Othello SEOC Exemplary Building Energy Study

ECOTOPE

Final Report

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SECTION I. SUMMARY AND PROJECT DESCRIPTION

Project description

The Othello Square Affordable Homeownership Building is a proposed affordable housing development located in the Rainier Valley neighborhood of South Seattle. The project consists of 5 residential levels above grade, over 1 level of below grade parking. The building area breakdown is shown in Table 1:

Table 1. Gross Floor Area

SPACE DESCRIPTION	MODELED AREA (SF)	BUILDING AREA (SF)
RESIDENTIAL	59,076	59,076
CLUB ROOM	1,110	1,110
CIRCULATION - CORRIDORS	6,121	6,121
CIRCULATION - STAIRS	1,748	1,748
CIRCULATION - ELEVATOR	451	451
LOBBY	1,548	1,548
BOH (MECH, ELEC, TRASH, STORAGE)	2,151	2,952
RETAIL	-	1,898
GARAGE	-	9,397
TOTAL	72,205	84,301

The garage area, unconditioned back of house spaces located in the garage level, and retail space located on Level 1 are not included in the building energy simulation model per assumption in the contract. Only residential areas including living units, lobby, amenity space, stairs, corridors, and conditioned back of house spaces were analyzed in this study.

The residential units are heated with electric resistance heaters with the main living spaces controlled by a 7-day programmable thermostat. Ventilation is provided with a continuously operating whole house exhaust fan in the bathroom. Makeup air is provided via operable windows and trickle vents.

Residential corridors are unconditioned and naturally ventilated via operable windows. Amenity spaces, including the Main Lobby and Club Room are conditioned with ductless split system heat pumps. Common residential amenity spaces are ventilated with an ERV system which also supplies the code-required ventilation to the Level 1 residential corridor. Domestic hot water (DHW) is provided with central CO_2 heat pump water heaters. DHW storage tanks are located in insulated rooms on the roof with the outdoor units located directly outside adjacent to the storage tank room. The final mechanical construction drawings are dated 6/14/2019.

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
1	Naturally Ventilated and Unconditioned Corridor	Packaged Rooftop Heat Pump
2	Common Space DHP + ERV	Packaged Rooftop Heat Pump
3	EnergyStar Appliances	Standard
4	Heat Pump Dryers	Standard
5	Stairwell & Corridor Lighting Controls	Stair Occ sensor, Corridor None
6	CO2 Heat Pump Water Heater	Electric Water Heater
7	Low-flow Fixtures	Standard
8	High-efficiency Elevator	Standard
9	Airtightness 0.25 CFM/SF @ 75Pa	Airtightness 0.3 CFM/SF @ 75Pa
10	Improved Fenestration	Standard
11	Efficient whole House Fan	Standard

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. On-site supply of renewable energy
2. Reduced lighting power

As part of prescriptively complying with the 2015 Seattle Energy Code, these two C406 measures were included in the baseline model. Per C406 and C411, the PV capacity is assumed to 25 kW (see Appendix A for details). Lighting power density (LPD) for interior spaces was reduced by 25% over the maximum allowed code value. The overall baseline energy consumption is 720,470 kWh/year and the proposed energy consumption is 421,860 kWh/year. PV generated electricity is 26,676 kWh/year.

The energy analysis was performed using a proportionate attribution of interactive effects. The baseline annual energy use is 34.1 (2,458,964kBtu/72,205ft^2/yr), 32.8 kBtu/ft^2/yr with solar PV. The total energy consumption of the proposed model is 19.9 (1,439,808kBtu/72,205ft^2/yr), 18.7 kBtu/ft^2/yr with solar PV. Annual energy savings are 14.2 kBtu/ft^2/yr or 41%. These EUI values do not include energy usage or area of garage.

SECTION II. ENERGY CONSERVATION MEASURES

The eleven energy conservation measures (ECM) were selected for their combined ability to reduce the building energy usage below an EUI of 20 kBtu/sf/yr.

