2021 WSEC-C – Third Party Cost Benefit Analysis

ECOTOPE

Draft 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:** High **Ecotope adjustment:** Revised analysis. Similar results
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-GP1-207	CMU Walls Table Footnote Modification	Luke Howard, Commerce	**Review Findings:** Revise energy values **Confidence in results:** High **Ecotope adjustment:** Revised analysis. Similar results
21-GP1-208	Elimination of CMU Wall Footnote	Luke Howard, Commerce	**Review Findings:** Revise energy values **Confidence in results:** High **Ecotope adjustment:** Revised analysis. Similar results
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

Proposal Number	Subject	Proponent	Ecotope Review:
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
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.

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.

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.

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.

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 type appears to reference 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 reference as well as the Pacific Northwest National Laboratory's (PNNL) life cycle cost analysis of VRF (see Thornton, 2011) and a published Elsevier report on the energy savings potential of VRF from VAV in the US (see Dongsu Kim, S. J., 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. 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.

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 while VAV with electric reheat is ~$21/ft^2. VRF compared to VAV with electric reheat has an energy cost reduction of 45%. VRF compared to a constant air volume system (CAV) with gas heat is 36%. Thus, while the upfront cost can be higher, the life cycle, and maintenance, repair, and replacement costs are shown to be lower than the alternative. A separate report on energy savings potential of VRF from VAV in the US shows an energy cost savings potential of 19% over VAV with gas heat. This study uses the EIA's electricity and natural gas utility rates for 2015 and does not consider maintenance, repair, and replacement costs.

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 44% more efficient than VAV in Seattle's climate. In Spokane's climate VRF is shown to be 40% more efficient. This is due to many factors, the main being the VRF system has a heating COP of 3.2 while a VAV system with gas heat has a heating COP of 0.8 and causes simultaneous heating and cooling to zones.

Whie 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 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). However, if the social cost of carbon is included, heat pumps show vast improvement beyond gas baseline systems. 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.

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 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. Ecotope performed an independent LCCA calculation using Washington State's default carbon metrics and found the HPWH system had a lower total lifecycle cost than an equivalent gas water heating system when considering the social cost of carbon. Updated LCCA, energy, and equipment cost data can be found in Appendices A, B, C respectively.

Cost Analysis

Comments on Proponent's Cost Analysis

1. The proponent's HPWH case does not satisfy the code proposal for the following reasons:
    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.
    b. Colmac CxA's will not operate at 17°F, as required by the proponent's code proposal.
2. Partial electric 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.
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. HPWH system cost should include additional electrical service.
7. 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.
8. Gas water heating system cost should include gas distribution piping.

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

Ecotope costed a CO_2 HPWH system that satisfies all the adjustments below, which resulted in a cost estimate of $263,600 – about 10% lower cost than the proponent's cost estimate. 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.

1. Base cost analysis off code compliant HPWH
    - → Ecotope used a price estimate provided by a CO_2 HPWH sales representative.
2. Incorporate supplementary electric resistance 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
5. Consider gas and electrical distribution piping
    - → Ecotope added line items for electrical and gas distribution.

Energy Analysis

Comments on Proponent's Energy Analysis

1. Proponent uses a HPWH system not compliant with code proposal. However, when using Proponent's methodology on a HPWH system that does comply, the energy savings over a gas water heater is 65%, higher than the original calculation. Energy savings over an electric water heater is 59%.
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 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-GP1-207: INSULATION REQUIREMENT FOOTNOTE MODIFICATION REGARDING CMU WALLS

Summary of Findings

Revised LCCA of 21-GPI-207 shows cost effectiveness. See Figure 2 in Appendix A: Updated Life Cycle Cost Analyses.

The economic analysis within proposal 21-GPI-207 relies heavily on a previous analysis and needs a proper citation and/or link to the study, Ecotope was able to find this link and is provided in the References (see Kennedy, 2014).

