.7.1.2: Requires electronically commutated motors for all service water heating circulation pumps.	In service water heating systems, circulation pumps with electronically commutated motors (ECM) offer up to 20% annual energy savings compared to circulation pumps with standard induction motors. There is an estimated $250 incremental cost per pump based on manufacturer data, with a net present LCCA savings of $677, with a 30% reduction in carbon emissions.
21-GP1-176	C404.7.3.1: New section to require thicker insulation for service water system piping in the circulation loop.	Estimated construction cost is $0.002 per square foot with an estimated annual energy savings of 0.1 kBtu per square foot.
21-GP1-177	C404.11.1: Requires heat pump water heaters on heated pools over 2000 gallons	Cost for pool heaters is not related to size of building. A heat pump pool heater costs approximately $1000 more than an electric resistance heater. Since pools are frequently used in warmer weather, the effective heat pump COP can be considerable higher than the rated COP at 50°F, reducing power consumption by as much as 80%. Specific savings will depend on frequency of use and size of pool.
21-GP1-178	**C405.2:** Lighting control requirements, including high end trim, for luminaire level lighting controls; requirement for LLLC in open plan office areas larger than 5,000 square feet	The requirement to conduct high-end trim will increase installation costs and deliver significant energy savings. This is an optional path, however. Task tuning is estimated at $0.06 per square foot. Assuming 80 square feet per fixture, the cost is approximately $5.28 per fixture, with an energy savings of 12.5kWh per year per fixture.
21-GP1-125	**C405.2.7.3:** Decreases the lamp wattage for luminaires requiring activity sensor control.	Costs and savings are estimated from the Nonresidential Outdoor Lighting Controls report from the CASE Initiative. Incremental construction cost increase was estimated at $72.30 for the activity sensor. The estimated annual savings is $145, with a 24% decrease in carbon emissions.
21-GP1-98	**C405.3:** Increases the efficiency requirements for lighting used for plant growth and maintenance.	The proposal represents a 6.3% improvement for greenhouses and a 18.8% savings for indoor growing applications. Indoor growing facilities can vary in size, but the exception threshold can be used as an example of savings. US DOE estimates that indoor growing facilities use

Code Change	Section/Description	Cost/Energy Savings
		lighting 5,200 to 6,570 hours per year. That results in a savings of 39-51 MWh per year for the smallest system subject to the requirement. DOE also estimates 2,000 hours of runtime in greenhouses, which would result in 5 MWh savings per year for the smallest system subject to the requirements. These will result in substantial operating savings for growers, particularly for operations that also require cooling to offset heat gains from lighting loads.
21-GP1-137	**C405.13:** Adds uninterruptible power supply requirements for computer rooms based on Energy Star requirements.	Incremental costs were found to be $112/kWh for high efficiency UPS systems and were converted to $/sq.ft. based on a 500 square foot room (the threshold for which a computer room does not qualify as a data center. The cost estimate is $0.22 per square foot, with an estimated energy savings of 6.5 kWh per square foot.
21-GP1-101	**C408.1**: Lowers the threshold for commissioning requirements.	Typical commercial building commissioning cost is $1.00 per square foot, resulting in an energy cost savings of 15% annually. Simple energy saving payback of 7-years Assuming occupant productivity cost improvement simple payback time is cut in half.

Code proposals identified as significant are identified in Table 2, and are detailed below.

TABLE 2
Code Change Proposals Marked as Significant Impact

Proposal Number	Subject	Proponent	Initial Cost Benefit Analysis
21-GP1-103	Space Heating Proposal	Jonny Kocher, RMI	Proponent's Cost Benefit Analysis
21-GP1-136	Heat Pump Water Heating	Jonny Kocher, RMI	Proponent's Cost Benefit Analysis
21-GP1-179	Electrical Receptacles at Gas Appliances	Duane Jonlin, City of Seattle	Proponent's Cost Benefit Analysis
21-GP1-78	On-Site Renewable Energy	Mark Frankel, Ecotope	Proponent's Cost Benefit Analysis
21-GP1-207	CMU Walls Table Footnote Modification	Luke Howard, Commerce	Proponent's Cost Benefit Analysis

Proposal Number	Subject	Proponent	Initial Cost Benefit Analysis
21-GP1-208	Elimination of CMU Wall Footnote	Luke Howard, Commerce	Proponent's Cost Benefit Analysis
21-GP1-69	HVAC TSPR	Michael Rosenberg PNNL	Proponent's Cost Benefit Analysis
21-GP1-95	Indoor Horticulture Dehumidification	Sean Denniston, New Buildings Institute	Proponent's Cost Benefit Analysis
21-GP1-99	DR Water Heaters	Sean Denniston, New Buildings Institute	Proponent's Cost Benefit Analysis
21-GP1-193	Compressed Air	Mike Kennedy	Proponent's Cost Benefit Analysis
21-GP1-180	Reduce Threshold for LPA Compliance on Remodels	Duane Jonlin, City of Seattle	Proponent's Cost Benefit Analysis
21-GP1-139	Boiler Controls	Nicholas O'Neil, Energy 350	Proponent's Cost Benefit Analysis
21-GP1-138	Fan Power Allowance Tables	Nicholas O'Neil, Energy 350	Proponent's Cost Benefit Analysis
21-GP1-160	PTAC U-factors	Duane Jonlin, City of Seattle	Proponent's Cost Benefit Analysis
21-GP1-164	Include Split Systems in HP Requirement	Duane Jonlin, City of Seattle	Proponent's Cost Benefit Analysis
21-GP1-133	High capacity space heating boiler	Mike Kennedy	Proponent's Cost Benefit Analysis
21-GP1-165	60% enthalpy ERV required for DOAS, except R1/R2	Duane Jonlin, City of Seattle	Proponent's Cost Benefit Analysis
21-GP1-97	DR Thermostats	Sean Denniston, New Buildings Institute	Proponent's Cost Benefit Analysis
21-GP1-190	DCV	Mike Kennedy	Proponent's Cost Benefit Analysis
21-GP1-204	Exterior Building Grounds Lighting	Michael Myer, PNNL	Proponent's Cost Benefit Analysis
21-GP1-198	Exterior Lighting	Michael Myer, PNNL	Proponent's Cost Benefit Analysis
21-GP1-146	Additional Efficiency Credits	Mark Frankel, Ecotope	Proponent's Cost Benefit Analysis
21-GP1-206	Load Management	Reid Hart, PNNL	Proponent's Cost Benefit Analysis

Heat Pump Space Heating, Proposal 21-GP1-103, adding a new section WAC 51-11C-40314 and modifying existing sections 51-11C-40702 and 51-11C-50300

Brief Description: Provide heat pump space heating, rather than fossil fuel or electric space heating, for all buildings. Exceptions are provided to allow electric resistance heating for small loads and as supplementary heat. Exceptions also allow fossil fuel auxiliary heat in Climate Zone 5 under certain conditions.

Purpose of code change: Heat pump space heating eliminates a significant source of fossil fuel combustion in buildings and is generally two to four times more energy efficient than either fossil fuel or electric resistance heating. This proposal aligns with State policy to increase energy efficiency by 70 percent by 2031. Additionally, this proposal will significantly reduce emissions and is aligned with State policy to achieve the broader goal of building zero fossil-fuel greenhouse gas emission homes and buildings by the year 2031. According to analysis based on the data from the 2021 Washington State Energy Strategy, we need to reduce the commercial buildings sector emissions by 38 percent to keep on track to meet our 2050 climate goals. To achieve this, the State will need to quadruple the proportion of annual sales of heat pumps from 11 percent of all commercial space heating equipment in 2020 to 40 percent by 2030. To get to this increase in market penetration of heat pumps, the Washington State Energy Code should require heat pump space heating in the 2021 code cycle. See Supplemental Attachment[3] for further details on emissions and market penetration.

Review Process: The TAG spent several 6-hour meetings reviewing this proposal. It was sent back several times to be revised and reviewed by workgroups, including the proponent and key stakeholders. Through these workgroups and TAG review, modifications were suggested and made to help mitigate impact on small business. Alternative provisions were added to allow gas auxiliary heat in climate zone 5 (eastern Washington). Impact on existing buildings was mitigated; with the requirements applicable only if the entire HVAC system is replaced. Further modifications allowing more significant use of fuel gas appliances were reviewed and rejected by the TAG. These minority report opinions were forwarded to the Mechanical, Ventilation and Energy Codes Committee and the Council, along with the TAG recommendations, for review and consideration as alternate options for adoption.[4]

Probable Benefits vs probable costs: Construction costs for heat pump space heating are often, but not always, higher than for conventional natural gas or electric resistance heating. Annual energy costs for heat pumps are much lower than for electric resistance heating, but the same or slightly higher when compared with gas heating, at current rates (World Bank long term forecasts indicate an increase of over 80% in gas prices over the coming decade.) When including the Washington State social cost of carbon, heat pump space heating is more cost effective than both gas heating and electric resistance heating over the life cycle analysis horizon.

Benefits to building owners, tenants, and businesses include early alignment with the Clean Buildings Bill (to avoid future performance compliance penalties) and reduced life cycle cost (especially when considering the potential increases to the Social Cost of Carbon). Given the state's climate goals and policy, this Energy Code proposal will help ensure new assets permitted beginning July 1, 2023, will not need to be immediately retrofitted to conform with the Clean Buildings requirements.

The average net present value capital cost increase for this proposal will be around $0.24/square foot. The average life cycle cost savings of $0.70/square foot and $2.70/square foot when including the social cost of carbon. See Supplemental Attachment (footnote 3) for more details.

[3] https://sbcc.wa.gov/sites/default/files/2021-10/103_HP%20Space%20Heat_supplemental.pdf
[4] https://sbcc.wa.gov/sites/default/files/2021-07/103_Minority%20Report_Amendment%28s%29_072121.pdf

Heat Pump Water Heating, Proposal 21-GP1-136, Option 2 provides a new Section C404.2.1 under WAC 51-11C-40402 and modifying sections 51-11C-40407 and 51-11C-50300, as well as adding new definitions for *Temperature Maintenance*, *Single-pass* and *Multi-pass*. If this proposal is not adopted, there also options within Section C406 that increase the number of credits required and provide credits for the installation of heat pump water heaters.

Brief Description: Provide heat pump water heating rather than fossil fuel or electric resistance water heating in commercial buildings. Exceptions are provided to allow electric resistance heating for hand washing facilities.

Purpose of code change: Heat pump water heating eliminates a significant source of fossil fuel combustion in buildings and is generally 2-4 times more energy efficient than either fossil fuel or electric resistance heating. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031. Additionally, this proposal will significantly reduce emissions, aligned with state policy to achieve the broader goal of building zero fossil-fuel greenhouse gas emission homes and buildings by the year 2031. According to analysis done on data from the 2021 Washington State Energy Strategy, we would need to reduce the commercial buildings sector emissions by 38 percent to keep on track to meet our 2050 climate goals. To achieve this, the state will need to dramatically increase the proportion of annual sales of heat pump water heaters from 2 percent of all commercial water heating equipment in 2020 to 50 percent by 2030. To get to this increase in market penetration of heat pump water heaters, the Washington State Energy Code should require heat pump water heating in the 2021 code cycle.

Review Process: The TAG spent several meetings reviewing this proposal, and it was sent back several times to be revised and reviewed by workgroups, including the proponent and key stakeholders. Through these workgroups and TAG review, modifications were suggested and made to help mitigate impact on small business, and to clarify and simplify the language. Impact on existing buildings was mitigated; allowing like-for-like replacement of existing water heaters. Further modifications allowing more significant use of fuel gas appliances were reviewed and rejected by the TAG. These minority report opinions were forwarded to the Mechanical, Ventilation and Energy Codes Committee and the Council, along with the TAG recommendations, for review and consideration as alternate options for adoption.[5] The proposed rule also reflects two options. The Energy Code Technical Advisory Group recommended adoption of this proposed change, but if it is ultimately not adopted there are other changes that should occur. Option 2 includes these changes as recommended by the TAG. Option 1 under Section C404.2.1 provides changes to require efficiency upgrades and other small changes to coordinate with other proposals. There are also options within Section C406 contingent upon the adoption of this measure.

Probable Benefits vs probable costs: The average net present value capital cost increase for this proposal will be around $2.47/square foot. The proposal will have a life cycle cost increase of $2.43/square foot when not accounting for the social cost of carbon. When accounting for the adjusted social cost of carbon, the heat pump water heater proposal will have a $0.38/sq ft savings.

[5] https://sbcc.wa.gov/sites/default/files/2021-08/136_Minority_Amendments_081221.pdf

See page 21 of the referenced economic and lifecycle cost analysis for further information.[6] The average energy savings will be approximately 5.5 kBtu per square foot. There is no anticipated increase in plan review or inspection time.