ECM Summary Table

Energy analysis was performed following the modeling method used for Washington State 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 modeled with the baseline plus an individual ECM is a non-interactive run. All of the ECMs included in the same model 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 were used to discuss the actual savings per ECM, since in reality all the measures are being performed together and not just one individually. This method accounts for the effect of the ECMs on each other. Table 3 shows a summary of each ECM and the noninteractive and proportional annual energy savings, associated energy cost savings assuming 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 ANNUAL KWH SAVINGS	PROPORTIONATE ANNUAL KWH SAVINGS	ANNUAL SAVINGS	BASELINE COST	INCREMENTAL COST	INCREMENTAL MAINTENANCE COST
1	Natural Corridor Ventilation, Uncond.	Remove space conditioning & ventilation fan power	13,990	11,852	$ 1,067	NA	$ 1,400	$ -
2	DHP + ERV for Common & Amenity	Mitsubishi Mini-split DHP + ERV w/ min 0.69 eff.	10,080	8,540	$ 769	$ 30,000	$ 21,300	$ -
3	EnergyStar Appliances	Unit EPD: 1.52 -> 1.35W/sf, Reduced DHW by ES app	35,040	29,686	$ 2,672	$ 120,750	$ 43,200	$ -
4	Heat Pump Dryers	EPD: 1.52 -> 1.40W/sf Misc. Fan: 2,720 -> 2,154kWh/yr Infiltration: 0.17 -> 0.15ACH	12,020	10,175	$ 916	$ 49,200	$ 42,900	$ (3,400)
5	Lighting Controls	Occ sensor reduces corridor LPD[1] by 25% Daylighting for corridor and stairs	14,510	12,293	$ 1,106	NA	$ 9,000	$ -
6	CO2 HPWH	System COP: 3.0	181,270	153,571	$ 13,821	$ 42,700	$ 75,740	$ 1,000
7	Low-flow fixture	Shower: 1.5 GPM Faucet: 1.0 GPM	52,530	44,495	$ 4,005	NA	$ -	$ -
8	High-efficiency elevator	Reduce direct load: 4.12 -> 0.82 MWh/yr	3,330	2,821	$ 254	$ 177,020	$ 70,375	$ -
9	Airtightness	Unit ACH: 0.17 -> 0.16 Other ACH: 0.15 -> 0.12	1,700	1,440	$ 130	NA	$ 15,000	$ -
10	Improved Fenestration	Non-metal: 0.3 -> 0.263, Metal: 0.383 -> 0.354	10,220	8,658	$ 779	150,000	$ 100,000	$ -
11	Efficient Whole house fan	Fan power: 0.714 W/cfm -> 0.13 W/cfm	17,810	15,080	$ 1,357	NA	$ 11,930	$ -
ALL	All ECMs		351,010	298,610	$ 26,875		$ 390,845	$ (2,400)

[1] Lighting Power Density (W/ft^2)

The ECMs were selected for their combined ability to reduce the project's EUI to under 20 kBTU/sf/yr. Each ECM may also have additional impact on the building health, comfort, and longevity.

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	Natural Corridor Ventilation, Unconditioned	-	-	+	+	+	+
2	DHP + ERV for Common and Amenity	+	+	N	N	N	N
3	EnergyStar Appliances	N	N	N	N	N	N
4	Heat Pump Dryers	+	+	-	N	N	+
5	Lighting Controls	N	N	+	-	-	-
6	CO2 HPWH	N	N	-	N	-	-
7	Low-flow fixture	N	-	N	N	N	N
8	High-efficiency elevator	N	N	+	+	+	+
9	Airtightness	+	+	N	N	N	N
10	Improved Fenestration	+	+	N	+	+	+
11	Efficient whole house fan	N	N	+	+	+	N

ECM Descriptions

ECM1: Naturally Ventilated and Unconditioned Corridor

Reliance on natural ventilation assumes that the occupants will open windows if corridors are stuffy or too warm and close windows if corridors get too drafty or cold. Modeling assumes that this operation results in a code-recommended outdoor airflow rate by operable windows. For the energy saving calculation, the system supply fan energy is reduced from 0.8 kW/cfm to 0 kW/cfm. This change derives fan energy saving by the natural ventilation in corridors.

