Sawara Exemplary Building Energy Study

ECOTOPE

Final Report

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Seattle City Light

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SECTION I. SUMMARY AND PROJECT DESCRIPTION

Project Description

This Energy Life Cycle Cost Analysis (ELCCA) report is being completed for the Sawara project located in the Central District of Seattle, Washington. The Seattle Housing Authority's Sawara project is a 114-unit 7-story affordable housing development with a community room, library, childcare units, and Social Service offices. The project is participating in the Housing Development Consortium's Exemplary Building demonstration program, which seeks to encourage the development of all-electric, ultra-high efficiency multifamily buildings with a modeled annual energy use of residential areas under 20 kBTU/sf/yr. The purpose of such demonstration projects is to reduce future costs of all-electric affordable housing by sharing the pursued energy conservation measures and use the projects as examples of where the market should trend.

For this study and report, the modeled building area includes only spaces utilized exclusively by residents, that can be uniformly expected and modeled across various multifamily buildings. Those spaces include residential units, a storage room on the bottom floor, horizontal and vertical circulation spaces, and laundry rooms. The modeled building boundary is shown in Appendix A, and the areas summarized in Table 1:

Table 1. Gross Modeled Floor Area

SPACE DESCRIPTION	CONDITIONED (SF)	UNCONDITIONED (SF)
RESIDENTIAL	88,675	-
CIRCULATION – CORRIDORS	11,708	4,294
CIRCULATION – STAIRS	2,059	172
STORAGE	1,122	-
LAUNDRY	891	-
TOTAL	104,455	4,466*

*The unconditioned floor area was not included in the energy model. However, the energy usage associated with this area has been included in the annual energy usage. Therefore, the EUI figures shown in the appended BEPS reports differ from the EUI stated throughout the report.

Areas excluded from the model include those that may be unique to this building and not necessarily present throughout the multifamily building stock. The garage area, unconditioned back of house spaces located in the garage level, and lobby area located on Level 1 are not included in the building energy simulation model per assumption in the contract. Exterior corridors and stairs were not explicitly modeled, but the lighting energy use and floor areas were included for the final EUI calculation.

Building Systems and Energy Measures

The residential dwelling units are heated with electric cove heaters with the main living spaces controlled by a 7-day programmable thermostat. Ventilation is provided continuously with high-efficiency energy recovery ventilators (ERVs). Occupants shall have the ability to boost their ventilation unit to full speed from a timer switch located in the primary bathroom. Operable windows are also provided for each unit. The west corridor is served by packaged rooftop air-source heat pumps while the two east wings are served by a split system heat pump systems and supply fans.

Domestic hot water (DHW) is provided with two independent central CO_2 heat pump water heating plants located in the garage, each serving half of the building.

The modeled energy conservation measures (ECM) and their baseline counterparts are listed in Table 2:

Table 2. Proposed Energy Conservation Measures

ECM ID	ECM	BASELINE	PROPOSED
1	**Air Tightness**	*SEC 2015 C406.9 Optional Measure* 0.25 cfm/sf @ 75 Pa	0.17 CFM/SF @75Pa
2	**High Efficiency Windows (vinyl)**	U-0.3, SHGC-0.35 (SEW), 0.53 (N)	U-0.26, SHGC-0.22
3	**Walls (wood)**	2x6 int, R-21 (U-0.056)	2x8 adv, R-31 blown-in (U-0.045)
4	**Roof**	R-38ci above-deck (U-0.027)	R-50ci above-deck (U-0.019)
5	**Residential Ventilation**	Whole-house Exhaust Fan @ 1.2 CFM/W	Panasonic FV-10VE2 ERVs, 75% SRE, 1.2 CFM/W
6	**Corridor HVAC**	Packaged rooftop unit, electric heat, code min DX cooling, 0.06 CFM/sf ventilation	Air-source Heat pump heating, 0.06 CFM/sf ventilation
7	**Appliances**	Federal Minimum	EnergyStar appliances (no dryer measure)
8	**Domestic Hot Water System**	Central electric boilers	Central Sanden CO2 Heat Pump Plants
9	**Low flow water fixture**	Shower 2.5 gpm Lavatory Faucets: 2.2 gpm 19 GPD/person hot water use	Shower 1.5 gpm Lavatory Faucets: 1.0 gpm 14 GPD/person hot water use
10	**Lighting (Corridors and Stairwells)**	*SEC 2015 C406.3 Optional Measure* 25% Lower LPD than Code	*SEC 2015 C406.3 Optional Measure* 25% Lower LPD than Code, occ sensors and corridor dimming

The project complied with the 2015 Seattle Energy Code (SEC) via the Target UA path and Section C406. The two measures selected to comply were:

1. C406.3 Reduced Lighting Power
2. C406.9 Reduced Air Infiltration

To prescriptively comply with the 2015 Seattle Energy Code, these two C406 measures were included in the baseline and proposed models. Lighting power density (LPD) for interior spaces was reduced by 25% over the maximum allowed code value. Air infiltration was reduced from 0.3 cfm/sf to 0.25 cfm/sf, measured at 75 Pa.

Through generous Renewable Energy Credits to be purchased by Seattle City Light, this project is pursuing a ~90kW solar array to be installed on the west roof as a deferred submittal by the PV contractor. Rough calculations, assuming the solar array will produce 1000 kWh/kW, mean this will lower the project's EUI by 2.8 kBtu/ft^2/yr. This solar array will fulfill the requirements of Section C411 (of roughly 6.6kW capacity). The modeled EUI from this report does not include solar energy credits unless clarified.

The energy analysis was performed using a proportionate attribution of interactive effects. The baseline annual energy use is 35.8 kBtu/ft^2/yr (3,895,257 kBtu/108,921 ft^2/yr). The total energy consumption of the proposed model is 18.1 (1,976,093 kBtu/108,921 ft^2/yr), excluding the solar PV energy credits. The annual modeled energy savings are 17.7 kBtu/ft^2/yr or 49%. These EUI values do not include energy usage or area of the garage.

Including the potential solar array, the annual EUI is expected to be 15.3 kBtu/ft^2/yr.

SECTION II. ENERGY CONSERVATION MEASURES

The ten energy conservation measures (ECM) were selected for their combined ability to reduce the building energy usage below an EUI of 20 kBtu/sf/yr while ensuring occupant comfort and ease of maintenance.

ECM Summary

Energy analysis was performed following the modeling method used for Seattle Energy Code Section C407 Total Building Performance, using the eQUEST modeling program. The following building simulation runs were performed:

Baseline
Baseline + ECM1
Baseline + ECM2
Baseline + ECM3
etc…
Baseline + all ECMs

Each run was modeled with the baseline plus an individual ECM is a non-interactive run, while all of the ECMs included at once is the interactive run. To determine the interactive energy savings per each ECM, the proportionate savings method was utilized, as shown below:

$$\text{Proportional ECM Savings} = \left[\frac{\text{Savings for noninteractive run for that ECM}}{\text{Sum of savings for noninteractive runs of all ECMs}}\right] * \text{Total savings from interactive run}$$

The proportional ECM savings was used to discuss the actual savings per ECM, since all the measures are being performed together and not just one individually. This method accounts for the interactive effect that various ECMs have on each other. Table 3 shows a summary of each ECM and the noninteractive and proportional annual energy savings, and associated energy cost savings assume an electricity rate of $0.09/kWh, and the incremental cost of each measure over the baseline building.