Benefits to building owners include early alignment with the Clean Buildings Bill (to avoid future performance compliance penalties) and annual energy costs for water heating. Given the state's climate goals and policy, this Energy Code proposal will help ensure new assets permitted beginning July 1, 2023, will not need to be immediately retrofitted to conform with the Clean Buildings requirements.

Electrical receptacles at gas appliances, Proposal 21-GP1-179, Adds a new section to WAC 51-11C-40507

Brief Description: Requires an electrical receptacle or junction box placed at the location of installed gas range, cooktop or over; gas clothes dryer, or gas water heater to enable future "plug and play" installation of electric appliances.

Purpose of Change: The installation of electrical infrastructure at the time of construction is cheaper and easier to install versus retrofitting. With the state focus on greenhouse gas reduction and reduction of fossil fuel appliances, it is assumed that future replacement will be with electric versions of household appliances.

Review Process: The Technical Advisory Group reviewed this proposal and made a few technical corrections to the requirements. They felt this was a reasonable requirement in light of state policy, although this was not a unanimous opinion.

Probable benefits vs. probable costs: There is an estimated cost of $250 per receptacle with no associated energy savings. Assuming an apartment has only one gas appliance installed, typically a stove, the average cost would be $0.33 per square foot. This would eliminate any additional cost when and if the appliance(s) is replaced in the future.

Renewable Energy Required, Proposal 21-GP1-078, Adds a new section to WAC 51-11C-41100.

Brief Description: Adds requirement for deployment of on-site renewable energy for commercial buildings over 10,000 sf.

Purpose of Change: To achieve state mandates of 70% energy use reduction by 2030, it will be necessary to incorporate some renewable energy into buildings to offset energy use. Renewable deployment needs to begin immediately to build up industry capacity to meet anticipated needs in the building sector over the next decade. This proposal starts down this path with modest renewable energy deployment requirements for commercial buildings. Renewable deployment also supports clean building and clean grid policies set by the state.

[6] https://sbcc.wa.gov/sites/default/files/2021-12/136_Economic_Package.pdf

Review Process: The Technical Advisory Group discussed this proposal over two meetings, with a meeting of a workgroup in between the two meetings. The workgroup centered around the costs, which showed a wide range, both higher and lower than those used in the cost calculations below. The general trend was that smaller systems cost more per Watt than larger systems, and the installation costs continue to decrease. The TAG also heard testimony from the Washington Public Utility Districts Association questioning the assumptions on payback in the cost analysis.

Probable benefits vs. probable costs: The proponent states this proposal results in 3-17% electricity savings for tenants and businesses and annual operating energy costs savings between $1,140.98 to $25,253.58 while resulting in an increase in first cost to building owners. On-site renewable generation provides a layer of resiliency against utility blackouts and other climate-related power supply events. This resiliency benefit has not been included in the economic impact analysis below.

Using the sources cited in the references, an intermediate cost (not the lowest) of $1.72/Wdc installed cost for nonresidential PV systems was used. This installed cost is reported by NREL. The SEIA report on the U.S. market states a lower cost of $1.36/Wdc, whereas other sources report slightly higher cost. With the PV and battery measure for nonresidential new construction in California's energy code (to be adopted in June 2021), and global and U.S. trends for installed PV costs, it is likely PV costs will continue to reduce and will be lower than today's costs by the time this measure is enforced for buildings in Washington state.

Energy and Cost Savings

1. Prototypical buildings developed by PNNL were used to develop energy and energy cost savings. PV system size (kW) was calculated based on the floor area and the 0.50 W/sf requirement.
2. NREL's PVWatts tool was used to estimate the PV generation in Seattle, WA. It is likely that generation will be higher in eastern Washington, given the higher solar resource.
3. EIA's energy prices for Washington State in 2021 were used ($0.092/kWh).
4. A simple payback of 17 years was calculated based on the installed cost and annual energy cost savings.

Prototype	Floor Area	# of Stories	kW Required	kWh Generation	Installed System Cost	Annual Energy Cost Savings	Simple Payback
Large Office	498,000	13	249	273,900	$428,280	$25,253.58	16.95
Medium Office	53,600	3	27	29,480	$46,096	$2,718.06	16.95
Small Office	5,500	1	3	3,025	$4,730	$278.91	16.95
Standalone Retail	24,700	1	12	13,585	$21,242	$1,252.54	16.95
Stripmall Retail	22,500	1	11	12,375	$19,350	$1,140.98	16.95
Primary School	73,960	1	37	40,678	$63,606	$3,750.51	16.95
Secondary School	210,900	2	105	115,995	$181,374	$10,694.74	16.95
Warehouse	49,495	1	25	27,222	$42,566	$2,509.89	16.95
Mid-rise Apartment	33,700	4	17	18,535	$28,982	$1,708.93	16.95
High-rise Apartment	84,360	10	42	46,398	$72,550	$4,277.90	16.95

Review Process: Testimony was received from the Washington Public Utility Districts Association stating that "the assumed retail price of electricity of $0.092/kWh is too high. It appears that the proponent looked to the Energy Information Agency (report EIA-861, 2019 data) and divided total revenue from commercial customers in Washington by total was delivered to those customers to come up with the estimated retail price. However, the total revenue includes fixed and demand charges. If the TAG is to use averages, the better estimate is from retail utility commercial energy rates. Those averaged $0.0619/kWh in 2018. However, averages mask the wide variability in commercial energy rates among Washington utilities. For example, the current commercial retail electric rates for Chelan and Douglas PUDs are $0.016 and $0.021/kWh, respectively, while Jefferson and Klickitat PUDs are $0.0785 and $0.084/kWh. If this proposal is adopted, customer savings are going to vary dramatically depending on the electric utility serving that customer. Also, if either "net metering" threshold identified in 1.a. is exceeded, then the utility is free to treat the facility as no different than any other power producer and pay wholesale market prices for electricity from that facility." Based on information from WPUDA, payback ranges from 25 to 97 years rather than the stated 17 years.

Conflicting testimony was received from the Washington Solar Energy Industries Association stating that "WAPUDA's economic analysis exaggerates the impact net metering statute would play on grid-tied solar installations under the proposal's changes to the code. Based on U.S. Department of Energy figures, the present day average electrical consumption of a commercial building is 22.5 kWh/sq ft… These solar installations would simply replace a portion of the building's expected electrical load and the electricity would be consumed onsite. Very little would be returned to the grid and therefore the retail rate is the correct valuation for the energy as documented in the Proposal. Additionally, the $0.09/kWh energy price disputed by WAPUDA is more likely too conservative than too high. The 2021 Washington State Energy Strategy projects the state's overall electrical load will double by 2045 because of aggressive efforts to electrify transportation, buildings and the industrial sector. While this further proves my above point that the electricity produced by the amendment's provisions will continue to be consumed onsite, it also undoubtedly puts an upward pressure on electricity rates statewide, across all building prototypes."

While the TAG did recognize there was a minority report regarding the cost of the system, it was felt that on-site generation is a necessary piece of the code requirements to be able to reach the 70 percent reduction/net-zero energy goals of the guiding statute.

CMU Walls, Proposal 21-GP1-207, Modifies footnote c on Table C402.1.3 and footnote d on Table C402.1.4.

Proposal 21-GP1-208, Eliminates footnote c on Table C402.1.3 and footnote d on Table C402.1.4

Brief Description: There are two options offered for both opaque thermal envelope tables. Option 1 (207) modifies the mass wall footnote c, limiting the application of the exception single wythe concrete block walls exposed on both sides. Option 2 (208) removes the exception.

Purpose of Change: This code proposal would increase the efficiency of CMU wall without additional construction costs. This proposal is consistent with the code development objectives of RCW 19.27A.020(2)(a) and RCW 19.27A.160. It is important to modernize the application of Concrete Masonry Unit (CMU) walls for the code to achieve the anticipated energy savings. This code proposal would eliminate the allowance for vermiculite core fill of covered/finished CMU walls which will effectively double the thermal resistance of effected walls by lowering the wall U-factor from 0.24 for vermiculite filled cores per this exception to 0.104 for insulating per C402.1.3/C402.1.4. This proposal is supported by the economic analysis done by Mike Kennedy for the 2015 code cycle, based on a study for the Bonneville Power Administration[7].

Probable benefits vs. probable costs: The table below lists the cost of labor and materials of insulating per C402.1.3/C402.1.4 of per the exceptions of footnotes c of C402.1.3 or d of C402.1.4. This table illustrates that for buildings finishing exterior CMU walls the costs to meet the prescriptive requirements of C402.1.3/C402.1.4 is no greater than that of compliance through the exceptions to C402.1.3 or C402.1.4.

Based on RS Means 2014 with cost data adjusted for inflation rate for the period between January 2014 and April 2021 per on-line inflation calculator maintained by the U.S. Bureau of Labor Statistics (BLS).

Insulation Strategy	U-Factor	Materials &Labor $/sf
Vermiculite, 50% of Cores (RSM p. 229) per exception	0.24	$1.30/sf
R-9.5 CI Interior (RSM p. 242) per C402.1.3/C402.1.4.	0.104	$1.29/sf

Key Analysis Variables (207 & 208)		**Building Characteristics**	
Study Period (years)	50	Gross (Sq.Ft)	24,695
Nominal Discount Rate	74.11%	Useable (Sq.Ft)	0
Maintenance Escalation	1.00%	Space Efficiency	0.0%
Zero Year (Current Year)	2020	Project Phase	0
Construction Years	0	Building Type	0

Life Cycle Cost Analysis (207)		**BEST**	
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intensity (kBtu/sq.ft)	35.5	34.3	34.2
1st Construction Costs	$14,557	$14,445	$18,365
PV of Capital Costs	$14,557	$14,445	$18,365
PV of Maintenance Costs			
PV of Utility Costs	$28,086	$27,072	$26,967
Total Life Cycle Cost (LCC)	**$42,643**	**$41,518**	**$45,332**
Net Present Savings (NPS)	**N/A**	**$1,126**	**$ (2,688)**

[7] https://sbcc.wa.gov/sites/default/files/2021-07/207_CMU_Evaluation_19July2015_MK.pdf

(GHG) Social Life Cycle Cost (207)		**BEST**	
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	1,202	1,166	1,163
% CO2e Reduction vs. Baseline	N/A	3%	3%
Present Social Cost of Carbon (SCC)	$10,201	$9,838	$9,800
Total LCC with SCC	**$52,844**	**$51,356**	**$55,132**
NPS with SCC	**N/A**	**$1,488**	**$ (2,288)**

Life Cycle Cost Analysis (208)	**BEST**		
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intensity (kBtu/sq.ft)	35.5	34.3	34.3
1st Construction Costs	$14,557	$42,776	$48,039
PV of Capital Costs	$14,557	$42,776	$48,039
PV of Maintenance Costs			
PV of Utility Costs	$28,086	$27,072	$27,072
Total Life Cycle Cost (LCC)	**$ 42,643**	**$69,849**	**$75,112**
Net Present Savings (NPS)	**N/A**	**$(27,205)**	**$(32,468)**
(GHG) Social Life Cycle Cost (208)	**BEST**		
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	1,202	1,166	1,166
% CO2e Reduction vs. Baseline	N/A	3%	3%
Present Social Cost of Carbon (SCC)	$10,201	$9,838	$9,838
Total LCC with SCC	**$52,844**	**$79,687**	**$84,950**
NPS with SCC	**N/A**	**$ (26,843)**	**$ (32,106)**

While the TAG recommended that both proposals move forward for public comment, with Council concurrence, based on the life cycle cost analysis it would appear that Proposal 208, while reducing carbon emissions by 3%, does not show either net present savings or social life cycle cost savings over current code requirements. Proposal 207 does show modest savings.

HVAC Total System Performance Ratio, Proposal 21-GP1-69: Modifies WAC 51-11C-40310, Section C403.1.1 and WAC 51-11C-80500, Appendix D

Purpose of code change: This change expands the scope of TSPR to cover multifamily residential buildings and also provides revisions to Appendix D: Calculation of HVAC Total System Performance Ratio to provide additional clarifications based on interpretation requests received, incorporate revisions made to Seattle energy code, and add additional system parameters added to Table D601.11.2. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

Review Process: The TAG spent some time in reviewing this proposal, and the modifications made were for clarity rather than any of the technical aspects. The final version was recommended with no stated opposition.

Probable benefits vs. probable costs: The estimated incremental cost for the expansion into multifamily is $0.02 per square foot or about $20 per dwelling unit) based on the design cost for a 60 unit apartment. It will likely not add to construction costs. For the multifamily buildings added to the scope of TSPR it is anticipated that a code official might need to spend 0.5 to 1.5 hours reviewing the submitted material.
The estimated annual energy savings for multifamily residential buildings is 1.94 kBtu per square foot.