In the baseline design, ventilation in all corridors is conducted by a packaged rooftop heat pump (PRHP) located on the roof per SEC 2015 Table C407.5.1(3) and Table C407.5.1(4). 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.

Table 5. Variable Changes of ECM1

	BASELINE	ECM1
SYSTEM SUPPLY FAN POWER	0.8 W/cfm	0 W/cfm

Table 6. Change in EUI by End Use as a Result of ECM1

EUI (KBTU/SF)	BASELINE	ECM1	DIFFERENCE
HEATING	6.88	7.01	+0.14
COOLING	0.11	0.04	-0.07
FAN	2.65	1.92	-0.73

The lack of heating and cooling in the corridors affects the heating and cooling energy usage of the residential units, shown in Table 6. Although there is a 0.14 kBtu/sf increase in heating energy, there is a decrease of 0.07 kBtu/sf cooling and 0.73 kBtu/sf fan energy. Overall switching to unconditioned corridors has a net saving of 0.66 kBtu/sf.

Naturally ventilated and unconditioned corridors are expected to save 11,852 kWh annually over the baseline PRHP. These energy savings translate to $1,067/year in energy bill savings, assuming an electricity rate of $0.09/kWh. The incremental cost of $1,400 assumes adding operable functionality to 19 corridors windows at $600/window and removing the cost of the PRHP at approximately $10,000.

ECM2: Common Space DHP + ERV

The common space for this ECM accounts for the residential lobby, corridor on the first floor, and amenity space. Heating, cooling, and ventilation are provided via PRHP in the baseline design in accordance with Table SEC 2015 Table C407.5.1(3) and Table C407.5.1(4).

The ECM measure replaces the common space PRHP with mini-split heat pumps to provide heating and cooling and energy recovery ventilators (ERVs) to provide ventilation. The fan in the heat pump shall cycle on with the load in the space and off when the space temperature is met. Heating/cooling efficiency and part load curve from the manufacturer were applied to the simulation.

The ERV runs continuously and ramps up to design cfm on call from the CO2/occupant sensor. The ERV efficiency is assumed 0.69. In the simulation, the ERV fan friction schedule based on the occupancy schedule was applied to represent the ERV control.

Table 7. ERV fan schedule

HRS	OCCUPANCY SCHEDULE	CALCULATED ERV CFM	ERV FAN SCHEDULE
1	0	220	0.5
2	0	220	0.5
3	0	220	0.5
4	0	220	0.5
5	0	220	0.5
6	0	220	0.5
7	0.1	242	0.55
8	0.2	264	0.6
9	0.2	264	0.6
10	0.1	242	0.55
11	0.05	231	0.525
12	0.05	231	0.525
13	0.05	231	0.525
14	0.05	231	0.525
15	0.05	231	0.525
16	0.05	231	0.525
17	0.2	264	0.6
18	0.3	286	0.65
19	0.4	308	0.7
20	0.5	330	0.75
21	0.3	286	0.65
22	0.3	286	0.65
23	0.1	242	0.55
24	0.1	242	0.55

Calculated based on ERV-1, high cfm: 440 cfm.
ERV runs continuous at ½ speed and ramps up to high cfm on CO2 sensor.
$Calculated\ ERV\ cfm\ = high\ cfm \times occ\ friction + low\ cfm \times (1 - occ\ fiction)$

Table 8. Variable Changes of ECM2

	BASELINE	ECM2
SYSTEM SUPPLY FAN POWER	0.8 W/cfm	0.06 W/cfm
HEATING EIR	0.243	0.236
COOLING EIR	0.240	0.239
PERFORMANCE CURVE	eQUEST default	Mitsubishi performance curve
ERV EFFICIENCY	NA	0.69
EXHAUST FAN (ERV) CONTROL	Always On	ERV fan schedule

Replacing the common space PRHP with a mini-split DHP and ERV is expected to save 8,540 kWh/year, resulting in $769/year in electricity cost savings. The incremental cost assumes replacing a $30,000 PRHP with a $10,000 DHP and $41,300 ERV.