Table 3. ECM Summary Table

ECM ID	ECM NAME	ECM DESCRIPTION	INDIVIDUAL SAVINGS (KWH/YR)	PROPORTIONATE SAVINGS (KWH/YR)	UTILITY SAVINGS ($/YR)	INCREMENTAL COST	INCREMENTAL MAINTENANCE COST
1	**Air Tightness**	0.17 CFM/SF @75Pa	1,300	1,194	$367	$84,196	$0
2	**High Efficiency Windows***	U-0.26 vinyl, SHGC-0.22	-12,100	-11,116	($3,414)	$96,207	$0
3	**Walls (wood)**	2x8 adv, R-31 blown-in (U-0.045)	13,000	11,943	$3,668	$137,158	$0
4	**Roof**	R-50ci above-deck (U-0.019)	8,100	7,441	$2,286	$37,090	$0
5	**Residential Ventilation**	Unit-by-unit ERVs 75% SRE, 1.2 CFM/W)	162,040	148,859	$45,725	$342,000	$0
6	**Corridor HVAC**	PRTU Air-source HP 0.06 CFM/sf	4,600	4,226	$1,298	$80,000	$0
7	**Appliances**	EnergyStar Appliances	43,600	40,053	$12,303	$132,008	$0
8	**DHW System**	Central Sanden CO2 HP Plants	294,860	270,875	$83,205	$165,789	$1,000
9	**Low-flow water fixture**	Low-flow fixtures: Shower1.5 gpm, Lav:1.0 gpm 14 GPD/person hot water use	91,000	83,598	$25,679	$0	$0
10	**Lighting (Corridor & Stairwell)**	Occ sensors & corridor dimming	5,700	5,236	$1,608	$26,725	$0
ALL			N/A	562,310	$172,725	$1,101,173	$1,000

*High efficiency windows: This measure modeled as negative energy savings due to the rated SHGC being lower than the code baseline value. While the U-value is lower than code, this is a believable result since the windows limit the amount of passive solar gains compared to the code baseline. This fenestration specification is the confluence of sound transmission ratings (HUD requirements) and U-value requirements to pass the component tradeoff pathway through the envelope requirements of the energy code. This lower SHGC value will limit the amount of overheating in the summer, improving occupant comfort in these units without mechanical cooling.

Table 4 details if each measure is expected to have a positive (+), negative (-), or neutral (N) impact, when compared to the baseline building, on the criteria listed below:

Table 4. Impact of ECMs on Building Health, Comfort, and Longevity

ECM ID	ECM NAME	INDOOR AIR QUALITY	THERMAL COMFORT	USABILITY	DURABILITY	RELIABILITY	EASE OF MAINTENANCE
1	Air Tightness	+	+	N	+	+	N
2	High Efficiency Windows	+	+	N	+	+	N
3	Improved Walls	+	+	N	+	+	N
4	Improved Roof	+	+	N	+	+	N
5	Residential Ventilation	+	+	+	-	+	-
6	Corridor HVAC	+	+	N	N	N	N
7	EnergyStar Appliances	N	N	N	N	N	N
8	CO2 HPWH	N	N	-	N	N	-
9	Low-flow fixtures	N	N	N	N	N	N
10	Lighting Controls	N	N	+	-	-	-

ECM Descriptions

ECM1: Improved Airtightness

An envelope airtightness level of 0.17 cfm/sf at 0.3 in. w.g. was applied for ECM1. Since the project selected the C406.9 additional efficiency package option from the SEC 2015, the baseline building airtightness level is modeled as 0.25 cfm/sf. The air leakage rates were converted to air change per hour (ACH) for modeling following Table C407.5.1(1) in the SEC2015.

The proposed balanced ventilation system is not designed to provide makeup air to the exhaust base appliances, therefore energy savings from ECM 1 is entirely due to the improved air barrier.Since the energy recovery ventilators (ERVs) in each apartment do not induce a pressure differential across the envelope, it can be assumed infiltration is therefore independent of the mechanical ventilation system and varies primarily based on wind effects on the exterior of the building (modeled in eQuest).

To derive the infiltration standard of air change per hour (ach) from the code standard of cubic feet per minute per square foot area (cfm/sf) the following equation was used:

$$ACH = \frac{60\ min}{1\ hr} * \left(\frac{\frac{CFM}{sf} @\ 0.3\ inWg * Total\ Envelope\ Area\ (sf)}{Total\ Building\ Volume\ (ft^3)} \right) * 0.112$$

Table 5. Input variable changes of ECM1 (Airtightness)

	BASELINE	ECM1
INFILTRATION (ACH)	0.16	0.11

ECM2: High Efficiency Windows

The baseline building fenestration U-value and SHGC are determined from 2015 SEC Table C402.4. The proposed design is modeling with U-0.26 and SHGC-0.22 for the area-weighted average values. Due to substantially lower SHGC values, this measure is not showing overall energy savings. This fenestration specification is due to the confluence of sound transmission ratings, U-value, and occupant comfort over the summer.

Table 6. Input variable changes of ECM2 (High Efficiency Windows)

	BASELINE	ECM2
NON-METAL WINDOW U-VALUE	U-0.30	U-0.26
SHGC	SEW: SHGC-0.35, N: SHGC-0.53	SHGC-0.22

ECM3: Enhanced Exterior Walls

The U-factor requirement for wood-framed walls in the SEC 2015 Table C402.1.4 is U-0.054. The proposed design has 2x8 advanced framing with R-31 blown-in insulation (U-0.045).

Table 7. Input variable changes of ECM3 (Walls)

	BASELINE	ECM3
U-VALUE OF EXTERIOR WOOD WALL	U-0.054	U-0.045

ECM4: Enhanced Roofs

The baseline design has the SEC 2015 requirement of R-38 ci above deck (U-0.027), while the proposed design has R-50 ci above deck (U-0.019).

Table 8. Input variable changes of ECM4 (Roof)

	BASELINE	ECM4
U-VALUE OF ROOF	U-0.027	U-0.019

ECM5: Residential Energy Recovery Ventilation

The whole house exhaust fan (1.4 cfm/W) was applied to the residential dwelling unit ventilation fans for the baseline model. In the proposed design, unit by unit ERV (Panasonic FV-10VE2) was applied. Per the 2015 Seattle Mechanical Code Table 403.3.1.1, the ventilation airflow rate in corridors is 0.12 cfm/sf when the corridors serve dwelling units with a whole-house exhaust system, while 0.06 cfm/sf for the corridors serving dwelling units with other than whole house exhaust system – this was taken as an energy savings measure alongside the ERV measure.

Table 9. Input variable changes of ECM5 (Dwelling Ventilation)

	BASELINE	ECM5
WHOLE HOUSE EXHAUST FAN POWER	0.714 W/cfm	NA
HEAT RECOVERY VENTILATION	NA	0.81 W/cfm, 0.75 sensible recovery
CORRIDOR VENTILATION RATE	0.12 cfm/sf	0.06 cfm/sf

ECM6: Corridor HVAC

The system type of baseline design in accordance with Table SEC 2015 Table C407.5.1(3) and Table C407.5.1(4). In the baseline, the system type for corridors is a packaged rooftop heat pump (PRHP), which has an electric heat pump and direct expansion cooling coil. The fan energy of PRHP is calculated per Table C407.5.1(1). Minimum heating and cooling efficiencies from Table C403.2.3(2) are adjusted to remove the supply fan energy per C407.5.3.

The proposed design includes a packaged rooftop air-source heat pump unit for the west building's corridors. A ductless heat pump unit with an untampered supply fan for ventilation is proposed for the east corridors. The fan in the heat pump will cycle on with the load in the space. Heating/cooling efficiency and part load curve from the manufacturer were applied to the proposed HVAC system.

Table 10. Input variable changes of ECM6 (Corridor HVAC)

		BASELINE	ECM6
WEST BUILDING CORRIDORS	SYSTEM TYPE	PRHP	PRHP
	SYSTEM FAN POWER	0.85 W/cfm	0.29 W/cfm
	HEATING EIR	0.24	0.31
	COOLING EIR	0.25	0.25
OTHER CORRIDORS	SYSTEM TYPE	PRHP	DHP + Supply fan
	SYSTEM FAN POWER	0.85 W/cfm	0.16 W/cfm
	HEATING EIR	0.24	0.28
	COOLING EIR	0.25	0.28
	PERFORMANCE CURVE	eQUEST default	Mitsubishi performance curve
	VENTILATION SUPPLY FAN POWER	NA	0.43 W/cfm

ECM7: Energy Star Appliances

Energy Star Appliances for refrigerator, dishwasher, and electric stove are installed to all 114 dwelling units in the ECM7. Only 24 out of 114 dwelling units have in-unit clothes washer. Common area laundry rooms are on floor 2 through 7. Baseline appliances meet federal, state, and local requirements.