The goal of the Total System Performance Ratio is to compare an HVAC system to systems with good known performance and efficiency to set a performance baseline for installed systems. A more efficient HVAC system will reduce life cycle costs for owners and tenants and lower carbon emissions. As Washington State works to achieve a 70 percent reduction in new building energy use, performance based codes will likely become more necessary and prevalent. The HVAC system performance requirements familiarize users with this approach and help establish a performance path towards Washington's long term goals.

Indoor Horticulture Dehumidification, Proposal 21-GP1-95: Adds a new section as WAC 51-11C-40394.

Purpose of code change: This proposal adds requirements for dehumidification efficiency for indoor growing facilities.

With lighting for indoor plant growth and maintenance becoming regulated under the 2021-IECC, HVAC loads emerge as the next major opportunity to improve the energy efficiency of indoor horticulture. Of those, dehumidification is the load that is the most under/un-addressed in the existing WSEC. This proposal is based on the requirements currently being adopted for the 2022 edition of Title 24.

This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

Review Process: The proposed language gives multiple options for meeting the requirement, which allows indoor growing facilities to options to integrate compliance dehumidification systems into multiple different HVAC designs and does not force facilities into a single dehumidification strategy.

There is currently no national standard for indoor growing dehumidification equipment. 10 CFR, Part 430, Subpart B - Appendix X1 does provide a method for measuring the energy input for standalone dehumidifiers, so this has been leveraged to set the threshold for that type of equipment. However, standalone equipment will not be an appropriate strategy for all facilities, so the proposal also includes options to utilize recovered energy for dehumidification reheat needs.

Probable benefits vs. probable costs: The CASE Report[8] found incremental costs of $8.11 per square foot of growing area. Total cost per square foot of building would vary based on how much of the facility is dedicated to non-growing uses. The savings per total building square footage would vary depending on the amount of space dedicated to non-growing uses. The CASE Report found that savings for CA climate zones 1,2 & 16 (the closest match to WA's climate zones), was 80-81 kBtu per square foot per year.[9] There will also be additional time required for both plan review and site inspection. The additional time should be minimal as this requirement just adds one additional criterion to equipment that plan checkers and site inspectors are already checking.

Demand Responsive Water Heating, Proposal 21-GP1-99: Adds new section, WAC 51-11C-40414.

Brief Description: This proposal adds demand responsive control requirements for certain water heaters.

Purpose of change: The revision provides editorial changes that align the language with the terminology to denote these water heaters in the water heating equipment efficiency table. The protocol has been changed to CTA-2045-A. Conversations with AHRI have indicated that there may not sufficient availability of equipment that meets CTA-2045-B by the time this code goes into effect. It also clarifies that the alternate demand responsive control needs to be equivalent to CTA-2045-A.

Water heaters can provide significant load shifting and energy storage capacity in many building types. ANSI/CTA-2045 standardizes the socket, and communications protocol, for heat pump water heaters so they can communicate with the electricity grid other demand response signal providers. In addition, 2045 adds control and communications requirements for mixing valves in heat pump water heaters to enable them to provide greater storage capacity to support increased load shifting. This proposal requires that water heaters with integrated storage tanks have this demand control functionality. The water heaters subject to this requirement generally serve lavatories and kitchenettes in commercial buildings and some water heating approaches in mid-rise residential.

Review Process: There was considerable discussion and modification of this proposal at the TAG level. There was concern expressed early on from manufacturers that this requirement conflicted with the rules developed by Commerce and a workgroup was formed to address industry concerns. The proposal going forward was modified to limit applicability and not conflict with the Commerce Department rule (WAC 194-24-180).

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[8] Final CASE Report: Controlled Environment Horticulture, California Statewide Codes and Standards Enhancement (CASE) Program, Oct. 2020, https://title24stakeholders.com/wp-content/uploads/2020/10/2022-T24-NR-CEH-Final-CASE-Report.pdf.

[9] Final CASE Report: Controlled Environment Horticulture, California Statewide Codes and Standards Enhancement (CASE) Program, Oct. 2020, https://title24stakeholders.com/wp-content/uploads/2020/10/2022-T24-NR-CEH-Final-CASE-Report.pdf.

Probable benefits vs. probable costs: Grid flexibility is one of the foundations of achieving meaningful decarbonization of building energy as it is an essential element of decarbonizing the electrical grid. Carbon free energy sources like solar and wind have varying production over the course of the day and the year. Demand responsive controls that can respond to demand response signals enable buildings to shape their loads to better align with available energy production. This could come in the form of curtailing energy use when demand is high or utilizing excess production for building tasks like pre-conditioning spaces or service hot water when demand is lower.

Demand control functionality will present a cost-saving opportunity for buildings in the future. More and more utilities are moving beyond voluntary programs and are expanding use of time-of-use rates for electricity as a tool for shaping demand. Installing demand-responsive lighting controls now will allow building tenants and owners to better control their utility costs. Since this requirement is part of the construction code, it will not require buildings to participate in any demand response programs. But it will ensure that buildings are capable of participating, so that buildings will be able to help integrate building loads with available production.

There are two cost scenarios for CTA-2045-enabled water heaters:

- **Heat Pump Water Heaters:** CTA-2045 has become a largely standard (but not universal) feature of heat pump water heaters. Rheem and AO Smith, the brands carried by Home Depot and Lowes, both include CTA-2045 ports. Therefore, for buildings that are already utilizing unitized HPWHs to meet performance requirements, the incremental cost is $0 through product selection.
- **Electric Resistance Water Heaters:** CTA-2045 electric resistance water heaters have been produced, but don't seem to be widely available since HPWHs have taken over the energy efficient segment of the market. Therefore, the most straightforward way to implement CTA-2045 is to move to a HPWH with an incremental cost in the $1000 range. However, many utilities in WA offer incentives in the $500 range.
  - Rheem 40-gal "Performance" electric resistance: $379[10]
  - Rheem 50-gal "Performance Platinum" HPWH: $1399[11]

This proposal will add a minimal amount of extra plan review. Spec sheets will need to be checked to ensure that the water heater meets the requirement. There should be no additional inspection time if site inspectors are checking that water heating equipment is consistent with the construction documents.

[10] https://www.homedepot.com/p/Rheem-Performance-40-Gal-Medium-6-Year-4500-4500-Watt-Elements-Electric-Tank-Water-Heater-XE40M06ST45U1/205810725. Accessed 6/30/2021
[11] https://www.homedepot.com/p/Rheem-Performance-Platinum-50-Gal-10-Year-Hybrid-High-Efficiency-Smart-Tank-Electric-Water-Heater-XE50T10H45U0/312742081. Accessed 6/30/2021

Compressed Air Systems, Proposal 21-GP1-193:

Purpose of code change: Adds new code section regulating compressed air systems. Language is taken from proposed Title 24 2022 language and is similar but much more comprehensive to City of Seattle requirements. The intent is that this would apply to process loads. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031 and reduce greenhouse gas emissions.

Review process: The TAG discussed adding further exceptions for laboratories and oil-free compressors, but in the end they decided to recommend that it go to public hearing as presented.

Probable benefits vs. probable costs: Increased first costs and decreased utility bills. The costs and saving are determined from Title 24 CASE Reports[12]. In both reports portions of the requirements were evaluated in 4 prototypes. For each requirement, data from the prototype where it was least cost effective was used to evaluate the measure in the OFM calculator. Thus the estimate cost benefit is very conservative

No independent cost estimate was made. Costs and saving are determined from Title 24 Case reports.

This proposal will require jurisdictions to review compressed air designs and verify testing and monitoring. A complete guess but maybe 4 hours per permit that has systems of this scale which is a small fraction of the total permits.

Requirement	T24 Worst Case	Initial Cost	Annual Energy Savings	Ongoing expense
Auto-shut down timer	Prototype 3	$6173	7025kWh	
Trim Compressor	Operating Profile 3 / 25 hp	$4000	8293kWh	
Pipe Sizing	Prototype 4	$272982	210147 kWh	
Monitoring	Prototype 1	$10685	42058 kWh	$300/yr data services for 2 comps + $500 every 5 for calibration
Leak Testing	Prototype 3	$3342	6548 kWh	

[12] Pipe Sizing, Monitoring, and Leak Testing for Compressed Air Systems: https://title24stakeholders.com/wp-content/uploads/2020/06/NR-Compressed-Air_Draft-CASE-Report.pdf; Final Case Report. Sept 2020. Prepared by AESC, Inc. and Energy Solutions: https://title24stakeholders.com/wp-content/uploads/2020/01/T24-2013-Final-CASE-Report-AirCompressors.pdf

Smart Controls

Life Cycle Cost Analysis		BEST	
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intensity (kBtu/sq.ft)	#DIV/0!	#DIV/0!	#DIV/0!
1st Construction Costs	$ -	$ 6,173	$ -
PV of Capital Costs	$ -	$ 15,237	$ -
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 333,677	$ 310,236	$ 333,677
Total Life Cycle Cost (LCC)	**$ 333,677**	**$ 325,474**	**$ 333,677**
Net Present Savings (NPS)	**N/A**	**$ 8,204**	**$ -**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost		BEST	
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	2,059	1,915	2,059
% CO2e Reduction vs. Baseline	N/A	7%	0%
Present Social Cost of Carbon (SCC)	$ 130,707	$ 121,525	$ 130,707
Total LCC with SCC	**$ 464,385**	**$ 446,999**	**$ 464,385**
NPS with SCC	**N/A**	**$ 17,386**	**$ -**

Trim Compressor

Life Cycle Cost Analysis		BEST	
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intensity (kBtu/sq.ft)	#DIV/0!	#DIV/0!	#DIV/0!
1st Construction Costs	$ -	$ 4,000	$ -
PV of Capital Costs	$ -	$ 9,873	$ -
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 333,677	$ 306,005	$ 333,677
Total Life Cycle Cost (LCC)	**$ 333,677**	**$ 315,879**	**$ 333,677**
Net Present Savings (NPS)	**N/A**	**$ 17,798**	**$ -**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost		BEST	
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	2,059	1,888	2,059
% CO2e Reduction vs. Baseline	N/A	8%	0%
Present Social Cost of Carbon (SCC)	$ 130,707	$ 119,868	$ 130,707
Total LCC with SCC	**$ 464,385**	**$ 435,747**	**$ 464,385**
NPS with SCC	**N/A**	**$ 28,638**	**$ -**

Pipe Sizing

Life Cycle Cost Analysis		BEST	
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intensity (kBtu/sq.ft)	#DIV/0!	#DIV/0!	#DIV/0!
1st Construction Costs	$ -	$ 272,982	$ -
PV of Capital Costs	$ -	$ 673,819	$ -
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 3,336,772	$ 2,635,559	$ 3,336,772
Total Life Cycle Cost (LCC)	**$ 3,336,772**	**$ 3,309,378**	**$ 3,336,772**
Net Present Savings (NPS)	**N/A**	**$ 27,394**	**$ -**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost		BEST	
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	20,592	16,265	20,592
% CO2e Reduction vs. Baseline	N/A	21%	0%
Present Social Cost of Carbon (SCC)	$ 1,307,074	$ 1,032,396	$ 1,307,074
Total LCC with SCC	**$ 4,643,845**	**$ 4,341,774**	**$ 4,643,845**
NPS with SCC	**N/A**	**$ 302,071**	**$ -**

Monitoring

Life Cycle Cost Analysis		BEST	
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intenstity (kBtu/sq.ft)	#DIV/0!	#DIV/0!	#DIV/0!
1st Construction Costs	$ -	$ 10,685	$ -
PV of Capital Costs	$ -	$ 26,374	$ -
PV of Maintenance Costs	$ -	$ 13,601	$ -
PV of Utility Costs	$ 3,336,772	$ 3,196,434	$ 3,336,772
Total Life Cycle Cost (LCC)	**$ 3,336,772**	**$ 3,236,409**	**$ 3,336,772**
Net Present Savings (NPS)	**N/A**	**$ 100,362**	**$ -**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost		BEST	
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	20,592	19,726	20,592
% CO2e Reduction vs. Baseline	N/A	4%	0%
Present Social Cost of Carbon (SCC)	$ 1,307,074	$ 1,252,101	$ 1,307,074
Total LCC with SCC	**$ 4,643,845**	**$ 4,488,510**	**$ 4,643,845**
NPS with SCC	**N/A**	**$ 155,335**	**$ -**

Leak Detection

Life Cycle Cost Analysis		BEST	
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intenstity (kBtu/sq.ft)	#DIV/0!	#DIV/0!	#DIV/0!
1st Construction Costs	$ -	$ 3,342	$ -
PV of Capital Costs	$ -	$ 8,249	$ -
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 3,336,772	$ 3,314,923	$ 3,336,772
Total Life Cycle Cost (LCC)	**$ 3,336,772**	**$ 3,323,172**	**$ 3,336,772**
Net Present Savings (NPS)	**N/A**	**$ 13,600**	**$ -**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost		BEST	
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	20,592	20,457	20,592
% CO2e Reduction vs. Baseline	N/A	1%	0%
Present Social Cost of Carbon (SCC)	$ 1,307,074	$ 1,298,515	$ 1,307,074
Total LCC with SCC	**$ 4,643,845**	**$ 4,621,687**	**$ 4,643,845**
NPS with SCC	**N/A**	**$ 22,159**	**$ -**

Reduced Threshold for LPA Compliance on Remodels, Proposal 21-GP1-180: Amends Section C503.7.2 within WAC 51-11C-50300

Brief Description: Requires alterations replacing 20 percent or more of existing lighting fixtures to comply with the lighting power allowance in Section C405. The previous threshold was 50 percent. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

Purpose of change: This proposal is based on current requirements in the Seattle code. The proposals lowered the threshold for replacement lighting needing to meet the lighting power allowance, requiring more projects to upgrade to more efficient lighting. Lighting is one of the largest end uses of electricity within commercial buildings.