ECM3: Energy Star Appliances

Energy Star Appliances for refrigerator, dishwasher, clothes washer, and electric stove are installed to all 68 dwelling units in the ECM3.

Energy Star appliances can save energy in two area: electricity and hot water. Equipment power density (EPD) savings by Energy Star Appliances are calculated based on 'Building America Research Benchmark Definition[2]. To estimate energy savings for the appliances, different appliance factors were applied to the annual electric loads of the benchmark. The annual electric loads were multiplied by 0.9 to express "new" appliances in the baseline and multiplied by 0.68 to express "Energy Star" appliance.

$$Baseline\ =\ Benchmark\ \times 0.9$$

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

Table 9. Annual appliance energy use

	BENCHMARK (KWH/YR)	BASELINE (NEW APPLIANCE FACTOR = 0.9, KWH/YR)	ENERGY STAR (ES APPLIANCE FACTOR = 0.68, KWH/YR)
REFRIGERATOR	669	602	455
DISHWASHER	163	147	111
CLOTHES WASHER	83	75	57
COOKING (ELECTRIC STOVE)	478	431	326

Energy savings from heat pump dryers are not included in this ECM3, as they are accounted for in ECM4.

Since Energy Star appliances use less hot water, Domestic Hot Water (DHW) demand savings by Energy Star dishwasher and clothes washer are considered in ECM3. DHW process flow GPM is adjusted to represent the hot water demand saving by Energy Star dishwasher and clothes washer.

Table 10. Energy Savings by Energy Star Appliances

	ITEMS	BASELINE	ECM3
ELECTRICAL SAVINGS	**Refrigerator**	602 kWh/yr	455 kWh/yr
	Dishwasher	147 kWh/yr	111 kWh/yr
	Clothes Washer	75 kWh/yr	57 kWh/yr
	Cooking (electric stove)	431 kWh/yr	326 kWh/yr
HOT WATER DEMAND SAVINGS	**Hot water demand (dishwasher)**	1290 gal/yr/unit	860 gal/yr/unit
	Hot water demand (clothes washer)	2436 gal/yr/unit	1127 gal/yr/unit

Table 11. Variable Changes of ECM3

	BASELINE	ECM3
RESIDENTIAL UNIT EPD	1.52 W/sf	1.35 W/sf
DHW PROCESS FLOW	12.64 gpm	11.68 gpm

[2] Hendron, R. January 2008. Building America Research Benchmark Definition. National Renewable Energy Lab. Contract # DE-AC36-99-GO10337. Table 12 on page 21.

Energy Star appliances are expected to save 29,686 kWh/year and $2,672/year in electricity cost. The incremental cost of Energy Star appliances over the baseline is dependent on appliance type and totals to $29,000 for appliances in all 68 units.

ECM4: Heat Pump Dryers

There are three energy saving impacts that can be considered from applying heat pump dryers: 1) energy-efficient appliance 2) laundry fan energy 3) reduction of infiltration. The lack of venting conditioned air reduces thermal gains and the need for makeup heating energy. The resulting savings are relatively minor and were not included in the model.

Energy-efficient appliance

The annual energy savings were derived from the Clothes Dryers Workbook from the Reginal Technical Forum (RTF) [3]. 'Raw' annual energy use data from the RTF is based on single-family house measurement. Therefore, the 'Raw' data was adjusted by the metering correction and occupancy scaling ratio. Multi-family occupancy 2.3 is the occupancy per unit calculated based on the unit number and estimated occupancy per unit from RASS occupancy data for multifamily homes[4]. Single family occupancy 2.7 is an average occupancy from the Residential building stock assessment: Metering study[5]. As a result, the annual energy saving by the heat pump dryers per unit is 124 kWh/yr.