Energy Star appliances can save energy in two areas: electricity and hot water. Equipment power density (EPD) savings by Energy Star Appliances are calculated based on 'Building America Research Benchmark Definition'.[1] To estimate energy savings for the appliances, different Appliance Level Factors were applied to the annual electric loads of the benchmark. The annual electric loads were multiplied by 0.9 to represent "new" appliances in the baseline and multiplied by 0.68 for "Energy Star" appliances.

$$Baseline = Benchmark \times 0.9$$

$$Energy\ Star = Benchmark \times 0.68$$

[1] Hendron, R. January 2008. Building America Research Benchmark Definition. National Renewable Energy Lab. Contract # DE-AC36-99-GO10337. Table 12 on page 21, https://www.nrel.gov/docs/fy09osti/44816.pdf

Table 11. Annual appliance energy use calculation

	BENCHMARK (KWH/YR)[2]	BASELINE (NEW APPLIANCE FACTOR = 0.9, KWH/YR)	ENERGY STAR (ES APPLIANCE FACTOR = 0.68, KWH/YR)
REFRIGERATOR	669	602	455
DISHWASHER	$103 + 34.3 \times N_{br}$	144	109
CLOTHES WASHER	$52.5 + 17.5 \times N_{br}$	73	55
CLOTHES DRYER	$418 + 139 \times N_{br}$	583	440
COOKING (ELECTRIC STOVE)	$302 + 101 \times N_{br}$	422	319

A national study that compared laundry use of residents in buildings with common laundry rooms versus apartments with in-unit laundry showed that the ratio of loads per dwelling unit is 0.41 (load per dwelling unit per week is 2.14 for common laundry rooms and 5.22 for in-unit laundry). [3] This was applied as an energy and water-saving measure to the building for all units which do not have an in-unit washer/dryer (all units under 3 bedrooms, non-family units).

$$Laundry\ room\ energy\ use = \frac{Loads\ of\ Common\ laundry}{Loads\ of\ In\ unit\ laundry} \times number\ of\ no\ laundry\ unit \times energy\ use\ of\ in\ unit\ washer\ and\ dryer$$

Table 12. Energy savings by Energy Star appliances (Laundry room)

	ITEMS	BASELINE	ECM7
ELECTRICAL SAVINGS	**Clothes Washer**	2,719 kWh/yr	2,048 kWh/yr
	Clothes Dryer	21,712 kWh/yr	16,386 kWh/yr
HOT WATER DEMAND SAVINGS	**Hot water demand (clothes washer)**	2,436 gal/yr/unit	1,127 gal/yr/unit

Since Energy Star appliances use less hot water, Domestic Hot Water (DHW) demand savings by Energy Star dishwasher and clothes washer are considered in ECM7. DHW process flow GPM is adjusted to represent the hot water demand saving by Energy Star dishwasher and clothes washer. The common laundry load ratio was also applied to estimate the hot water demand for clothes washer in the common laundry rooms.

Table 13. Energy savings by Energy Star appliances (Dwelling unit)

	ITEMS	BASELINE	ECM7
ELECTRICAL SAVINGS	**Refrigerator**	602 kWh/yr	455 kWh/yr
	Dishwasher	144 kWh/yr	109 kWh/yr
	Clothes Washer	73 kWh/yr	55 kWh/yr

[2] $N_{br} = number\ of\ bedrooms, N_{br} = 1.6\ (average)$

[3] National Research Center Inc. (2002). A National Study of Water & Energy Consumption in Multifamily Housing (Vol. 2002). Multi-housing Laundry Association, https://www.mla-online.com/pdf/NRC-2002-A-National-Study-of-Water-and-Energy-Consumption-in-Mutli-Family-Housing.pdf

	Clothes Dryer	583 kWh/yr	440 kWh/yr
	Cooking (electric stove)	422 kWh/yr	319 kWh/yr
HOT WATER DEMAND SAVINGS	**Hot water demand (dishwasher)**	1,290 gal/yr/unit	860 gal/yr/unit
	Hot water demand (clothes washer)	2,436 gal/yr/unit	1,127 gal/yr/unit

Table 14. Input variable changes of ECM7 (Appliances)

	BASELINE	ECM7
RESIDENTIAL UNIT EPD	1.39 W/sf	1.20 W/sf
COMMON LAUNDRY ROOM EPD	13.0 W/sf	9.8 W/sf
DHW PROCESS FLOW	19.67 gpm	18.86 gpm

ECM8: CO2 Heat Pump Water Heater

Domestic hot water savings are attributed to the heating equipment efficiency in ECM8. A CO_2 heat pump water heater utilizes a vapor compression cycle to bring city cold water (50°F) up to 120°F at an annual coefficient of performance (COP) of 3.0. The 3.0 COP is a conservative estimate based on the measured value from previous Ecotope projects[4]. The COP is comprehensive for the entire domestic water heating system and includes the energy usage for both the primary load and the recirculation load. For the Sawara HPWH system, over half of the recirculation load is met by the primary CO_2 heat pump and the remaining load is met by an electric resistance swing tank.

Energy savings are determined from a manual engineering calculation. Distribution pipe heat loss was included for both the baseline and ECM8. The assumed distribution pipe heat loss is 60 Watts per apartment and is based on research that Ecotope has performed on multifamily buildings with similarly designed central recirculation systems.[5] This heat loss per apartment metric matches closely with research conducted for the California Energy Commissions which found roughly 33% of DHW energy use is lost through circulation piping.[6]

Ecotope's research on this matter has led to an effort to implement back-to-back risers to reduce overall piping, as a reduction in surface area correlates to a reduction in piping heat loss. There are no code measures that currently relate to this topic. The annual system COP is applied to a gallon/person/day usage rate of hot water that is kept constant between both the baseline and proposed models.

[4] Banks, A., Grist, C., & Heller, J. (2020). CO2 Heat Pump Water Heater Multifamily Retrofit: Seattle WA. Bonneville Power Administration (BPA), https://www.bpa.gov/EE/Technology/EE-emerging-technologies/Documents/CO2_Heat_Pump_Water_Heater_Final.pdf

[5] Heller, J. Oram, S. (2015) RCC Pilot Project: Mutlifamily Heat Pump Water Heaters in Below Grade Parking Garages in the Pacific Northwest. Bonnevill Power Administration (BPS), https://www.bpa.gov/EE/Technology/EE-emerging-technologies/Projects-Reports-Archives/Documents/Dec2015%20RCC%20Report%20with%20Appendix.pdf

[6] Zhang, Y. (2013). Multifamily Central Domestic Hot Water Distribution Systems. California Energy Commission (CEC), https://www.redwoodenergy.tech/wp-content/uploads/2017/07/Zhang-mutlifamily-PIER-study-CEC-500-2013-011.pdf

Table 15. HPWH DHW Calculation

DHW Calcs (HPWH)		
Temp		
Entering water temperature (F)	50	F
Hot water setpoint (F)	120	F
Ambient air temperature (F)	67.5	F
# of Units	114	dwelling units
# of in-unit laundry	24	dwelling units
Loads ratio of Common laundry/In-unit	0.41	
# of people	282	persons
Volume of Storage	2040	Gal
Baseline DHW Heating Efficiency (%/h)	0.313	%/h
Baseline DHW Heating Efficiency (SL)	**2795**	Btu/hr
Recirc pipe heat loss	60	W/unit
Baseline DHW Heating Efficiency (COP)	1.0	Electric tanks
Proposed DHW Heating Efficiency (COP)	3.0	CO2 HPWH (System COP)
Proposed Recirc HPWH Efficiency (COP)	3.0	CO2 HPWH (System COP)
Baseline HW Demand	**19.19**	GPD/per
Fixture	GPM/Fixture	
Faucets	1.00	
Shower Heads	1.50	
Proposed HW Demand	**19.19**	GPD/per
Energy Star Dishwasher Savings		
Baseline	1290.0	gal/year/unit
Proposed	1290.0	gal/year/unit
Savings	0	gal/year/unit
Savings	**0.00**	gal/day/unit
Baseline	3.53	gal/day/unit
Energy Star Clothes Washer Savings		
Baseline HW (In-unit)	2436.0	gal/year/unit
Proposed HW (In-unit)	2436.0	gal/year/unit
Savings	0	gal/year/unit
Savings	**0.00**	gal/day/unit
Baseline HW (In-unit)	6.67	gal/day/unit
Baseline HW Demand	**2,203,661**	gal/yr
Proposed HW Demand	**2,203,661**	gal/yr
Baseline DHW Energy Consumption (w/ recirc)	**1,509,308,681**	BTU/yr
Proposed DHW Energy Consumption (w/ recirc)	**503,102,894**	BTU/yr
Savings	**1,006,205,788**	BTU/yr

ECM9: Low Flow Water Fixtures

Energy savings for ECM 9 low flow fixtures are determined from a manual engineering calculation. The hot water demand by low flow fixtures was assumed 14 gal/person/day based on 2015 ASHRAE Handbook – HVAC Applicants 50.15 Table 7. The baseline hot water demand was calculated using the Energy Star MFHR Simulation Guidelines. The domestic hot water load (DHW process flow GPM) was adjusted in each energy model until the results matched the manual calculation.

$$BaselineHWDemand = ProposedHWDemand/(0.36 + 0.54 \times \frac{LFS}{2.5} + 0.1 \times \frac{LFF}{2.5})$$

Where:

$$LFS\left[GPM_{80psi}\right] = rated\ flow\ rate\ of\ the\ low - flow\ showerheads\ specified\ on\ the\ drawings\ (1.5)$$

$$LFF\left[GPM_{80psi}\right] = rated\ flow\ rate\ of\ the\ low - flow\ facucets\ specified\ on\ the\ drawings, (1.0)$$

The calculated baseline, shown in Table 16, is approximately 19 gpd/person of hot water usage. This baseline for low flow fixtures meets federal, state, and local requirements. Flows shown in Table 16 meet HB 1444 which references Title 20 1605.3 requirements.