Review Process: There was some concern that this may have a negative impact on retrofit projects, but it was noted that this reduction was championed at ASHRAE by Puget Sound Energy. The TAG was generally in agreement with the proposal.

Probable benefits vs. probable costs: A detailed analysis was not done, since there were no control requirements, just a lower lighting power allowance

Cost: Estimate of $0.75 per square foot. Energy Savings: Estimate of 0.13 kWh per square foot.

Boiler Controls, Proposal 21-GP1-139: Modifies WAC 51-11C-40334.

Brief Description: Adds definitions for commercial and process boilers and adds a new section with criteria for combustion air controls and minimum stack gas oxygen concentration levels for boiler systems. These requirements are applied to commercial building and process boilers.

Purpose of Change: Boiler oxygen controls, combustion air controls, and variable fan motors have been commonplace in other state codes on larger boilers for quite some time. This proposal would align requirements forthcoming in California Title 24 with the forthcoming code in WA as the specifications are the same. The effect will be an improvement in the part-load operation of larger boilers. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

Review Process: There was little discussion or controversy at the TAG level for this proposal. The requirements have been in effect in California for a few years.

Probable benefits vs. probable costs: The analysis is based on EnergyPlus modeling of prototype buildings for California CASE study for 2022 Title 24.[13] Savings shown here are assuming a large office building in CA Climate Zone 2 (equivalent to CZ 4C) which is 13 stories. Provisions shown to be cost-effective for commercial boilers in all modeled scenarios for this climate zone except mixed use and apartment high-rise. Process boilers cost-effective in all cases due to constant load assumptions.

Estimated incremental cost: $0.098/square foot:
- Flue damper cost = $1665 ($1500 2013 inflated 11% to 2021) + $166 ($150 2013 inflated 11%) every 10 years
- VFD cost = $4716 ($4249 2013 inflated 11% to 2021) + ½ hour per year in maintenance @$100/hr
- O2 trim controls cost = $7500 (2022) + 4 hours per year in maintenance @$100/hr

Estimated annual energy savings: 2.116 KBTU/ square foot:
- Flue damper – 2.5 mmbtu boiler 229 therms
- VFD – 10 hp fan 4080 kWh
- O2 trim controls – 5 mmBtu boiler 2746 therms

[13] Final CASE report available here: https://title24stakeholders.com/wp-content/uploads/2020/08/NR-Boilers-and-Water-Heating_Final-CASE-Report.pdf

Key Analysis Variables		Building Characteristics	
Study Period (years)	50	Gross (Sq.Ft)	147,176
Nominal Discount Rate	5.00%	Useable (Sq.Ft)	147,176
Maintenance Escalation	1.00%	Space Efficiency	100.0%
Zero Year (Current Year)	2020	Project Phase	0
Construction Years	0	Building Type	0

Life Cycle Cost Analysis		BEST	
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intenstity (kBtu/sq.ft)	246.2	244.0	
1st Construction Costs	$	$13,881	$
PV of Capital Costs	$	$34,439	$
PV of Maintenance Costs	$	$18,702	$
PV of Utility Costs	$19,826,323	$19,714,377	$
Total Life Cycle Cost (LCC)	**$ 19,826,323**	**$ 19,767,518**	**$**
Net Present Savings (NPS)	**N/A**	**$58,806**	**$**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost		BEST	
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	71,232	70,427	-
% CO2e Reduction vs. Baseline	N/A	1%	101%
Present Social Cost of Carbon (SCC)	$4,659,220	$4,607,990	$
Total LCC with SCC	**$24,485,543**	**$24,375,508**	**$**
NPS with SCC	**N/A**	**$110,036**	**$-**

Fan Power Allowance, Proposal 21-GP1-138: Replaces Section C403.8.1 and associated tables in WAC 51-11C-4038

Brief Description: Revises the fan power allowance tables and updates them to align with new fan power budget and allowances based on system type in the 2022 Title 24 code. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

Purpose of Change: This proposal updates the approach to fan power limitations and aligns with California's Title 24 method. Existing fan power limitations applies a "one-size-fits-all" approach to limiting fan power which leads to the requirements being easy to meet for many projects, especially with smaller fan systems. It has been widely acknowledged that the design of the current code requirements is somewhat stringent on larger systems, but less stringent for smaller fan systems. An assumption about the pressure drop a fan must overcome and fan efficiency is built into the existing

fan power limitations equation. Currently, the underlying total static pressure assumption in the fan power limitations is 5.35 in. wg for VAV fan systems and 3.85 in. wg for CAV systems, regardless of the fan system air flow or components. This has the effect of making it easy to meet the standard for smaller buildings with shorter duct runs with lower pressure drop, as compared to larger more complex buildings with longer duct runs (higher pressure drop).
This also moves the threshold down as there are many fan systems between 1 kW and 5 nameplate HP which were previously not subject to the fan power limitations. Fan power requirements have not changed since they were adopted by the WSEC 2012 and prior to that, 90.1-2001. Adopting title 24 fan power budgets could saving up to 12% of fan power per system, especially for multi-zone systems such as VAV and DOAS serving a larger number of spaces.
Finally, an allowance of 0.6 in. wg for supply systems and 0.3 in. wg for exhaust/return/relief systems (where the combined total equals 0.9 in. wg) is allowed for additions/alterations.

Re-designs fan power allowances section to become more stringent for smaller fan systems (which comprise a large market share and were previously exempt) and keeps stringency for larger fan systems.

Review Process: There was input from the engineers on the TAG who felt this was already being done from the design standpoint but had concerns about application to existing ductwork. The TAG modified the application to replacement of existing HVAC systems to mitigate the impact.

Probable benefits vs probable costs: Primarily benefits owners and tenants who pay electric bill to reduce energy consumption of fan systems serving the HVAC needs of the building.

Construction cost $0.29/square foot
Annual energy savings 0.372 KWH/ square foot
Some increase in review time expected in the beginning to identify whether designer correctly accounted for fan system power among all fans, especially smaller fans that were previously exempt.

The incremental cost for the fan power budget was conservatively determined to be $0.29/ft2 and the B/C ratio averaged 3.8 across all building types modeled and all climate zones. A large office prototype model was used to determine likely layout and associated costs. Cost of ductwork designs were reviewed by a professional cost estimator and showed an incremental cost of $0.27/ft2 for a CAV and $0.31/ft2 for VAV system to comply with the new fan power budget allowances. This cost was largely due to larger diameter ductwork and better fittings selection, showing that compliance can be achieved through good design without equipment changes (though that is also another method to comply with the new fan power budget thresholds).
Detailed cost information was obtained from the Final CASE report for the 2022 Title 24.[14]

This proposal changes the current fan BHP or motor nameplate HP method to fan electrical input power to capture transmission and motor efficiency losses. The fan power budget electrical input power calculation is largely based on AMCA-208-18. (AMCA 2018). It also requires a fan power budget calculation be performed separately for each fan system and denotes the fan power as a function of airflow, system type, and components of the fan system, instead of just HP or bhp with adjustments. The proposed changes modeled in California prototype buildings showed a range between 12-34 percent per fan system, leading to a ~2 percent electricity savings per building.

[14] https://title24stakeholders.com/wp-content/uploads/2020/09/2022_T24-Final-CASE-Report_Air-Distribution.pdf

Expected building energy consumption based on CBSA average EUI's for large office building and CASE study prototype savings[15].

Key Analysis Variables		Building Characteristics	
Study Period (years)	50	Gross (Sq.Ft)	32,100
Nominal Discount Rate	5.00%	Useable (Sq.Ft)	32,100
Maintenance Escalation	1.00%	Space Efficiency	100.0%
Zero Year (Current Year)	2020	Project Phase	0
Construction Years	0	Building Type	0

Life Cycle Cost Analysis		**BEST**	
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intenstity (kBtu/sq.ft)	24.6	23.3	
1st Construction Costs	$	$9,309	$
PV of Capital Costs	$	$23,096	$
PV of Maintenance Costs	$	$	$
PV of Utility Costs	$641,887	$608,723	$
Total Life Cycle Cost (LCC)	**$641,887**	**$631,818**	**$**
Net Present Savings (NPS)	**N/A**	**$10,069**	**$**

(GHG) Social Life Cycle Cost		**BEST**	
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	857	812	-
% CO2e Reduction vs. Baseline	N/A	5%	105%
Present Social Cost of Carbon (SCC)	$61,205	$58,042	$-
Total LCC with SCC	**$703,091**	**$ 689,861**	**$**
NPS with SCC	**N/A**	**$ 13,231**	**$**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

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PTAC U-factor, Proposal 21-GP1-160: Adds a new section to WAC 51-11C-40214; Section C402.1.4.3

Brief Description: Requires heat loss though PTACs, PTHPs, and other through-wall mechanical equipment to be calculated as part of envelope U-factor compliance. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

[15] https://title24stakeholders.com/wp-content/uploads/2020/09/2022_T24-Final-CASE-Report_Air-Distribution.pdf

Purpose of Change: Provides a more realistic assessment of envelope heat loss through PTACs and PTHPs in exterior walls, which is several times greater than heat loss through a typical code-minimum exterior wall assembly.

Review Process: There was little discussion or controversy at the TAG level for this proposal. It was felt that this requirement would encourage the use of products requiring only a small envelope opening.

Probable benefits vs. probable costs: Costs and savings calculated per the assumptions listed below.

Estimated incremental cost: $0.24per square foot.
Estimated annual energy savings: $95 per year savings

A typical PTHP unit fits in an opening of 42 x 16 inches = 4.7 square feet
Walls of an apartment building floor 65 x 100 x 11 feet floor-to-floor would be 3630 gross sf.
Subtracting 840 sf (12 apts x 69 sf each) for fenestration would leave 2790 sf
Assumed U-factor for PTAC = 0.5
Max U-factor for wood-framed walls = U-0.051
Opaque walls depreciated for PTHP = U-0.061
To bring those walls back to U-0.051 requires R-13 cavity + R-12 c.i. (instead of R-13 + R-7.5 c.i.)
From Table A103.3.1(2)
Additional cost for R-12 (2-1/2”) insulation (instead of R-7.5 (1-12”) c.i.)
Additional $500 per 1000 sf @ 2734 sf = $1,365 + $200 for larger fasteners = $1,565
Cost per sf of floor area = $1565/6500 sf= $0.24/sf
Seattle HDD = 4424 Spokane HDD = 6655
UA w/ PTHP = 0.061 x 2790 = 170 x 4424 HDD = 752,920 = 753 kBTU/3.4 = 221 KWH x $0.11 x 24hr = $583.44
UA w/o PTHP = 0.051 x 2790 = 142 = 4424 = 628,208 = 628 KBTU/3.4 = 185 KWH x $0.11 x 24hr = $488
$583 - $488 = $95 per year savings

Extend Heat Pump Requirement to Include Split Systems, Proposal 21-GP1-164: Modifies Section C403.3.2.6 in WAC 51-11C-40332

Brief Description: Requires packaged and split systems providing heating and cooling, or cooling only, to be heat pumps. The requirement previously applied to packaged systems with both heating and cooling.

Purpose of change: Extend heat pump requirement from packaged equipment to include split systems. This may not be necessary if C403.1.4 heat pump requirement (21-GP1-103) is approved. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031 and reduce greenhouse gas emissions.

Review Process: This change was also impacted by another proposal, 21-GP1-194, which adjusted the configuration of heat pumps to allow more package terminal heat pump models to meet code.

While this code be seen as a lessening of the stringency of the code, the requirement for additional systems to meet the requirement compensates.