The proponent's analysis focused on a retail building. Per Kennedy's findings, the most common commercial buildings utilizing CMU walls are retail, schools, and warehouses; but it is also important to capture energy savings from a building type that is fully conditioned. Therefore, the assumption to base the high-level cost benefit of this proposal off a Retail prototype seems accurate.

Ecotope's review of this code proposal sought to mesh the energy savings from the 2014 Kennedy modeling study with the 2022 cost data provided by the proponent. Other updates included: adding the cost of interior furring and wall coverings, using OFM default variables in the LCCA analysis, and reducing measure life to 25 years (Kennedy, 2014).

Cost Analysis

Comments on Proponent's Cost Analysis

1. 2014 RSMeans and US Bureau of Labor Statistics are referenced in the cost analysis – both are reliable sources for costing. 2022 RSMeans data would be preferred, but the rate of inflation was accounted for.
2. Did not include furring or Gypsum Board, which would likely be applied over interior insulation. While this code proposal allows many envelope upgrades to satisfy requirements (via UA tradeoffs), some sort of added cost should be compared to a baseline of exposed CMU.
3. The proposed code change does not apply to exposed CMU walls, meaning cost would not change for applications with CMU walls.
4. A discount rate of 70% was used in the LCCA
5. Measure life was assumed to be 51 years

Cost Adjustments (→ Ecotope updates)

6. Add furring and Gypsum Board to cost analysis
   - → Ecotope sourced costs from 21-GP1-208. Added cost for furring and reinforced gypsum is $3.00/sf wall area. This is a worst-case assumption from the information provided.
7. Use OFM default values
   - → Proponent used a discount rate of 70%. OFM default is 0.7%
8. Use a conservative measure life (see Kennedy, 2014). Interior gypsum will likely require replacement.
   - → Dropped measure life to 25 years, for a more conservative estimate

Energy Analysis

Comments on Proponent's Energy Analysis

1. Energy savings estimates rely heavily on a previous CMU Evaluation Report, which is not easily attainable online. Therefore, savings claimed in this code proposal cannot be validated.
2. It's unclear whether energy savings reference square foot of floor space or square foot of wall area, what the building characteristics are, where the building is located, or what the HVAC operation assumptions are.

Energy Projection Adjustments (→ Ecotope updates)

1. Provide a proper link to the referenced study
   - ➔ See Kennedy, 2014 in References
2. Provide details on energy savings estimates (that are used for cost benefit)
   - ➔ Per Kennedy study: retail building, located in Seattle climate zone, using ASHRAE insulation values, and cycling heat/cool fans (current code requirements for retail occupancies)
3. Complete LCCA with updated cost and energy values
   - ➔ See LCCA report in Appendix A: Updated Life Cycle Cost Analyses

21-GP1-208: ELIMINATION OF FOOTNOTE IN REQUIRED INSULATION TABLE REGARDING CMU WALLS

Summary of Findings

Revised LCCA of 21-GPI-208 shows cost effectiveness. See Figure 2 in Appendix A: Updated Life Cycle Cost Analyses.

Similar to 21-GP1-207, the cost analysis in this proposal is a fair representation of the proposed code change and references reputable sources.

The economic analysis within proposal 21-GPI-208 relies heavily on a previous analysis and needs a proper citation and/or link to the study, Ecotope was able to find this link and is provided in the References (see Kennedy, 2014).

The proponent's analysis focused on a retail building. Per Kennedy's findings, the most common commercial buildings utilizing CMU walls are retail, schools, and warehouses; but it is also important to capture energy savings from a building type that is fully conditioned. Therefore, the assumption to base the high-level cost benefit of this proposal off a Retail prototype seems accurate.

Ecotope's review of this code proposal sought to mesh the energy savings from the 2014 Kennedy modeling study with the 2022 cost data provided by the proponent. Other updates included: adding the cost of interior furring and wall coverings, using OFM default variables in the LCCA analysis, and reducing measure life to 25 years (Kennedy, 2014).