Table 16. ECM 7 Low Flow Fixture Rates and Total Hot Water Use

	BASELINE	ECM7
SHOWERS (GPM)	1.8	1.5
LAVATORY FAUCETS (GPM)	2.2	1.0
TOTAL HOT WATER USE (GPD/PERSON)	19	14

Shown in Table 17 are the values used to calculate savings associated with low flow fixtures and the results of the calculations, summarized in Table 16.

Table 17. Low Flow Fixtures DHW Calculation

DHW Calcs (Low-flow fixtures)		
Temp		
Entering water temperature (F)	50	F
Hot water setpoint (F)	120	F
Ambient air temperature (F)	67.5	F
# of Units	114	dwelling units
# of in-unit laundry	24	dwelling units
Loads ratio of Common laundry/In-unit	0.41	
# of people	282	persons
Volume of Storage	2040	Gal
Baseline DHW Heating Efficiency (%/h)	0.313	%/h
Baseline DHW Heating Efficiency (SL)	**2795**	Btu/hr
Recirc pipe heat loss	60	W/unit
Baseline DHW Heating Efficiency (COP)	1.0	Electric tanks
Proposed DHW Heating Efficiency (COP)	1.0	Electric tanks
Proposed Recirc HPWH Efficiency (COP)	1.0	Electric tanks
Baseline HW Demand	**19.19**	GPD/person
Fixture	GPM/Fixture	
Faucets	1.00	
Shower Heads	1.50	
Proposed HW Demand	**14.00**	GPD/person
Energy Star Dishwasher Savings		
Baseline	1290.0	gal/year/unit
Proposed	1290.0	gal/year/unit
Savings	0	gal/year/unit
Savings	**0.00**	gal/day/unit
Baseline	3.53	gal/day/unit
Energy Star Clothes Washer Savings		
Baseline HW (In-unit)	2436.0	gal/year/unit
Proposed HW (In-unit)	2436.0	gal/year/unit
Savings	0	gal/year/unit
Savings	**0.00**	gal/day/unit
Baseline HW (In-unit)	6.67	gal/day/unit
Baseline HW Demand	**2,203,661**	gal/yr
Proposed HW Demand	**1,669,205**	gal/yr
Baseline DHW Energy Consumption (w/ recirc)	**1,509,308,681**	BTU/yr
Proposed DHW Energy Consumption (w/ recirc)	**1,198,789,704**	BTU/yr
Savings	**310,518,978**	BTU/yr

ECM10: Common Space Lighting Controls

ECM 10 provides occupancy sensors in the corridors, and daylighting in the corridors, lobby, and stairs. The occupancy sensor adjustment is entered as a change to the lighting power density (LPD). The daylighting is analyzed by eQuest and is not reflected in the LPD inputs.

Common space in ECM10 indicates corridors and stairs, which includes occupancy sensors (OS) and daylight sensors. eQUEST default daylight control scenario (Switch: 2 Level + Off) is set to the common spaces for ECM10. A 25% reduction in building LPD was applied to both the proposed and baseline models, in compliance with the C406 reduced measure selected.

An additional reduction in LPD was applied to stairways in compliance with section C405.2.5, which requires lighting control for stairwells. ECM10 then applies an LPD reduction for corridor lighting control, estimated as a 35% reduction in LPD for stairways and a 25% reduction for corridors per EnergyStar MFHR Simulation guidelines.[7] Then, in the eQUEST, the daylighting controls are applied to corridors, lobby, and stairway, which have windows. Table 18 shows the decreases in LPD for stairways and corridors.

Table 18. Variable Changes of ECM10 (Lighting Controls)

	SEC 2015 CODE REQUIREMENT	C406 25% REDUCED LIGHTING POWER	BASELINE - C405.2.5 OS FOR STAIRWAYS (35% REDUCTION)	ECM5 - ADDING OS TO CORRIDORS (25% REDUCTION) AND DAYLIGHTING
STAIRWAY LPD	0.5	0.38	0.24	0.24 W/sf
CORRIDOR, LOBBY LPD	0.48	0.36	0.36	0.27 W/sf
DAYLIGHTING	NA	-	-	Switch: 2 Level + Off

[7] ENERGY STAR® MULTIFAMILY HIGH RISE PROGRAM Simulation Guidelines Version 1.0, Revision 03 https://www.energystar.gov/partner_resources/residential_new/program_reqs/mfhr/guidance

SECTION III. ANALYSIS OF OVERALL PROJECT

Life Cycle Cost Analysis

The Washington State Life Cycle Cost Analysis Tool was used to determine the total life cycle cost and net present savings of the proposed building. The executive summary in Table 19 shows the proposed building (Alt. 1) provides the best financial and social payback.

Table 19. Life Cycle Cost Analysis Executive Summary

KEY ANALYSIS VARIABLES		BUILDING CHARACTERISTICS	
STUDY PERIOD (YEARS)	50	Gross (Sq. Ft)	108,921
NOMINAL DISCOUNT RATE	3.14%	Useable (Sq. Ft)	104,455
MAINTENANCE ESCALATION	1.00%	Space Efficiency	95.9%
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
EUI (KBTU/SQ. FT)	35.8	18.1	
1ST CONSTRUCTION COSTS	$ -	$979,637	$ -
PV OF CAPITAL COSTS	$ -	$2,000,284	$ -
PV OF MAINTENANCE COSTS	$ -	$44,897	$ -
PV OF UTILITY COSTS	$4,808,691	$2,439,488	$ -
TOTAL LIFE CYCLE COST (LCC)	**$4,808,691**	**$4,484,669**	$ -
NET PRESENT SAVINGS (NPS)	**N/A**	**$324,023**	$ -
(GHG) SOCIAL LIFE CYCLE COST		**BEST**	
GHG IMPACT FROM UTILITY CONSUMPTION	Baseline	Alt. 1	Alt. 2
TONS OF CO2E OVER STUDY PERIOD	4,230	2,146	-
% CO2E REDUCTION VS. BASELINE	N/A	49%	-
PRESENT SOCIAL COST OF CARBON (SCC)	$321,188	$162,941	$ -
TOTAL LCC WITH SCC	**$5,129,880**	**$4,647,610**	**$ -**
NPS WITH SCC	**N/A**	**$482,269**	**$ -**

Building Energy Usage

The modeled baseline and proposed energy use intensity (EUI) by end-use are shown in Table 20. The total energy consumption of the proposed model is 18.1 kBtu/sf/yr (1,976,093 kBtu/ 108,921 sf/yr). The baseline annual energy use is 35.8 kBtu/sf/yr (3,895,257 kBtu/ 108,921 sf/yr). The annual savings are 17.7 kBtu/sf/yr or 49%. The largest energy reduction is in domestic water heating. Low-flow fixtures and CO2 HPWHs reduce the EUI by 10.4 kBtu/sf/yr. The second-largest reduction is in the heating energy. Residential heating systems in both baseline and proposed designs are identical (electric resistance heater). However, Energy Recovery Ventilator (ERV) in the residential unit provides a substantial reduction in heating energy.

Table 20: EUI Comparison

END-USE	MODELED BASELINE EUI (KBTU/SF/YR)	MODELED PROPOSED EUI (KBTU/SF/YR)	REDUCTION %
DHW	13.9	3.5	75%
LIGHTS	2.3	1.9	17%
HEAT	9.0	3.4	62%
PLUGS	8.9	7.6	15%
COOL	0.1	0.1	-8%
FAN	1.5	1.6	-3%
SUM	**35.8**	**18.1**	**49%**

The donut charts in Figure 1 show the reduction of EUI by end-use category. The baseline and proposed model EUI's are stated in the donut hole. The white spaces in the proposed chart represent the savings in each energy use category over baseline.