Probable benefits vs. probable costs: Estimate of the construction cost $0.10 per square foot. Estimate of the annual energy savings 5.4 KBTU per square foot

$10,000 additional cost for 100,000 sf building
Typical EUI of 40, heating EUI of 8 (20% of total), 2/3 reduction by use of heat pump = 5.4 kbut/sf/yr

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High Capacity Space Heating Boiler, Proposal 21-GP1-133: Adds a new section C403.3.4.5 to WAC 51-11C-40334.

Brief Description: Adds requirements from ASHRAE 90.1 for high capacity gas-fired hot water boiler systems to have condensing boilers.

Purpose of Change: Achieve energy savings in gas fired hot water heated buildings while staying close to national code language. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

ASHRAE published 90.1-2019 addendum bc implementing requirements for high capacity gas-fired hot water boiler systems to have condensing boilers. This language has been adapted to the WSEC with one modification being to delete renewable energy from the options of exception 1 due to the more mainstream role renewables are playing in code.

Review Process: This was another proposal that did not receive much discussion, as it was adopted into ASHRAE 90.1. The proposal has some interaction with boiler controls proposal, 21-GP1-139, but not outright conflicts.

Probable benefits vs probable costs: The cost analysis was taken from that done for ASHRAE 90.1-2019 addendum bc. There will possibly be a small amount of additional time necessary to review boiler system size and efficiency and design criteria used for coils. Since systems are generally central this effort will not be substantial

Average estimate of $0.10 per kWh across various building types and climate zones. Energy Savings: Using the Standard 90.1 scalar ratio, the economic analysis shows an average scalar ratio of 4.2. The maximum scalar ratio of 17.2 for boilers with a life expectancy of 25 years. Models and estimates show that all prototypes fall within the maximum scalar ratio and are cost-effective.

First cost was determined from the 2012 GSA Condensing Boiler Study[16], which estimates $38.50/MBtu for noncondensing and $42.00/MBtu for condensing boilers. In addition, the study estimates an additional average annual maintenance cost of $400 for condensing boilers. Energy Savings were found using energy modeling simulations run using DOE's EnergyPlus. Three prototype buildings were used—large office, hospital and secondary school—in various US climate zones. A

[16] https://www.gsa.gov/cdnstatic/GPG_Findings_004-Condensing_Boilers.pdf

blended cost of $0.10kWh was assumed. Using the Standard 90.1 scalar ratio[17], the economic analysis shows an average scalar ratio of 4.2. the maximum scalar ratio of 17.2 for boilers with a life expectancy of 25 years. Models and estimates show that all prototypes fall within the maximum scalar ratio and are cost-effective.

Increasing ERV Effectiveness, Proposal 21-GP1-165: Modifying Section C403.3.5.1 in WAC 51-11C-40335.

Brief Description: Increase ERV effectiveness to 60% enthalpy (from 50%) and limit main exception to spaces smaller than 650 sf.

Purpose of Change: Improve heat recovery effectiveness for non-residential occupancies, taking advantage of commonly available ERV equipment. Eliminate DCV exception for spaces larger than 650 sf.

This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

Review Process: The original proposal removed the sensible recovery effectiveness from the main body of the section and allowed it only for Group R-2. The TAG felt it should be retained because not all heat recovery ventilators have an enthalpy rating, so it may be advantageous to retain the sensible recovery rating. The sensible recovery effectiveness was increased from 60% to 68% to correlate with the original change.

Probable benefits vs. probable costs: Will slightly increase costs for ERVs in non-residential occupancies that require DOAS and will add energy recovery to larger spaces that have DCV. This will decrease heating and cooling costs.

Estimate of the construction cost is $0.10 per square foot based on the assumption of a $10,000 increase for HVAC cost for a 100,000 square foot building.

Estimated annual energy savings: Reduce annual HVAC energy usage by 2%, or about 0.3 kWh per square foot
50 EUI x 0.02/3.4 = 0.3 KWH/sf/yr @ $0.11 = $0.03/sf
If HVAC usage is 1/3 of total energy usage, 0.03/3 = $0.01/sf

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Demand Responsive Thermostats, Proposal 21-GP1-97: Adds new Section C403.4.1.7 to WAC 51-11C-40341

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

Brief Description: Adds a requirement for demand responsive controls for thermostats in all buildings except health care and assisted living. It does not require participation in any demand response programs.:

Purpose of Change: Demand responsive functionality will present a cost-saving opportunity for buildings in the future. More and more utilities are moving beyond voluntary programs and are expanding use of time-of-use rates for electricity as a tool for shaping demand. Installing demand-responsive thermostats now will allow building tenants and owners to better control their utility costs.

Demand responsive functionality has been required in Title24 since the 2013 edition and was found cost effective in CA.[18] In the 8 years since, equipment prices have decreased (less than $60 for a basic DR thermostat[19] compared to just under $30 for a basic 7-day programmable thermostat[20]) and WA peak prices have increased.

Review Process: The TAG was initially concerned about how this change would impact some systems, and the proponent was asked to come back with a revision incorporating more of the language from the original Title 24 language. There was also some concern that what was provided may not be compatible with the utility programs. The final proposal does not include all of the Title 24 approach. The Title 24 approach is very prescriptive and can be restrictive, as evidence by efforts in the 2022 proposals to open it up to accommodate emerging technologies. By being more descriptive in the requirements, this proposal will better accommodate this rapidly emerging field.

Probable benefits vs. probable cost: Estimated incremental construction cost: $0.03 per square foot, based on an assumption of $30 per unit controlling a 1000 square foot zone

$30/unit x (10 units) / 10,000sf

10,000 sf office with 10 thermostat zones of 1000 sf each.

Estimated annual energy savings: A California study reported an annual energy savings of 83 to 274 kWh in CA climate zones 1, 2 and 16 (the closest analogous climate zones to WA's climate zones) for a 10,000 office[21].

This proposal will add a minimal amount of extra plan review. Spec sheets will need to be checked to ensure that the thermostat meets the requirement. There should be no additional inspection time if site inspectors are checking that thermostats are consistent with the construction documents.

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[18] *Final CASE Report: Upgradeable Setback Thermostats*, California Statewide Codes and Standards Enhancement (CASE) Program, October 2011, https://title24stakeholders.com/wp-content/uploads/2020/01/2013_CASE-Report_Upgradeable-Setback-Thermostats.pdf

[19] https://www.supplyhouse.com/Venstar-T3700-Explorer-T3700-Residential-Digital-Thermostat-2-Heat-1-Cool

[20] https://www.supplyhouse.com/Lux-P711-010-7-Day-5-2-day-Programming-or-Non-Programmable-Thermostat-Horizontal-Mount-1-Heat-1-Cool

[21] *Final CASE Report: Upgradeable Setback Thermostats*, California Statewide Codes and Standards Enhancement (CASE) Program, October 2011, https://title24stakeholders.com/wp-content/uploads/2020/01/2013_CASE-Report_Upgradeable-Setback-Thermostats.pdf

Demand Control Ventilation, Proposal 21-GP1-190: Revises Section C403.7.1, WAC 51-11C-40371

Brief Description: Replace current C403.7.1 with new section which removes energy recovery exception and reduces and reconfigures various thresholds. The proposal also adds specific requirements for DCV. Gas sensors are required in spaces and systems are required to have VSD control or as allowed modulated dampers. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

Purpose of Change: The intent is that DCV applies to all single zone systems (DOAS or other) that provide ventilation. Additionally, the intent is that a DOAS system larger than 1500 cfm that provides ventilation to more than one space also requires DCV (unless exceptions apply). The change will achieve energy savings by requiring DCV in many more cases and update language.

Spaces served by systems with heat recovery will no longer be exempt. Space size thresholds are changed from floor area to the people component cfm of outdoor air. Systems without economizer will have to start providing DCV down to 750 cfm or 1500 cfm with heat recovery rather than the current 3000 cfm.

The room size thresholds are derived from 90.1-2019 addendum b. First, the 90.1-2019 addendum b room size thresholds were reduced until the savings (scaled by area) and cost (fixed) were just cost effective in the OFM calculator including the price of carbon. This resulted in rooms sizes 57% smaller than 90.1-2019. In addition, the 90.1-2019 criteria of occupant outdoor air component in cfm per 1000 square feet was simplified to occupant outdoor air flow in cfm.

Review Process: The TAG reviewed this proposal and made several clarifying changes, but the proposal remain substantively as submitted. There were no dissenting opinions or objections to the recommended adoption.

Probable benefits vs. probable cost: Increased control and equipment costs and decreasing operating costs. Cost and savings are based upon 90.1-2019 addendum b (completed and published 4/1/2021[22]). Room and system size thresholds are scaled down to account for OFM calculator assumptions and carbon.

When cost-effective, demand control ventilation (DCV) should be required for occupied spaces, considering the required outdoor air for ventilation based on number of people in the space, varying space sizes, use of energy recovery equipment, and climate zone. The current requirement has a threshold based only on space size and space occupancy. This proposal seeks to more effectively align DCV requirements with all other relevant variables to produce a cost-effective solution.

The single-threshold parameters are replaced by a table where the floor area threshold requirement is based on climate zone and occupant outdoor airflow rates per 1000 ft2 (100 m2) determined in accordance with ASHRAE Standard 62.1. The requirements are grouped by occupant outdoor airflow component ranges (cfm/1000 ft2 [L/s/100 m2]) based on default parameters in Standard 62.1. While the exact value for a particular space type varies, the three groups in the table generally correspond to (a) retail, break rooms, or bank lobbies; (b) classrooms or conference rooms; and (c) lecture halls, theatre, or assembly.

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22 https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_b_20210401.pdf

The exhaust air energy recovery exception was removed and replaced with higher floor area thresholds in the table. The exception for design outdoor airflow less than 750 cfm was also removed, as this factor is accounted for in the cost-effectiveness analysis. One new exception was added to account for spaces that are not allowed to reduce outdoor airflow per the requirements in ASHRAE Standard 170, other applicable codes, or accreditation standards. The net effect of these changes will increase the cost of construction. Because an economizer or motorized dampers are already required by this section, the cost to add a sensor and wiring is expected to be $300 or less per unit. A present value allowance of $63 is added to the cost to allow for replacement of up to 50% of sensor elements halfway through the measure life. The square footage thresholds in the table result in cost effectiveness for a 15-year life control measure based on a calculated discounted payback of less than 11.8 years.

Life Cycle Cost Analysis	**BEST**		
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intenstity (kBtu/sq.ft)	#DIV/0!	#DIV/0!	
1st Construction Costs	$ -	$ 600	$ -
PV of Capital Costs	$ -	$ 1,481	$ -
PV of Maintenance Costs	$ -	$ 272	$ -
PV of Utility Costs	$ 44,741	$ 43,561	$ -
Total Life Cycle Cost (LCC)	**$ 44,741**	**$ 45,314**	**$ -**
Net Present Savings (NPS)	**N/A**	**$ (573)**	**$ -**

Societal LCC takes into consideration the social cost of carbon dioxide emissions caused by operational energy consumption

(GHG) Social Life Cycle Cost		**BEST**	
GHG Impact from Utility Consumption	Baseline	Alt. 1	Alt. 2
Tons of CO2e over Study Period	348	338	-
% CO2e Reduction vs. Baseline	N/A	3%	103%
Present Social Cost of Carbon (SCC)	$ 22,085	$ 21,474	$ -
Total LCC with SCC	**$ 66,826**	**$ 66,788**	**$ -**
NPS with SCC	**N/A**	**$ 38**	**$ -**

Exterior Building Grounds Lighting, Proposal 21-GP1-204: Modifies WAC 51-11C-405061, Section C405.5.1

Brief Description: Reduction of the efficacy threshold for exterior lighting, with removal of redundancy in exterior lighting efficacy/controls requirement. This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

Purpose of Change: With LED sources being dominant, the wattage requirement threshold can be reduced from 50 W to 25 W without much impact. LED fixtures are the dominant light source, and the efficacy is better than other sources and the wattage of many LED fixtures in exterior applications is below 50 W. Reducing from 50 W to 25 W is staying consistent with the original intent of the requirement.

Review Process: The proposed change was reviewed at two TAG meetings, but changes were minor and only editorial in nature. The change in wattage was supported through the discussions.

Probable benefits vs. probable costs: The estimate of annual energy savings is 0.109 kWh per square foot, with little or no additional cost. Assumes 4,380 hours of operation as the lower wattage fixture is not required to be connected to an occupancy sensor. 25 W x 4,380 hours and assumed to light 1,000 square feet of space.

Exterior Lighting, Proposal 21-GP1-198: C405.5.3: Modifies Tables C405.5.3(2) and C405.5.3(3) in WAC 51-11C-405064

Brief Description: Updates the exterior lighting tables in response to changes in technology, with an approximate 40 percent reduction across the board.