Cost Analysis

Comments on Proponent's Cost Analysis

1. 2014 RSMeans and US Bureau of Labor Statistics are referenced in the cost analysis – both are reliable sources for costing. 2022 RSMeans data would be preferred, but the rate of inflation was accounted for.

Recommended Cost Adjustments (→ Ecotope updates)

1. Use OFM default values
   - ➔ Proponent used a discount rate of 70%. OFM default is 0.7%
2. Use a conservative measure life (see Kennedy, 2014). Interior gypsum will likely require replacement.
   - ➔ Dropped measure life to 25 years, for a more conservative estimate

Energy Analysis

Comments on Proponent's Energy Analysis

1. Energy savings estimates rely heavily on a previous CMU Evaluation Report, which is not easily attainable online. Therefore, savings claimed in this code proposal cannot be validated.
2. It's unclear whether energy savings reference square foot of floor space or square foot of wall area, what the building characteristics are, where the building is located, or what the HVAC operation assumptions are.

Energy Projection Adjustments (→ Ecotope updates)

1. Provide a proper link to the referenced study
   - ➔ See Kennedy, 2014 in References
2. Provide details on energy savings estimates (that are used for cost benefit)
   - ➔ Per Kennedy study: retail building, located in Seattle climate zone, using ASHRAE insulation values, and cycling heat/cool fans (current code requirements for retail occupancies)
3. Complete LCCA with updated cost and energy values
   - ➔ See LCCA report in Appendix A: Updated Life Cycle Cost Analyses

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. Tim 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.*

Kennedy, M. (2014) Energy Code change proposals 15-E029 and 15-E036. Retrieved from: https://www.sbcc.wa.gov/sites/default/files/2021-07/207_CMU_Evaluation_19July2015_MK.pdf

Thornton, B. (2011). *VRF Life Cycle Cost Analysis.* Seattle: Pacific Northwest National Laboratory. Retrieved from: https://pdfs.semanticscholar.org/3ed6/e44b227ed7adf894daa77215cccceb8dd394.pdf

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)

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	3.14%	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	$ 263,600	$ 58,400	$ -
PV of Capital Costs	$ 783,434	$ 173,568	$ -
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 672,155	$ 1,008,560	$ -
Total Life Cycle Cost (LCC)	**$ 1,455,589**	**$ 1,182,128**	**$ -**
Net Present Savings (NPS)	**N/A**	**$ 273,461**	**$ -**

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	650	4,584	-
% CO2e Reduction vs. Baseline	N/A	-605%	14%
Present Social Cost of Carbon (SCC)	$ 49,385	$ 395,466	$ -
Total LCC with SCC	**$ 1,504,974**	**$ 1,577,594**	**$ -**
NPS with SCC	**N/A**	**$ (72,620)**	**$ -**

Baseline Input Page

Total Building Annual Utility Analysis	$ 15,793	Water (CCF)	Electricity (KWH)
Annual Utility Bill [$]			$ 15,793
Annual Utility Consumption Not Entered Below			175,483
Sum of Annual Utility Consumption Below		-	-
Total Annual Utility Consumption		-	175,483
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							$ 263,600	Entries Below for Component S	
	A	Substructure								
	B	Shell								
	C	Interiors								
	D	Services								
x	D20	Plumbing								
x	D201098	Gas Baseline								
x	D202098	Central Heat Pump Water Heater		1	15	$263,600.00		$ 263,600		
	E	Equipment & Furnishings								
	F	Special Construction & Demolition								
	G	Building Sitework								

Alternative 1 Input Page

Total Building Annual Utility Analysis	$ 18,122
Annual Utility Bill [$]	
Annual Utility Consumption Not Entered Below	
Sum of Annual Utility Consumption Below	
Total Annual Utility Consumption	
Annual Utility Bill ÷ Total Utility Consumption	