The "plugs" section relates to miscellaneous end use and includes unregulated energy consumption such as plug loads and appliances. The savings of approximately 1.3 EUI for this section are due EnergyStar Appliances (ECM 7), as there is no reduction to plug loads. The proportion of energy use attributed to plug load use increases in the proposed building due to less overall energy use (smaller denominator) and shown in the BEPS report.

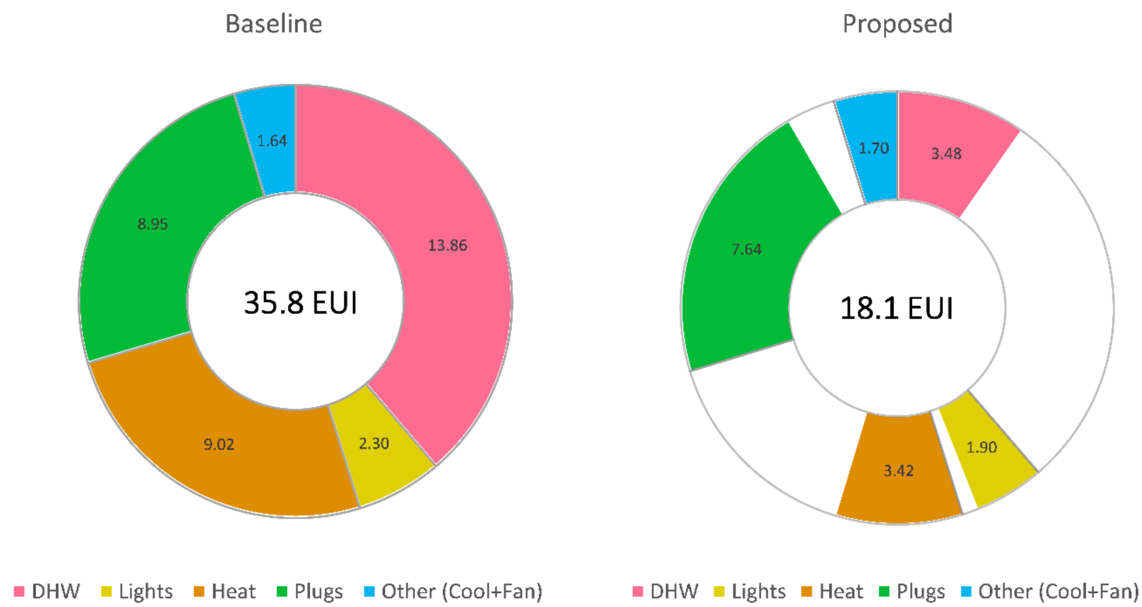

Figure 1: EUI comparison between Baseline and Proposed Building Models (w/o PV generation)

The expected monthly energy usage for the baseline and proposed buildings are shown in Figure 2. The two models have similar profiles; however, the proposed model is shifted down by approximately 47,000 kWh each month.

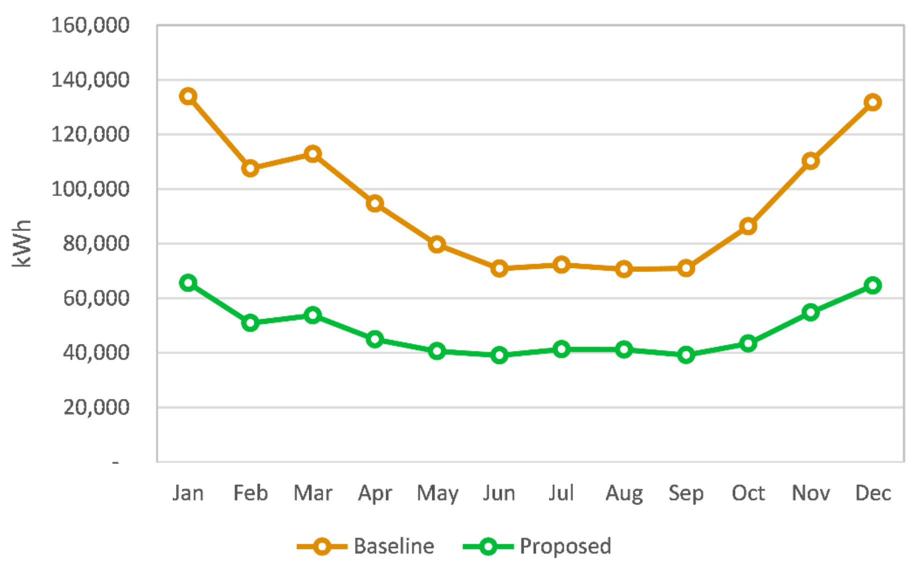

Figure 2: Total Monthly kWh consumption

Parking Garage Energy Consumption

Although the parking garage energy usage was not included in the model, it is important to understand the expected energy consumption for post-construction EUI analysis. Table 21 shows the energy usage by end-use in the parking garage, with a detailed explanation in the sections below.

Table 21: Energy Consumption for Proposed Garage

ESTIMATION FOR GARAGE	PROPOSED ENERGY (KWH)
GARAGE LIGHTING (KWH/YR)	14,404
GARAGE FAN (KWH/YR)	4,942

The total parking garage energy consumption of 19,346 kWh/yr increases the proposed modeled building EUI by 0.18 kBtu/sf/yr.

Garage Lighting Energy

The estimated floor area for the proposed garage is 17,400 sf. The interior lighting power allowances for the interior parking garage is 0.14 W/sf in accordance with SEC2015-Table C405.4.2(2). Then, 25% of energy savings is applied in accordance with the selection of C406.3 measure. Since the additional lighting controls is required for parking areas per C405.2.5, 10% of lighting energy savings due to the occupancy sensor (OS) is added refer to Energy Star Multifamily High-Rise Program Simulation Guidelines V1.0 R03 Table 3.

$$\text{Garage area } \times \text{Allowed W/sf } \times (1-25\%) \times (1-\text{OS savings}) \times 8760\text{ hrs} = \text{Annual lighting energy use for a garage}$$

$$17{,}400\text{ sf} \times 0.14\text{ W/sf} \times (1-0.25) \times (1-0.1) \times 8760\text{ hrs} = 14{,}404\text{ kWh}$$

Garage Fan Energy

In the proposed design, garage ventilation is performed by a 13,000 cfm, 2.44 BHP exhaust fan (Greenheck SBE-3L30-30) and 5,000 cfm, 1.71 BHP transfer fan (Greenheck BCF-212-20). The control modulates exhaust fan speed to the minimum flow rate (6% of designed cfm or 20 Hz, whichever is greater) during off-peak load hours and ramps the fan up to high by VFD, signal per CO/NO2 sensors. The garage exhaust fan is assumed to operate at minimum speed continuously and ramp-up to 100 percent in the morning and evenings (4 hours). The transfer fan is assumed to run 4 hours per day.

$$\left\{2.44\,bhp \times 735.5\frac{W}{bhp} \times 4\,hrs \times 365\frac{days}{yr} \times \frac{1\,kW}{1000\,W}\right\} + \left\{2.44\,hp \times 735.5\frac{W}{bhp} \times (24-4)\,hrs \times 365\frac{days}{yr} \times \frac{1\,kW}{1000\,W} \times \left(\frac{13000\,cfm \times (\frac{20}{60})}{13000\,cfm}\right)^3\right\} + \left\{1.71\,bph \times 735.5\frac{W}{bhp} \times 4\,hrs \times 365\frac{days}{yr} \times \frac{1kW}{1000W}\right\} = 4{,}942\text{ kWh/yr}$$

SECTION IV. POST CONSTRUCTION MONITORING RECOMMENDATIONS

Post-construction monitoring has been a topic amongst SHA and design team throughout the design project thus far. With interest in the longevity of energy savings as well as ensuring thermal comfort and indoor air quality for the occupants, the three primary topics of interest include: Sanden heat pump water heater performance monitoring, Indoor Air Quality (IAQ) sampling of select residential units, and hot + cold water submetering data.

The functioning of the CO2 Sanden HPWHs is a potentially important area for monitoring. Due to the backup electric water heaters, it is possible for the HPWHs to fail and no one to notice because the DHW plant will continue to provide sufficient hot water. Being notified by automatic alarms in the event of HPWH failure would allow for maintenance staff to remedy the issue without relying too long on electric and overly reducing the energy efficiency of the DHW production. By the time of install, Sanden is anticipated to have this system successfully integrated in their product, and there should be no to minimal additional cost.