Purpose of Change: Reduces exterior lighting values (last updated in 2016) in response to changes in technology. Changes the metric from footprint to gross floor area in most cases.

The values in the table have not been updated since 2016. As of 2016, LED technology was relatively new, and the efficacy was around 82 lumens per Watt. As of 2021, exterior LEDs are easily 105 lumens per Watt and many exceed 120 lm/W. In 2016, light loss factors for LEDs were somewhat an unknown. As of 2021, the lighting industry's knowledge is deeper and different light loss factors are used now. These values are change in available lighting technology as well as informed design practices.

This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

Review Process: The TAG discussed this proposal at two meetings. There were no opponents to the proposal at either meeting, and there was stated agreement that the update is a good idea. There was some discussion at how the new table values were reached. The proponent stated they took into account a 25 to 35 precent efficiency gain in LED technology coupled with new data that shows less depreciation over time.

Probable benefits vs. probable costs: Limited economic impact on building owners, tenants, and business.

These values are slightly greater than California's Title 24 which had an economic analysis and were deemed cost effective. These values are similar to a draft addendum of ANSI/ASHRAE/IES Standard 90.1. BC Hydro funded some cost analysis for the 90.1 proposal. Other than exchange rate, the cost of lighting equipment in Canada and US is the same. BC Hydro's lighting subcontractor provided a cost analysis and cost data of the 90.1 addendum indicating that 2021 is equipment is similar cost of 2016 equipment, but the efficacy had an increased over the period of time.

This proposal is similar to other energy code changes that involved cost analyses and those cost requirements were met.

Estimate of annual energy savings: 0.08 kWh per square foot.

Assumed at 30,000 square foot parking lot. The LPD reduced is reduced by 40% between the existing (0.06 W/ft^2) and new value (0.037 W/ft^2). The values in the table are roughly a 40% reduction across the board. Assumes 2,230 kWh saved. 2,230 kWh / 30,000 = 0.076 kWh / ft^2

Additional energy efficiency, Proposal 21-GP1-146: Modifies Section C406.1 in WAC 51-11C-4600

Brief Description: Increases the required number of energy efficiency credits to be achieved.

Purpose of Change: The requirements were increased approximately 16 percent, if the heat pump water heating proposal is adopted, and by approximately 33 percent if it is not.

This proposal aligns with state policy to increase energy efficiency by 70 percent by 2031.

Review Process: This proposal, and the restructuring of C406, were highly debated throughout the TAG meetings. This was one of the last proposals addressed, to take into account other proposed changes to the code and the efficiency gains already achieved. The final recommendation is at a lower increase than that originally proposed, with a yet lower level recommended if the heat pump water heating proposal is ultimately adopted.

Probable benefits vs. probable costs: The cost will vary greatly depending on the type of building and the measures selected. Not all measures are appropriate for all building types. Energy Efficiency: There will be some variation here as well, since not all building types have the same credit requirements. However, the average credit increase is 8, with each point corresponding to a 0.1 percent carbon reduction for an average 0.8 percent reduction.

Load management credits Proposal 21-GP1-206: New section WAC 51-11C-40630

Brief Description: Adds load management requirements for new buildings to prepare buildings to interact efficiency with the evolving electrical grid in the future.

Purpose of Change: The load management credit requirements are the lesser of HVAC or lighting peak shedding controls. The purpose for adding the load management requirement is to encourage reducing and shifting building load in conjunction with increasing building efficiency. Load shifting measures require installing communication controls and programming to automatically reduce electric energy use during high demand periods. Thus, the load management credits take into account the time-sensitive value of efficiency and the ability to optimize energy use for grid services. It supports the state's objective to reduce building carbon emissions and will "future proof" buildings so they can respond to changing grid needs over time. The measure savings and corresponding credit values are based on electricity cost savings determined using the ASHRAE 90.-1 time-of-use rate, which was incorporated in the ASHRAE 90.1-2022 Work Plan as an optional rate to use to demonstrate the cost effectiveness of new code change proposals involving demand flexibility measures. Utilization of this representative US TOU rate, which results in similar annual electricity costs as the average national blended rate, is intended to serve as a proxy for valuing reduced grid impact, which accommodates increases in PV, regional growth, and other grid changes impacting peak periods over time.

Review Process: This proposal contains more than just the load management changes, but the load management portion is where there is an economic impact. This, along with the rest of the changes to Section C406, was heavily debated and revised and revisited a number of times to ultimately be proposed to moved forward to public hearing.

Probable benefits vs. probable costs: Range from $19,900 for a 240,000 sf hospital to $453 for a 5,000 sf office or restaurant, with simple payback ranging from 1.1 year (restaurant) to 25.0 years (warehouse), with a 3.66 year statistical average. Demand responsive lighting controls cost approximately $0.0825 per square foot. Energy Savings: Annual energy savings ranged from $5,700 for the hospital to $117 for the 5,000 sf office, with the statistical average of a 3.66 year payback.

The required load management credits are the lessor of either lighting control or HVAC setback/setup control during peak periods. HVAC time shift control is evaluated for cost effectiveness with the following results:

Load Management Credit Cost Effectiveness Calculation
Demand responsive HVAC Measure

	Floor Area	DR connectivity incremental cost	Annual Energy Cost Savings ($/year)	Simple Payback (years)
ApartmentMidRise	33,741	$ 2,780	$ 736	3.8
Hospital	241,501	$ 19,900	$ 5,718	3.5
HotelSmall	43,202	$ 3,560	$ 1,181	3.0
OfficeMedium	53,628	$ 4,419	$ 2,146	2.1
OfficeSmall	5,503	$ 453	$ 117	3.9
RestaurantSitDown	5,502	$ 453	$ 416	1.1
RetailStripmall	22,500	$ 1,854	$ 342	5.4
SchoolPrimary	73,959	$ 6,094	$ 1,552	3.9
Warehouse	52,045	$ 4,289	$ 172	25.0

Reference: Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code, Nonresidential Grid Integration, Final CASE Report, August 2020

Demand Responsive Lighting – incremental costs per 10,000 sq. ft.

1) Connected Controls with Native OpenADR VEN => $823
2) Piecemeal Connected Control System with Non-Native OpenADR VEN => $826

Estimated annual energy savings: $0.0823 per square foot

Load Management Credit Cost Effectiveness Calculation
Demand responsive HVAC Measure

	Floor Area	DR connectivity incremental cost	Annual Energy Cost Savings ($/year)	Simple Payback (years)
ApartmentMidRise	33,741	$ 2,780	$ 736	3.8
Hospital	241,501	$ 19,900	$ 5,718	3.5
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OfficeMedium	53,628	$ 4,419	$ 2,146	2.1
OfficeSmall	5,503	$ 453	$ 117	3.9
RestaurantSitDown	5,502	$ 453	$ 416	1.1
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Demand Responsive Lighting – incremental costs per 10,000 sq. ft.

1) Connected Controls with Native OpenADR VEN => $823
2) Piecemeal Connected Control System with Non-Native OpenADR VEN => $826

Public Comments Received on Preliminary Cost Benefit Analysis

WASHINGTON PUBLIC UTILITY DISTRICTS ASSOCIATION
WPUDA
YOUR connection

March 8, 2022

Mr. Stoyan Bumbalov
Managing Director
State Building Code Council
Washington State Department of Enterprise Services
1500 Jefferson St SE

Olympia, WA 98501

RE: Proposed Changes to the Washington State Commercial Building Code: Requirement for On-Site Renewable Energy for Commercial Buildings over 10,000 square feet - Section # C411, with carry over to C406, C407

Dear Mr. Bumbalov:

In our letter of September 13, 2021, the Washington Public Utility Districts Association (WPUDA) strongly implored the State Building Code Council (SBCC) to defer action on the proposed code change that would mandate on-site renewable energy for commercial buildings over 10,000 square feet (Section #C411). Our letter demonstrated that the proponent's Initial Cost-Benefit analysis was deeply flawed. As such, the SBCC has no reasonable basis to conclude that the probable benefits of this proposal exceeds its probable costs; or that it would impose the least burden necessary to achieve the general goals and specific objectives of the statute it implements. These are non-discretionary findings that our state legislature requires the SBCC to make for each distinct part of proposed significant legislative rules (see RCW 34.05.328)[1].

[1] The state legislature, when amending the administrative rulemaking procedures in 1995 declared that: "…Washington's regulatory system must not impose excessive, unreasonable, or unnecessary obligations; to do so serves only to discredit government, makes enforcement of essential regulations more difficult, and detrimentally affects the economy of the state and the well-being of our citizens."

212 Union Ave. SE, Suite 201 I Olympia, WA 98501
Phone: (360) 741-2675 I Fax: (360) 741-2686 I www.wpuda.org

While taking no position on the proposed requirement for on-site renewable energy for commercial buildings over 10,000 square feet, WPUDA reminds the SBCC of the seven fundamental flaws in the initial Cost-Benefit analysis identified in our September 13, 2021, letter. We enclosed that letter so that it may be included in the official rulemaking record.

Furthermore, by this letter we add an important eighth item that fundamentally affects the cost-effectiveness of larger on-site generation systems. A super majority of utilities in Washington state purchase wholesale power from BPA under terms specified in Tier I contracts. Those terms impose significant consequences on utilities when their customers install generating resource(s) larger than 200kW in capacity:

- If all or part of a consumer-owned resource reduces the retail load served by the host utility, then that utility's rights to Tier 1 or Tier 2 purchases is decremented.
- BPA requires the host utility submit a small generation interconnection request and a $2,500 application fee.
- The host utility must obtain a transmission interconnection agreement with BPA that meets certain requirements:
    - Compliance with BPA's open access transmission tariff for small generation;
    - Compliance with NEPA standards;
    - Revenue quality metering with hourly values available via telephone dial-up;
    - Protective relaying to prevent islanding when isolated from the grid;
    - Multi-party operations & maintenance agreements among participants in the project; and
    - Participation by local serving utility staff and their active communications with the BPA Dispatcher.

Enclosed is a document from BPA that provides more information about the requirements it places upon utilities should a utility customer seek to interconnect a generating facility larger than 200kW.

WPUDA brings these contract terms to the attention of the SBCC because of the 249kW solar system required for the "Large Office" prototypical building. The proponents' Cost-Benefit analysis included none of the costs associated with the consequences triggered by this larger than 200kW generating system. It is important to note that the proposed code mandating "On-Site Renewable Energy for Commercial Buildings" has no upper limit size of the generation system that must be installed.

In conclusion, WPUDA reminds the SBCC that our request is only that you defer action on the proposed code change **On-Site Renewable Energy for Commercial Buildings Over 10,000 - Section # C411, with carry over to C406, C407**. We make this request so that the Technical Advisory Group may correct the fundamental flaws in the accompanying initial Cost-Benefit analysis. It is WPUDA's firm conviction that the SBCC can neither affirm that the proposal satisfies the standards set by the legislature for significant legislative rules, nor assess whether the proposal is in the public interest without an accurate and sound economic analysis.

Finally, WPUDA stands ready to assist the SBCC in correcting flaws in the Financial Analysis so that it more accurately and fairly reflects the likely financial impacts to citizens of this state.

Sincerely,

Nicolas Garcia, Policy Director
Washington Public Utility Districts Association

enclosures

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

MEMORANDUM

NORTHWEST GAS ASSOCIATION

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TO: Council Members, Washington State Building Codes Council (SBCC)
Stoyan Bumbalov, SBCC Managing Director
Henry Odum, Ecotope

FROM: Dan Kirschner, Executive Director

DATE: March 11, 2022

RE: Comments, Analysis and Corrections On Cost Benefit Analyses "103_Economic Package", "136_Economic Package" and "179_Economic Package"

VIA ELECTRONIC MAIL: sbcc@des.wa.gov; stoyan.bumbalov@des.wa.gov; henry@ecotope.com

WSEC-C-CR102, 21-GP1-103
Requiring Heat Pumps for Space Heat and Banning Fossil Fuel Heating
Comments on the Cost Benefit Analysis "103_Economic_Package"

GENERAL COMMENTS

- Not Specific to Washington State
  - The proponent is using source data from a "Reach Code Cost Effectiveness Survey" submitted to the Codes and Standards Program of the State of California. There is no Washington State specific data in this report. It's based on energy studies assuming California Climate Zones and California construction costs.
  - Because the study is based on construction costs in California, it does not account for the more stringent Energy Codes currently in place in Washington State. Therefore, the approximated CAPEX installation costs presented are not an accurate representation of the real, present value build costs in Washington State.
- Not Current
  - The date on the report is 2019. Therefore, construction cost data is at least 3 years old and doesn't reflect present value construction costs, which incurred significant inflation over that time.
- Limited Occupancy Type
  - Only two occupancy types were analyzed – Retail and Office. Space uses with high occupancy loads such as Gyms, Auditoriums, Places of Religious Worship and Classrooms were not included. The analysis of these spaces is important because of the high corresponding ventilation load in these occupancy types. Analyzing these space types would show a greater deviation in operating costs

between gas and electric heat because tempering outside air in low ambient conditions is likely more expensive when using electric resistance heat.