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)
	Primary Entries Below: # of Units must be > 0 to be counted; Useful Life must be >= 2							
	Match Baseline: Filter to Select All & Drag Copy O14:S14 & U14:AG14							$ 58,400
	A	Substructure						
	B	Shell						
	C	Interiors						
	D	Services						
	D20	Plumbing						
	D201098	Gas Baseline		1	15	$58,400.00		$ 58,400
	D202098	Central Heat Pump Water Heater						
	E	Equipment & Furnishings						
	F	Special Construction & Demolition						
	G	Building Sitework						

Figure 2: 21-GP1-207 and 21-GP1-208 CMU Walls – LCCA Summary (Revised)

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)	24,695
Nominal Discount Rate	3.14%	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		BEST	
Alternative	Baseline	Alt. 1	Alt. 2
Energy Use Intensity (kBtu/sq.ft)	9.8	2.3	
1st Construction Costs	$ 14,557	$ 48,039	$ -
PV of Capital Costs	$ 14,356	$ 88,391	$ -
PV of Maintenance Costs	$ -	$ -	$ -
PV of Utility Costs	$ 161,225	$ 48,601	$ -
Total Life Cycle Cost (LCC)	**$ 175,581**	**$ 136,992**	**$ -**
Net Present Savings (NPS)	**N/A**	**$ 38,589**	**$ -**

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	584	103	40
% CO2e Reduction vs. Baseline	N/A	82%	529%
Present Social Cost of Carbon (SCC)	$ 49,961	$ 8,533	$ 3,057
Total LCC with SCC	**$ 225,542**	**$ 145,525**	**$ 3,057**
NPS with SCC	**N/A**	**$ 80,016**	**$ 222,485**

Baseline Input Page

Total Building Annual Utility Analysis	$ 3,127	Water (CCF)	Electricity (KWH)	Natural Gas (Therms)
Annual Utility Bill [$]			$ 978	$ 2,149
Annual Utility Consumption Not Entered Below			10,862	2,047
Sum of Annual Utility Consumption Below		-	-	-
Total Annual Utility Consumption		-	10,862	2,047
Annual Utility Bill ÷ Total Utility Consumption		$ -	$ 0.09	$ 1.05

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							$ 14,557	Entries Below for Component Specific Utility An		
	A	Substructure									
	B	Shell									
¤	B20	Exterior Enclosure									
¤	B201098	Vermiculite, 50%		11198	51	$1.30		$ 14,557			
¤	B201097	R-9.5ci									
	C	Interiors									
	D	Services									

Alternative 1 Input Page

Total Building Annual Utility Analysis	$ 1,056	Water (CCF)	Electricity (KWH)	Natural Gas (Therms)
Annual Utility Bill [$]			$ 776	$ 280
Annual Utility Consumption Not Entered Below			8,622	267
Sum of Annual Utility Consumption Below		-	-	-
Total Annual Utility Consumption		-	8,622	267
Annual Utility Bill ÷ Total Utility Consumption		$ -	$ 0.09	$ 1.05

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 Anal		
Match Baseline: Filter to Select All & Drag Copy O14:S14 & U14:AG14								$ 48,039			
.	A	**Substructure**									
	B	**Shell**									
x	B20	**Exterior Enclosure**									
x	B201098	Vermiculite, 50%									
x	B201097	R-9.5ci		11198	25	$4.29		$ 48,039			
	C	**Interiors**									

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

Table 2: 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 3: 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 4: 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 CO_2 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	**QTY**	**Unit Price**	**Install and Markup***	**Total Cost**	**Reference**
CO2 HPWH	2	38570	80%	$ 138,852	Equipment quote
500 Gal Storage Tank	3	12000	80%	$ 64,800	Original cost analysis with updated sizing
Rheem Supplementary Electeric WH (36kW)	1	1060	80%	$ 1,908	Home Depot and Supply House (heater, pump, RIB, Aquastat)
Temperature Maint. Heater - 120 gal, 26kW	1	15880	included	$ 15,880	RSMeans 2022
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
Controls	included			$ -	
			Total:	$ 244,615	

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				$ -	
				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