Balanced flow ventilation using energy recovery ventilators (ERVs) is recognized as the best combination of ventilation performance and energy savings for residential construction. With more frequent wildfires in our region, along with Interstate-5 nearby this building, providing a mechanical system design that ensures indoor environmental quality has been a primary focus for this project and EB program. Installing temperature, CO2 sensors, and possibly VOC sensors in a sample of residential units (~10% of total units) would allow for long-term monitoring of the indoor air quality and environmental comfort for the residents. Since balanced flow ERVs will be required under the 2018 Seattle and Washington State energy code, this would be a good opportunity to measure the effectiveness of these systems and determine if the airflow requirements and boost capabilities meet the needs of the occupants. Veris wireless combined CO2/temperature sensors (about $500 each) could be installed in a sampling of units. A rough order of magnitude cost to design a study, install sensors and monitoring equipment, collect, and analyze data, and write a report is approximately $45,000.

A final study area of interest would be to receive cold and hot water usage data from SHA. This is already standard across all their projects, so the addition of cold-water meters (not required by code) is not a cost adder to the project. On top of that, SHA uses this monthly data to incentivize their residents to save on water usage by providing a utility credit if their unit’s use is below the average. This sort of data is incredibly useful in properly sizing central hot water systems for multifamily buildings and would be valuable for the EB program to have for the education of future projects. Cost for this study TBD based on SHA participation the amount of data scrubbing needed to share publicity.