- Irrelevant HVAC System Data
    - One of the two HVAC systems presented for economic analysis is a VAV system with electric resistance heat at VAV zone boxes. However, under Section C403.1.4 of the proposed CR102, electric resistance in VAV terminal units is not allowed. Therefore, half of this analysis is not relevant because the proposed VAV system cannot be legally built in Washington State. Relevant code section language from draft CR102 below…

NEW SECTION WAC 51-11C-40314 Section C403.1.4—HVAC heating equipment. C403.1.4 Use of electric resistance and fossil fuel-fired HVAC heating equipment. HVAC heating energy shall not be provided by electric resistance or fossil fuel combustion appliances. For the purposes of this section, electric resistance HVAC heating appliances include, but are not limited to, electric baseboard, electric resistance fan coil and VAV electric resistance terminal reheat units and electric resistance boilers. For the purposes of this section, fossil fuel combustion HVAC heating appliances include, but are not limited to, appliances burning natural gas, heating oil, propane, or other fossil fuels.

- Irrelevant / Unlabeled Charts and Graphs
    - There are data tables included in this report referencing "Commercial Hot Water Heating" which are not relevant to this code change proposal. There are also graphs without labels and no descriptions to identify what, if any, relevancy they have on the analysis of this report.
- Irrelevant Costs of Gas Infrastructure
    - The report references gas infrastructure costs as a burden to the building owner. Such costs include Plan Review, Meter, and Service Extension. These costs are approximated to be $18,316. In reality, these costs are incurred by the gas utility provider and should not be included as part of the construction costs paid by the end user.

SUMMARY AND RECOMMENDATIONS

The Economic Benefit Analysis provided references one, three-year-old report using data from California. It references only 2 HVAC system types, one of which cannot be legally built in Washington State under current provision of the CR102. It only references two occupancy types, both of which have low to moderate ventilation load which shows an operating cost benefit towards electric heating. This is not a cohesive, standalone document, it contains hyperlinks (some of which are not functional) to other source material that is not pertinent to the supporting data of the analysis in this report.

For the above stated reasons, we are recommending the Economic Benefit Analysis, as submitted, be rejected in its entirety under the grounds that it is insufficient and irrelevant. It does not meet the objective of providing an Economic Analysis for the proposed code measure.

WSEC-C-CR102, 21-GP1-136
Heat Pump Water Heating
Comments on the Cost Benefit Analysis "136_Economic_Package"

GENERAL COMMENTS

- Not Current
  - The submitted cost benefit analysis is based on the initial code change proposal. The analysis has not been revised to reflect the many exceptions now incorporated in the CR102 version.
- Limited Occupancy Type
  - Only one occupancy type was analyzed – multifamily housing. What are the impacts on much higher energy users like hospitals and laboratories?
- Not Reflective of the Commercial Market
  - The energy saving and carbon impact implications for this single occupancy appear to be extended to all commercial buildings. Most commercial space – office, retail, etc. – will have much lower domestic hot water demands and will therefore fall under the exceptions in the current version of this proposal. That means under this proposal, most commercial space will be served by electric resistance water heaters. The energy and carbon impacts of this has not been evaluated.
- Not Locale-Specific
  - Costs for electrical infrastructure upgrades source a CA study, not a prototypical WA construction project.

SPECIFIC COMMENTS

- Missing Space Cost Impact
  - It appears no accounting was done for the larger mechanical space required to house the tanks and other appurtenances required for HPWH systems – pumps, more piping, etc. Based on (4) 2000-gallon tanks, (2) Colmac HP units, (1) recirc heater and associated pumps, we estimate 570 square feet (SF) are needed. A single gas water heater with a recirculation pump could fit in a 70 SF room (or less), a difference of 500 SF. Using an average cost of $225/SF for midrise multifamily housing construction in Washington, that equates to $112,500 additional cost for the HPWH system. Ecotope is an experienced expert at designing HPWH systems – they should have exact space requirements for HPWH systems if our estimate needs refining.
- CAPEX and OPEX Problems
  - Several discrepancies in the system CAPEX and OPEX calculations are identified in the attached. In short, it appears the gas-fired water heater plant is vastly

overpriced while the HWPH plant is underpriced. We expect Ecotope has recent cost data for HPWH plants if the changes proposed need refining. Also, the operating cost of the HPWH plant is understated. Specifically, the *current* code proposal allows resistance heating for recirculation losses, making that the code minimum standard (least cost) – the cost/benefit analysis should match.

- Life-Cycle Analysis Updates
  - The suggested revisions to energy usage, CAPEX and OPEX above will affect the rest of the cost-benefit and life-cycle analyses for multifamily housing. Reworking the proponent's analyses is far beyond the scope of this letter – that work should be performed by the proponent or the economic impact reviewer.

From Page 27 of "136 Economic Package"

AS PROPOSED

RECIRC COP	2.4

SUGGESTED REVISION

RECIRC COP	1

Notes: The final proposal allows electric resistance for recirc heat, therefore that would be "code minimum" - the cheapest and simplest option
The economic analysis should match and use electric resistance, not a heat pump, for recirc heat

AS PROPOSED

HPWH Electic Usage (2.8 COP RCC)	143963	kWh/yr
HPWH Recirc Loss	63145	kWh/yr
HPWH Total Electrical Usage	207108	kWh/yr

SUGGESTED REVISION

HPWH Electic Usage (2.8 COP RCC)	143963	kWh/yr
HPWH Recirc Loss (1.0 COP)	151548	kWh/yr
HPWH Total Electrical Usage	295511	kWh/yr

Notes: Recirc heat is a large fraction (majority) of the total load

AS PROPOSED

Heat Pump Plant	QTY	Unit Price	Install and Markup	Total Costs
Heat Pumps (2) CXA-15 and (1) CXA-10	1	$ 79,000	$ 63,200	$ 142,200
Hot Water Storage (2000 gallons)	4	$ 12,000	$ 9,600	$ 86,400
Controls	1	$ 15,000	$ 20,000	$ 35,000
		$ 106,000	**$ 92,800**	**$ 263,600**

SUGGESTED REVISION

Heat Pump Plant	QTY	Unit Price	Install and Markup	Total Costs
Heat Pumps (2) CXA-15 and (1) CXA-10	1	$ 79,000	$ 63,200	$ 142,200
Hot Water Storage (2000 gallons)	4	$ 40,885	$ 5,942	$ 187,308
Controls	1	$ 15,000	$ 12,000	$ 27,000
		$ 134,885	**$ 81,142**	**$ 356,508**

Source: RS Means, 2022, line# 221223133240, Water heater storage tank, glass lined, 2000 gal
Notes: Storage tanks appear underpriced; Controls install and markup appears overpriced (greater than the 80% Mark Up Cost)
Heat pump plant cost may decrease with electric resistance recirc heater. Does the plant cost include pumps, piping, insulation, etc?

From Page 28 of "136 Economic Package"

AS PROPOSED

Central Gas Boiler	QTY	Unit Price	Install and Markup	Total Costs
Gas Boiler (275,000 BTU/hr)	1	$ 6,200	$ 4,960	$ 11,160
Hot Water Storage (2000 gallons)	4	$ 12,000	$ 9,600	$ 86,400
Controls	1	$ 15,000	$ 20,000	$ 35,000
		$ 33,200	**$ 34,560**	**$ 132,560**

SUGGESTED REVISION

Central Gas Boiler	QTY	Unit Price	Install and Markup	Total Costs
Gas Boiler system (600,000 BTU/hr)	1			$ 40,417
Hot Water Storage (2000 gallons)	0			$ -
Controls	0			$ -
		$ -	$ -	**$ 40,417**

Source: RS Means, 2022, line# D20202502260, gas fired water heater system; line# 221123110510, pump (recirc); plus $2K for flue
Notes: A gas boiler system does not require external storage or controls - they are inherent in the water heater
Gas system sized per AO Smith ProSize online app for 137 unit apartment with in-unit laundry, medium demand profile

AS PROPOSED

Capital Cost	Total Cost
Central Electric HPWH	$ 273,940
Central Gas Boiler	$ 132,560

Operational Cost	Total Cost
Central Electric HPWH	$ 17,728
Central Gas Boiler	$ 14,067

SUGGESTED REVISION

Capital Cost	Total Cost
Central Electric HPWH	$ 356,508
Central Gas Boiler	$ 40,417

Operational Cost	Total Cost
Central Electric HPWH	$ 25,298
Central Gas Boiler	$ 14,067

Notes: Reflecting capital costs and usage changes from above

WSEC-C-CR102, 21-GP1-179
Electrical Receptacles
Comments on the Cost Benefit Analysis "179_Economic_Package"

- Not All-Inclusive
  - The cost per receptacle is within reason – for the receptacle itself and wiring to the dwelling unit electrical panel. However, there are many other costs not accounted for:
    - larger electrical panels in each dwelling unit
    - larger feeders to serve those panels from house panels
    - larger or greater number of house panels
    - larger feeders from main switchgear to those house panels
    - larger switchgear
    - larger feeders from the electrical service to the main switchgear

Also, for a normal project the added cost of utility-side electrical service feeders and transformers will often be borne by the electric utility, but that is not a given. In the case of this proposal, "cost to serve" is more likely since dwelling unit appliance loads will not be online when construction is complete, or anytime soon thereafter.

Please include these costs in the cost/benefit analysis.

###

NORTHWEST GAS ASSOCIATION

MEMORANDUM

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TO: Council Members, Washington State Building Code Council
Mr. Stoyan Bumbalov, Managing Director, Washington SBCC
Mr. Henry Odum, Ecotope

FR: Dan Kirschner, Executive Director
NW Gas Association

DT: April 1, 2022

RE: Follow-up Comments, Analysis & Corrections on the Cost Benefit Analysis "103_Economic_Package", "136_Economic_Package" and "179_Economic_Package"

DELIVERED VIA ELECTRONIC MAIL:
sbcc@des.wa.gov; stoyan.bumbalov@des.wa.gov; henry@ecotope.com

Thank you for the opportunity to review the draft Cost Benefit Analysis at the public hearing on March 16, 2022. While some of the concerns expressed in our March 11, 2022 comment letter were addressed by Ecotope, the draft CBA still failed to address some critical pieces, either adequately or in some cases, at all.

WSEC-C-CR102, 21-GP1-103
Requiring Heat Pumps for Space Heat and Banning Fossil Fuel Heating
Comments on the Cost Benefit Analysis "103_Economic_Package"

GENERAL COMMENTS

- Limited Occupancy Type
  - Only two occupancy types were analyzed – Retail and Office. Space uses with high occupancy loads such as Gyms, Auditoriums, Places of Religious Worship and Classrooms were not included nor analyzed. Both the inclusion and analysis of these spaces is important because of the high corresponding ventilation load in these

occupancy types. Analyzing these space types would show a greater deviation in operating costs between gas and electric heat because tempering outside air in low ambient conditions is likely more expensive when using electric resistance heat.

- Costs of Gas Infrastructure
  - The report references gas infrastructure costs as a "burden" to the building owner, but the owner does not see those costs. Such costs include Plan Review, Meter and Service Extension. According to the Ecotope report, these costs are approximately $18,316. In reality, these costs are incurred by the gas utility provider and should not be included as part of the construction costs paid by the end user.
  - During the Cost Benefit Analysis testimony by Jonny Kocher from RMI, the proposal proponent, he claimed that eventually the rate payer would incur the gas infrastructure expense because the current depreciation schedules used by the gas utility are not aligned with Washington state energy strategy and he assumed, without any foundation or analysis, that the allowances for line extensions will be reduced over time. That is speculation at best and not relevant to this code cycle. That will only become relevant should the Legislature makes the changes that Mr Kocher alludes to, but not before then.

SUMMARY AND RECOMMENDATIONS FOR SPACE HEATING

We would like to emphasize the importance of a thorough, complete and balanced economic study that includes all commercial building types in both predominant Climate Zones of Washington State. The two building types analyzed are arguably the most advantageous for Heat Pumps. Presenting an outdated report from another state does not provide sufficient analysis for the far-reaching economic impacts this proposed code change will have on the commercial building industry.

Additionally, there was no analysis presented concerning the retrofit costs incurred by building owners to convert to heat pumps from gas equipment which may be required by most like-in-kind HVAC system changeouts under section C503.4.5 in the current draft CR102. The absence of any consideration of these costs as a burden to owners represents t best an inaccurate analysis and at worst evidence of a potential bias in the incomplete analysis presented, particularly when the cost of gas infrastructure was inaccurately attributed as a burden to owners.