APPENDIX A. MODELED BUILDING AREA

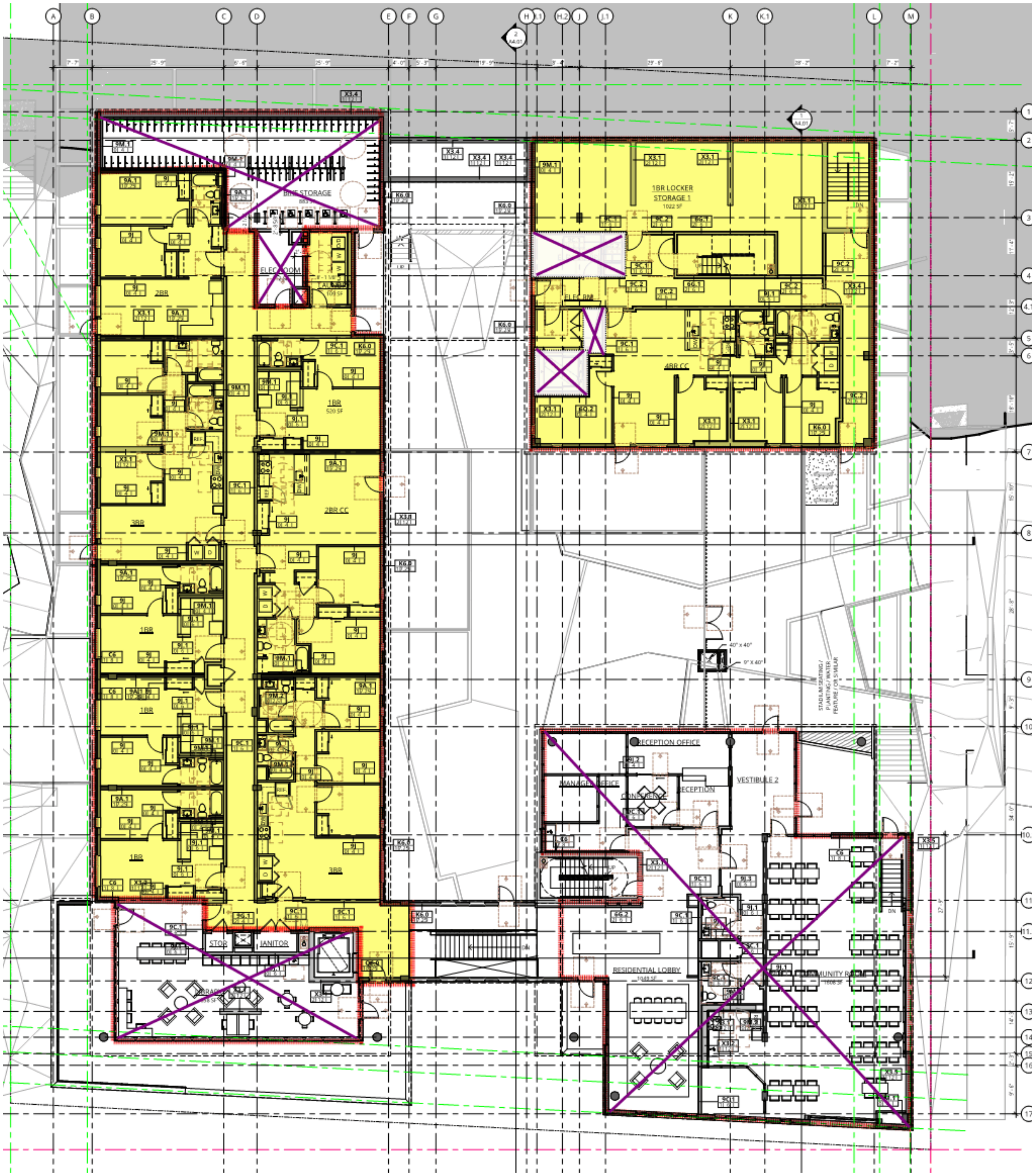

Figure 3. Modeled Building Area: Level 2

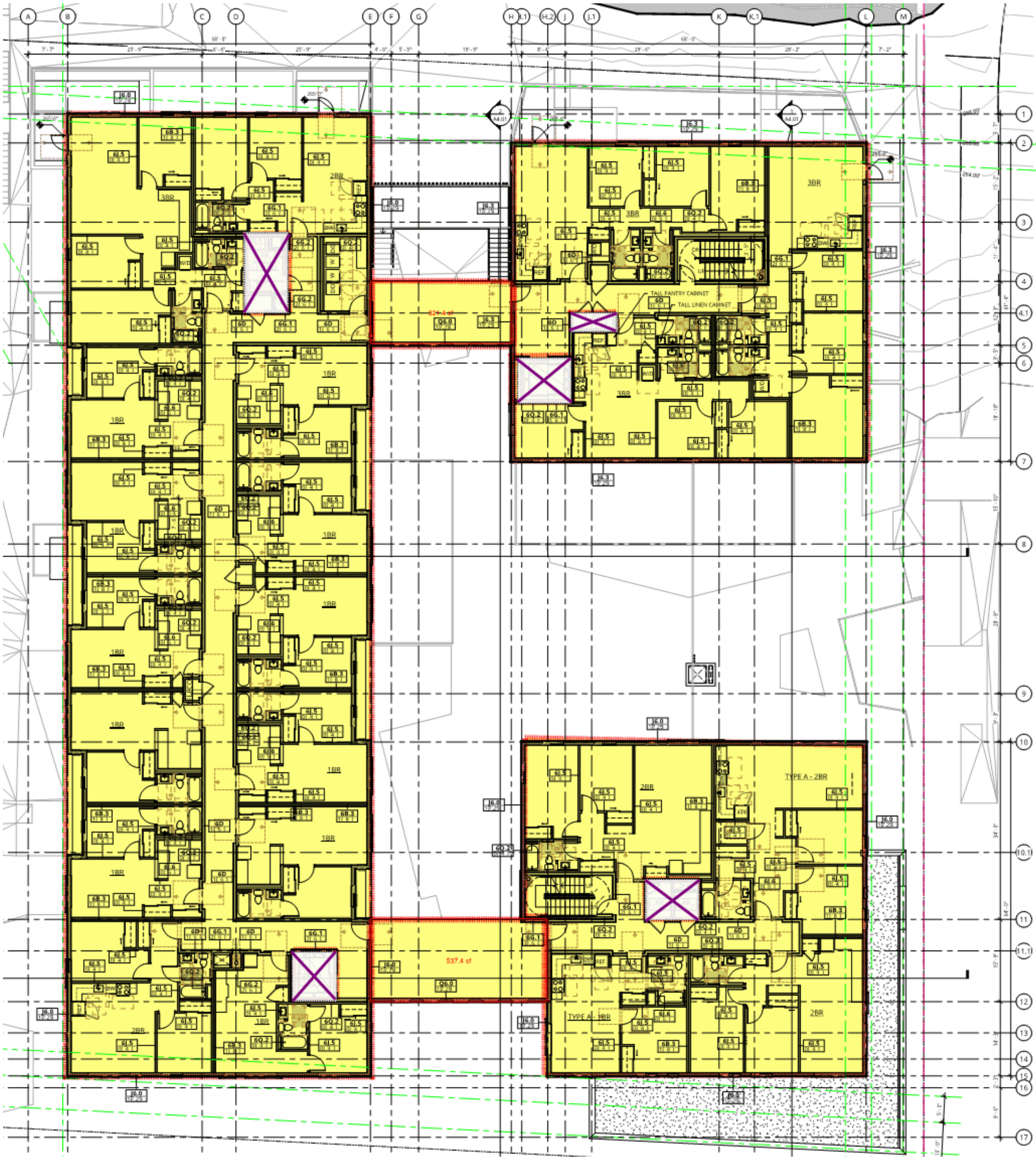

Figure 4. Modeled Building Area: Level 3-7

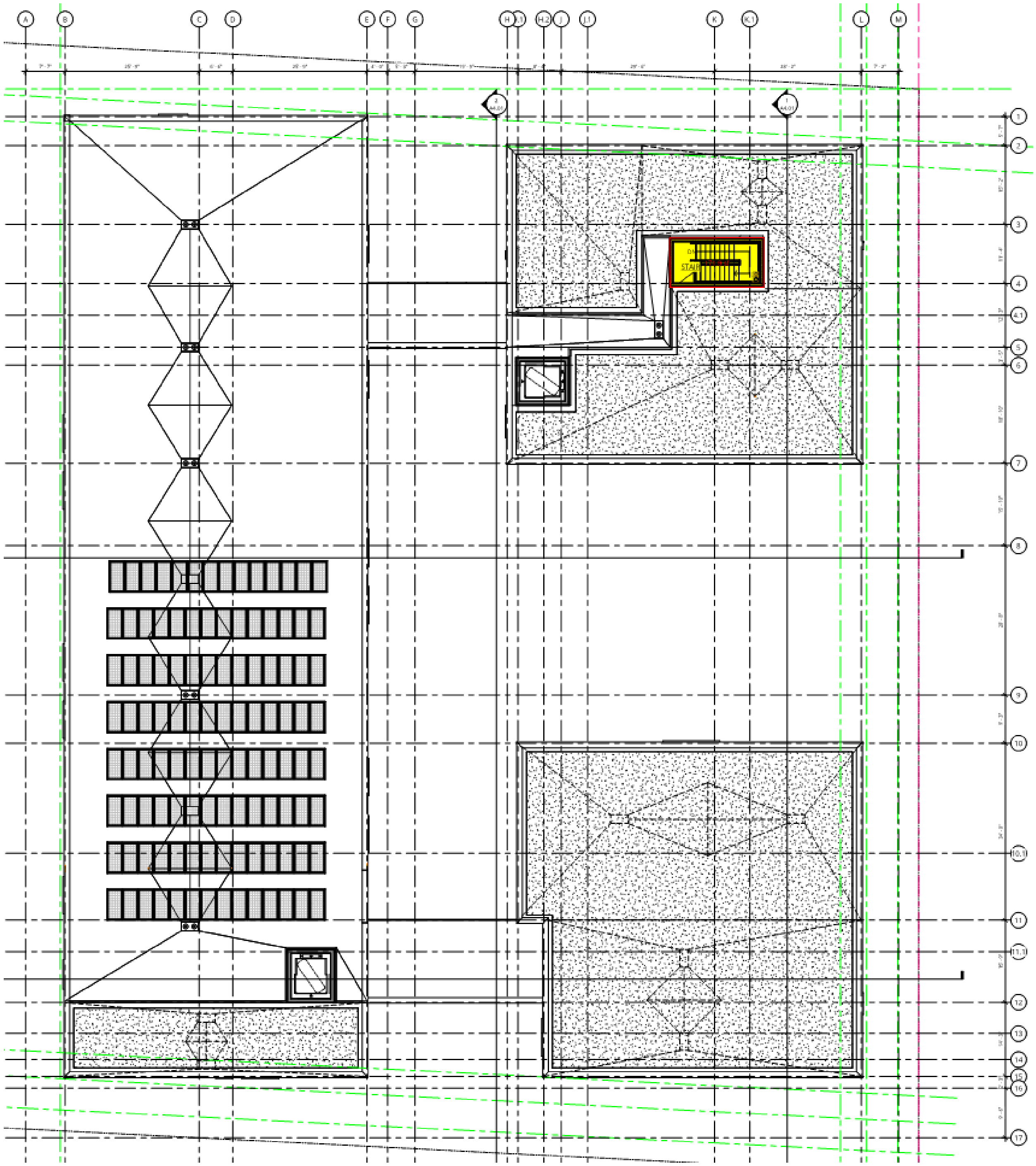

Figure 5. Modeled Building Area: Roof

APPENDIX B. ELCCA INPUTS AND OUTPUT

Baseline Input Page

Total Building Annual Utility Analysis	$ 112,989	Water (CCF)	Electricity (KWH)
Annual Utility Bill [$]			$ 112,989
Annual Utility Consumption Not Entered Below			1,141,300
Sum of Annual Utility Consumption Below		-	-
Total Annual Utility Consumption		-	1,141,300
Annual Utility Bill ÷ Total Utility Consumption		$ -	$ 0.10

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							$ -	Entries Below for Component Spe	
x	A102098	ECM01 - Air Tightness			50	$84,196				-1,194
x	A103098	ECM02 - Glazing			25	$96,207				11,116
x	A201098	ECM03 - Walls			50	$137,158				-11,943
x	A202098	ECM04 - Roof			50	$37,090				-7,441
x	B101098	ECM05 - Res Ventilation			20	$342,000				-148,859
x	B102098	ECM06 - Corridor HVAC			20	$80,000				-4,226
x	B201098	ECM07 - EnergyStar Appliances			14	$10,472				-40,053
x	B202098	ECM08 - DHW - HPWH			15	$165,789	$1,000			-270,875
x	B203098	ECM09 - DHW - Low-flow Fixtures			15	$0				-83,598
x	B301098	ECM10 - Lighting			15	$26,725				-5,236

Figure 6. ELCCA Baseline Input Page

Alternative 1 Input Page

Total Building Annual Utility Analysis	$ 57,320	Water (CCF)	Electricity (KWH)
Annual Utility Bill [$]			$ 57,320
Annual Utility Consumption Not Entered Below			1,141,300
Sum of Annual Utility Consumption Below		-	(562,309)
Total Annual Utility Consumption		-	578,991
Annual Utility Bill ÷ Total Utility Consumption		$ -	$ 0.10

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								Entries Below for Component Spe	
	Match Baseline: Filter to Select All & Drag Copy O14:S14 & U14:AG14							$ 979,637		
.	A	Substructure								
	A102098	ECM01 - Air Tightness		1	50	$84,196.00		$ 84,196		-1194
	A103098	ECM02 - Glazing		1	25	$96,207.00		$ 96,207		11116
	A201098	ECM03 - Walls		1	50	$137,158.00		$ 137,158		-11943
	A202098	ECM04 - Roof		1	50	$37,090.00		$ 37,090		-7441
	B101098	ECM05 - Res Ventilation		1	20	$342,000.00		$ 342,000		-148859
	B102098	ECM06 - Corridor HVAC		1	20	$80,000.00		$ 80,000		-4226
	B201098	ECM07 - EnergyStar Appliances		1	14	$10,472.00		$ 10,472		-40053
	B202098	ECM08 - DHW - HPWH		1	15	$165,789.00	$1,000.00	$ 165,789		-270875
	B203098	ECM09 - DHW - Low-flow Fixtures		1	15			$ -		-83598
	B301098	ECM10 - Lighting		1	15	$26,725.00		$ 26,725		-5236

Figure 7. ELCCA Alternative 1 Input Page

Alternative 2 Input Page

Total Building Annual Utility Analysis	$ -	Water (CCF)	Electricity (KWH)
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		$ -	$ -

Note: No Units Assigned to a Component with Entries

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								Entries Below for Component Spe	
	Match Baseline: Filter to Select All & Drag Copy O14:S14 & U14:AG14							$ -		
.	A	Substructure								
	A101098	Other								
	A102098	ECM01 - Air Tightness			50	$84,196.00				-1194.257252
	A103098	ECM02 - Glazing			25	$96,207.00				11115.73396
	A201098	ECM03 - Walls			50	$137,158.00				-11942.57252
	A202098	ECM04 - Roof			50	$37,090.00				-7440.600006
	B	Shell								
	B101098	ECM05 - Res Ventilation			20	$342,000.00				-148859.0683
	B102098	ECM06 - Corridor HVAC			20	$80,000.00				-4225.900967
	B201098	ECM07 - EnergyStar Appliances			14	$10,472.00				-40053.32552
	B202098	ECM08 - DHW - HPWH			15	$165,789.00	$1,000.00			-270875.1831
	B203098	ECM09 - DHW - Low-flow Fixtures			15					-83597.71462
	B301098	ECM10 - Lighting			15	$26,725.00				-5236.448872

Figure 8. ELCCA Alternative 2 Input Page

Executive Report

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

Key Analysis Variables		**Building Characteristics**	
Study Period (years)	50	Gross (Sq.Ft)	108,921
Nominal Discount Rate	3.14%	Useable (Sq.Ft)	104,455
Maintenance Escalation	1.00%	Space Efficiency	95.9%
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)	35.8	18.1	
1st Construction Costs	$ -	$ 979,637	$ -
PV of Capital Costs	$ -	$ 2,000,284	$ -
PV of Maintenance Costs	$ -	$ 44,897	$ -
PV of Utility Costs	$ 4,808,691	$ 2,439,488	$ -
Total Life Cycle Cost (LCC)	**$ 4,808,691**	**$ 4,484,669**	**$ -**
Net Present Savings (NPS)	**N/A**	**$ 324,023**	**$ -**

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	4,230	2,146	-
% CO2e Reduction vs. Baseline	N/A	49%	
Present Social Cost of Carbon (SCC)	$ 321,188	$ 162,941	$ -
Total LCC with SCC	**$ 5,129,880**	**$ 4,647,610**	**$ -**
NPS with SCC	**N/A**	**$ 482,269**	**$ -**

Figure 9. ELCCA Executive Summary Output Page

APPENDIX C. BEPS REPORTS

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	250.3	0.0	974.3	972.1	14.8	0.0	0.0	164.0	0.0	10.2	1510.0	0.0	3895.4
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	250.3	0.0	974.3	972.1	14.8	0.0	0.0	164.0	0.0	10.2	1510.0	0.0	3895.4

TOTAL SITE ENERGY 3895.39 MBTU 37.3 KBTU/SQFT-YR GROSS-AREA 37.3 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 11686.20 MBTU 111.9 KBTU/SQFT-YR GROSS-AREA 111.9 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.47
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 36
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 180

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	250.3	0.0	974.3	967.2	14.8	0.0	0.0	164.3	0.0	10.1	1510.0	0.0	3890.7
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	250.3	0.0	974.3	967.2	14.8	0.0	0.0	164.3	0.0	10.1	1510.0	0.0	3890.7

TOTAL SITE ENERGY 3890.73 MBTU 37.2 KBTU/SQFT-YR GROSS-AREA 37.2 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 11672.20 MBTU 111.7 KBTU/SQFT-YR GROSS-AREA 111.7 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.41
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 36
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 175

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	250.3	0.0	974.3	1023.0	10.4	0.0	0.0	158.2	0.0	10.3	1510.0	0.0	3936.4
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	250.3	0.0	974.3	1023.0	10.4	0.0	0.0	158.2	0.0	10.3	1510.0	0.0	3936.4

TOTAL SITE ENERGY 3936.37 MBTU 37.7 KBTU/SQFT-YR GROSS-AREA 37.7 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 11809.10 MBTU 113.1 KBTU/SQFT-YR GROSS-AREA 113.1 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.20
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 7
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 186

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	250.3	0.0	974.3	926.6	15.0	0.0	0.0	164.8	0.0	10.0	1510.0	0.0	3850.7
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	250.3	0.0	974.3	926.6	15.0	0.0	0.0	164.8	0.0	10.0	1510.0	0.0	3850.7

TOTAL SITE ENERGY 3850.75 MBTU 36.9 KBTU/SQFT-YR GROSS-AREA 36.9 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 11552.30 MBTU 110.6 KBTU/SQFT-YR GROSS-AREA 110.6 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.37
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 36
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 172

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	250.3	0.0	974.3	943.7	14.9	0.0	0.0	164.7	0.0	9.9	1510.0	0.0	3867.6
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	250.3	0.0	974.3	943.7	14.9	0.0	0.0	164.7	0.0	9.9	1510.0	0.0	3867.6

TOTAL SITE ENERGY 3867.62 MBTU 37.0 KBTU/SQFT-YR GROSS-AREA 37.0 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 11602.90 MBTU 111.1 KBTU/SQFT-YR GROSS-AREA 111.1 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.13
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 34
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 153

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	250.3	0.0	974.3	380.6	32.6	0.0	0.0	190.5	0.0	4.1	1510.0	0.0	3342.2
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	250.3	0.0	974.3	380.6	32.6	0.0	0.0	190.5	0.0	4.1	1510.0	0.0	3342.2

TOTAL SITE ENERGY 3342.17 MBTU 32.0 KBTU/SQFT-YR GROSS-AREA 32.0 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 10026.50 MBTU 96.0 KBTU/SQFT-YR GROSS-AREA 96.0 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.10
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 117
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 67

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	250.3	0.0	974.3	973.0	10.6	0.0	0.0	158.8	0.0	2.8	1510.0	0.0	3879.4
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	250.3	0.0	974.3	973.0	10.6	0.0	0.0	158.8	0.0	2.8	1510.0	0.0	3879.4

TOTAL SITE ENERGY 3879.41 MBTU 37.1 KBTU/SQFT-YR GROSS-AREA 37.1 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 11638.20 MBTU 111.4 KBTU/SQFT-YR GROSS-AREA 111.4 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 3.90
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 35
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 307

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	250.3	0.0	831.9	1031.0	13.3	0.0	0.0	161.2	0.0	10.3	1448.0	0.0	3746.2
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	250.3	0.0	831.9	1031.0	13.3	0.0	0.0	161.2	0.0	10.3	1448.0	0.0	3746.2

TOTAL SITE ENERGY 3746.25 MBTU 35.9 KBTU/SQFT-YR GROSS-AREA 35.9 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 11238.70 MBTU 107.6 KBTU/SQFT-YR GROSS-AREA 107.6 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.43
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 32
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 181

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	250.3	0.0	974.3	972.1	14.8	0.0	0.0	164.0	0.0	10.2	503.2	0.0	2888.9
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	250.3	0.0	974.3	972.1	14.8	0.0	0.0	164.0	0.0	10.2	503.2	0.0	2888.9

TOTAL SITE ENERGY 2888.87 MBTU 27.7 KBTU/SQFT-YR GROSS-AREA 27.7 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 8666.63 MBTU 83.0 KBTU/SQFT-YR GROSS-AREA 83.0 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.47
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 36
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 180

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	250.3	0.0	974.3	972.1	14.8	0.0	0.0	164.0	0.0	10.2	1199.0	0.0	3584.8
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	250.3	0.0	974.3	972.1	14.8	0.0	0.0	164.0	0.0	10.2	1199.0	0.0	3584.8

TOTAL SITE ENERGY 3584.75 MBTU 34.3 KBTU/SQFT-YR GROSS-AREA 34.3 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 10754.30 MBTU 103.0 KBTU/SQFT-YR GROSS-AREA 103.0 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.47
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 36
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 180

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	218.8	0.0	974.3	985.8	13.8	0.0	0.0	162.7	0.0	10.7	1510.0	0.0	3875.9
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	========
MBTU	218.8	0.0	974.3	985.8	13.8	0.0	0.0	162.7	0.0	10.7	1510.0	0.0	3875.9

TOTAL SITE ENERGY 3875.93 MBTU 37.1 KBTU/SQFT-YR GROSS-AREA 37.1 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 11627.80 MBTU 111.3 KBTU/SQFT-YR GROSS-AREA 111.3 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.86
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 33
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 218

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

REPORT- BEPS Building Energy Performance WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	207.1	0.0	831.9	371.5	15.8	0.0	0.0	169.4	0.0	1.2	379.1	0.0	1976.1
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	207.1	0.0	831.9	371.5	15.8	0.0	0.0	169.4	0.0	1.2	379.1	0.0	1976.1

TOTAL SITE ENERGY 1976.08 MBTU 18.9 KBTU/SQFT-YR GROSS-AREA 18.9 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 5928.25 MBTU 56.8 KBTU/SQFT-YR GROSS-AREA 56.8 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 0.75
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 8
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 58

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.