WSEC-C-CR102, 21-GP1-136
Heat Pump Water Heating
Comments on the Cost Benefit Analysis “136_Economic_Package”

GENERAL COMMENTS

- Limited Occupancy Type
    - Only one occupancy type was analyzed – multifamily housing. For what was supposed to be a complete, not cursory and fragmented analysis, the absence of analysis of the impacts on much higher energy users like hospitals and laboratories is a critical flaw.

- Not Reflective of the Commercial Market
    - The energy saving and carbon impact implications for this single occupancy type appear to be extended to all commercial buildings. Most commercial space – office, retail, etc. – will have much lower domestic hot water demands and will therefore fall under the exceptions in the current version of this proposal. That means under this proposal, most commercial space will be served by electric resistance water heaters, for which the energy and carbon impacts have not been evaluated in any sufficient or reasonable way.

SPECIFIC COMMENTS

- Missing Space Cost Impact
    - No accounting was done for the larger mechanical space required to house the tanks and other appurtenances required for HPWH systems – pumps, more piping, etc. Ecotope asserted, without any particular grounding in research or analysis, that that these mechanical rooms only take up ‘waste’ space in parking garages. This is contrary to our experience that all space in commercial buildings has a price, whether it consumes available parking spaces or requires additional structure and building materials for a rooftop mechanical penthouse. Ecotope is an experienced expert at designing HPWH systems – they should have exact space requirements for HPWH systems as compared to traditional gas-fired systems, but failed to make that a visible part of their analysis. Please add this cost to the Life Cycle Cost Analysis.
    - For anecdotal reference, we know of a multifamily project under construction with an electric heat pump water heating system. The mechanical room for that project is approximately 1320 square feet – including ventilation shafts required to get air into and out of the space to supply the heat pumps, clearances around heat pumps for airflow and maintenance, etc. We estimate a traditional gas-fired water heater system would occupy 340 square feet. The difference is equivalent to 6 leasable parking spaces – certainly not ‘waste’ space.

- No OPEX Detail
    - Appendix C of the Ecotope report shows details for capital expenses, but no details for operating expenses. Operating expenses can be significant and impact costs for the life of a building. We ask that this information be shared so that stakeholders are able to assess the completeness of the cost benefit analysis review.

- Life-Cycle Analysis Updates
    - The suggested revisions to water heating operating costs will affect the rest of the cost-benefit and life-cycle analyses. Life Cycle Cost Analyses are typically sensitive to economic inputs. Since operating cost details were not available for public review, the validity of those analyses is in question. This is significant because the Social Life Cycle Cost of the gas-fired and heat pump systems were close – within 5%.

WSEC-C-CR102, 21-GP1-179
Electrical Receptacles
Comments on the Cost Benefit Analysis "179_Economic_Package". The comments below were not addressed during the March 16, 2022 hearing.

- Estimated Costs Not All-Inclusive
    - The revised cost per receptacle is within reason – for the receptacle itself and wiring to the dwelling unit electrical panel. However, there are many other costs still not accounted for:
        - larger electrical panels in each dwelling unit
        - larger feeders to serve those panels from house panels
        - larger or greater number of house panels
        - larger feeders from main switchgear to those house panels
        - larger switchgear
        - larger feeders from the electrical service to the main switchgear

Also, for a normal project the added cost of utility-side electrical service feeders and transformers will often be borne by the electric utility, but that is not a given. In the case of this proposal, "cost to serve" is more likely since dwelling unit appliance loads will not be online when construction is complete, or anytime soon thereafter.

Please include these additional costs for measure 179 costs into the cost/benefit analysis.

OVERALL SUMMARY AND RECOMMENDATIONS

We strongly encourage the Code Council to require the code change proponents and Ecotope to provide a more thorough economic analysis for these proposed changes before considering putting them into code.

###

March 9, 2022

Stoyan Bumbalov, Managing Director
Washington State Building Code Council
PO BOX 41449
1500 Jefferson St SE
Olympia, WA Z98504

sbcc@des.wa.gov

Re: WSEC-2021 Preliminary Cost Benefit Analysis – Public Comment

Dear Mr. Bumbalov,

Please find enclosed our public comments on the Preliminary Cost Benefit Analysis (CBA) pertaining to the major proposed changes in the WSEC-2021 CR-102. We appreciate the opportunity to participate in the code development process. We hope our comments on proposals 103 and 136, based on decades of industry experience, are fully considered for integration into the final Cost Benefit Analysis.

Energy codes are essential tools in decarbonizing the built environment and the construction industry at large. So, the key question before the council is not if, but how to move forward responsibly. Understanding what code proposals do *not* require is just as important as understanding what they intend to accomplish. If I can emphasize two critical points, it is that 1) the proposed heat pump space heating and heat pump water heating proposals (primarily) only impact new construction, and 2) new construction is where these technologies are integrated for little or no cost premium. McKinstry fully supports the heat pump space heating and heat pump water heating proposals because they target the most feasible and cost-effective place to create impact and enable a ramp period for us collectively, industry participants, building owners and manufacturers, to get ready for more sweeping electrification code changes coming in the future.

Please do not hesitate to contact me with any questions or clarifications.

Sincerely,

Michael Frank, P.E. | Vice President, Engineering & Design, McKinstry
206.832.8484 | michaelf@mckinstry.com

WSEC-2021 Preliminary CBA Public Comment

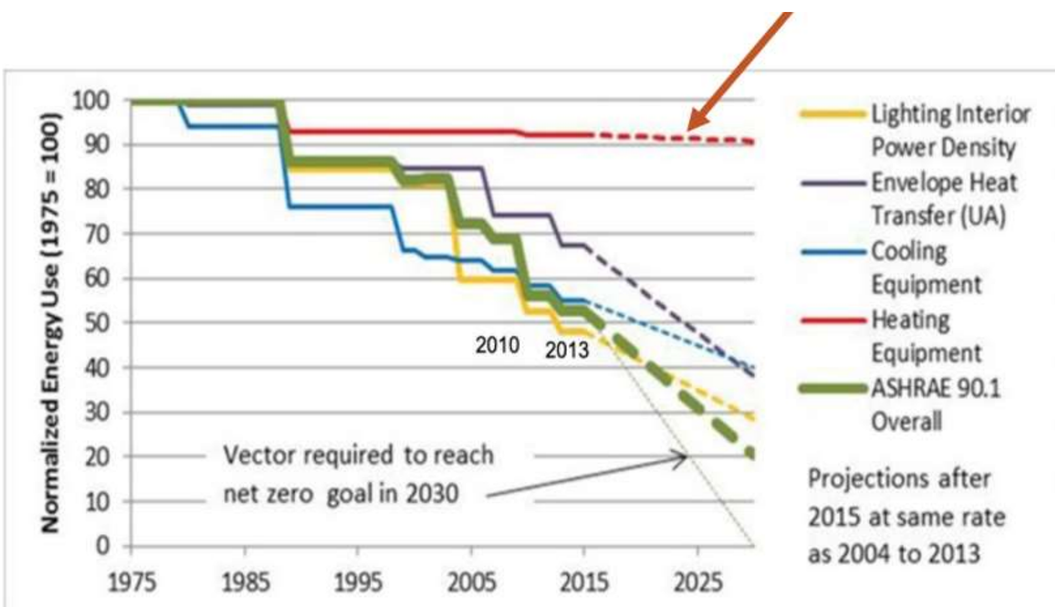
GENERAL COMMENTS: PAGES 1-3

While much of the cost benefit analysis is at the individual building level, it is important to consider community level costs and benefits. Many safety and environmental requirements don't provide a financial return at the individual level. This is part of why the Administrative Procedure Act exists – to ensure Washington State agencies consider statewide and long-term costs and benefits to our collective community. Adding a note to this affect in the first few pages of the CBA would be beneficial.

HEAT PUMP SPACE HEATING AND WATER HEATING, PROPOSALS 21-GP1-103 AND 136

Brief Description: We suggest adding a sentence at the end of the description to clarify the proposal has minimal impact on existing buildings and ***does not require existing building conversions to heat pumps*** except in the case of major renovations. Much discussion of this proposal has focused on challenges with existing building retrofits; it is critical that stakeholders understand the impact of this proposal is 99% on not-yet constructed new commercial buildings. Buildings built today will last for generations – we must ensure they are set up for long-term success, not costly near-term retrofits.

Purpose of Code Change: One element missing from this section is a discussion of the limited progress of the WSEC in terms of heating efficiency. Our national model and state codes have been immensely successful in improving envelope, lighting, and cooling performance; however, we've made little progress in heating efficiency since the 1970's. Without targeted heating efficiency requirements, we are missing important opportunities to meet our seventy percent energy reduction and zero fossil-fuel greenhouse gas emissions buildings targets.



Improvement in ASHRAE Standard 90/90.1 (1975-2013) with Projections to 2030. Courtesy of Pacific Northwest National Laboratory.

Review Process: No comments.

Probable Benefits vs Probable Costs: Our thoughts regarding additional context and content to potentially be included in this section are provided here.

Regarding Probable Costs:

- The submitted LCCA is imperfect in that it does not account for the probable need of near-term retrofits of baseline fossil fuel-fired heating systems. **When that cost is added in year 7 or 10, a heat pump system installed in year 0 will always be more cost effective.** Industry knowledge today suggests electric heat pumps are a less risky solution (in terms of acquiring needed heating emissions reductions) than relying on alternative pathways. It is critical for Washington Stakeholders to understand that we can accrue deep energy and emission savings for little or no upfront cost if heat pumps are incorporated into new buildings now. Retrofitting buildings is a far more challenging hurdle; possible, but more difficult.
- If costs are isolated to individual elements, percent differences amongst mechanical systems or components can be quite high. Evaluation of **total MEP system costs** inclusive of all impacted systems and design and construction costs is more appropriate. Through this lens, the impact of the heat pump space heating proposal on total installed and commissioned MEP system cost is anywhere in the range of -3% to +5%. MEP system cost is in turn only a portion of total project cost, often dominated by land acquisition, architectural, structural, and tenant or occupant needs.
- The first cost premium or savings from a heat pump system is highly dependent on both the selection of the baseline and the proposed system type. While a heat pump VRF system is certainly less costly than a gas boiler and air-cooled chiller hydronic design, an air-to-water heat pump hydronic system compared to an all air-based DX-gas RTU option will certainly show a premium. An owner who may have opted for rooftop DX gas units can now select rooftop heat pumps. An owner who may have selected gas-fired boilers can now select air-to-water heat pumps with electric boilers (or with gas-fired boilers in climate zone 5). That is all to say that there is flexibility in how a building owner can choose to meet the proposed requirements. And with flexibility in approach and design comes flexibility and variation in first cost.
- Code requirements have a history of driving down costs through innovation and economies of scale. Our market has adapted and innovated to react to efficiency stringency changes for chillers, for DOAS, and for controls (as examples). With the adoption of this provision, we would expect new equipment options to only continue expanding, driving down costs and increasing competition.
- Importantly, a growing portion of new commercial construction square footage is already subject to these requirements as Seattle, Shoreline, Bellingham, and others have adopted or are considering adopting these amendments. These early adopters are shouldering learning and training costs that will benefit other Washington communities should these proposals get adopted statewide.
- Lastly, costs and case studies of potential alternatives to electric heat pumps such as gas-engine heat pumps, gas-fired absorption heat pumps, green hydrogen, or renewable natural gas have not been made available for stakeholder consideration.

Regarding Probable Benefits:

- With code-driven changes, suppliers have dependable markets and buyers, designers and engineers have clear direction, building owners have leverage to drive innovation, and everyone moves forward together – ultimately driving down costs and normalizing change. A major benefit of driving the adoption of heat pumps through the energy code is this step-level change, resulting in overall statewide cost savings. This same rate of change is not easily accomplished in new construction through other mechanisms such as utility incentives or tax credits.

- It is likely that an outcome of this requirement will be the installation of cooling in more multi-family housing. While this benefit will increase summer energy use, it will also improve the quality of life for many thousands of Washingtonians.
- Another likely outcome of this code proposal is greater engagement between utility providers and building operators to leverage load management measures to mutual advantage and cost savings. A key benefit of the heat pump water heating proposal is built-in thermal storage. This system storage not only enhances localized building resiliency but is potentially a future cash-flow if utilities incent load shifting.
- In terms of safety and air quality, combustion-free designs exclude use of the Fuel Gas Code and eliminate items such as utility trenching, gas piping, gas meters, gas regulators, combustion ventilation air and exhaust infrastructure, safety sensors for carbon monoxide, safety alarms, and safety shut-off valves.