Table 12. Annual Energy Use Calculation of Dryers

	SINGLE-FAMILY		**MULTIFAMILY**
	RTF "Raw"	Corrected*	Corrected and Occupancy Adjusted**
	Dryer Use	Dryer Use	Dryer Use
TIER	kWh/yr	kWh/yr	kWh/yr
CONVENTIONAL, NON-ENERGY STAR, VENTED	831	725	625
CONVENTIONAL, ENERGY STAR, VENTED	816	712	614
HEAT PUMP/HYBRID DRYER FOR BASELINE (USE WHIRLPOOL DUET), VENTLESS	666	581	501

$$*\mathbf{Correction\ ratio} = \frac{\mathbf{RBSA\ metering\ baseline\ dryer\ use}}{\mathbf{RTF\ Baseline\ use}} = \frac{\mathbf{725 kWh/yr}}{\mathbf{831\ kWh/yr}} = \mathbf{0.87}$$

$$**\mathbf{Occupancy\ scaling\ ratio} = \frac{\mathbf{Multi\ family\ occupancy}}{\mathbf{Single\ family\ occupancy}} = \frac{\mathbf{2.3}}{\mathbf{2.7}} = \mathbf{0.862}$$

[3] https://rtf.nwcouncil.org/measure/clothes-dryers-sf-mh-and-mf-unit, v3.0, SavingsData&Analysis

[4] Kruis, N., Wilcox, P. B., Lutz, J., & Barnaby, C. (2017). Development of Realistic Water Draw Profiles for California Residential Water Heating Energy Estimation. In Proceedings of the 15th IBPSA Conference San Francisco, CA, USA, Aug. 7–9. Table 8.

[5] Larson, B., Gilman, L., Davis, R., Logsdon, M., Uslan, J., Hannas, B., ... & Kvaltine, N. (2014). Residential building stock assessment: Metering study. Retrieved August, 25, 2014. Table 15.

Laundry fan energy

Since heat pump dryers do not require dryer venting, laundry fans are not needed. The laundry fan energy can be considered energy savings.

Table 13. Annual Energy-Saving Calculation from Laundry Fans

USE	CFM	QUANTITIES	BASELINE WATT	HRS/DAY	ANNUAL BASELINE (KWH/YR)	ANNUAL PROPOSED (KWH)
LAUNDRY FAN	130	68	35.7	0.64	566	0

Infiltration reduction

Infiltration rate increases during the laundry fan operation. To capture the energy savings from infiltration reduction, the increased infiltration air change per hour (ACH) from the conventional dryers is calculated based on annual laundry loads, dryer cycle duration, and outdoor airflow rate. Then, the increased infiltration is applied to the residential units of the baseline model.

Table 14. Infiltration Changes from Laundry Fans

LOADS/ YEAR [6]	CFM/ DRYER [7]	DRYER CYCLE DURATION (MIN)	ADDED INFILTRATION/ DRYER (FT^3)	AVERAGE DWELLING UNIT VOLUME (FT^3)	ACH INCREASE
233	130	60	1,816,606	9,077	0.023

Table 15. Variable Changes of ECM4

	BASELINE	ECM4
RESIDENTIAL UNIT EPD	1.52 W/sf	1.40 W/sf
RESIDENTIAL LAUNDRY FAN ENERGY	566 kWh/yr	0 kWh/yr
RESIDENTIAL UNIT INFILTRATION	0.17 ACH	0.15 ACH

Heat pump dryers are expected to save 10,175 kWh/year and $916/year. The incremental cost of $42,900 is the cost difference of heat pump dryers over standard dryers, including the reduced cost of not venting or soffiting. The incremental maintenance cost is -$3,400 as there is no longer a need to clean out the dryer vent annually, estimated at $50/unit.

ECM5: Common Space Lighting Controls

Common space in ECM5 indicates residential lobby, hall on the first floor, corridors, and stairs. Occupancy sensors and daylight sensors are suggested for the ECM5. eQUEST default daylight control scenario (Switch: 2 Level + Off) is set to the common spaces for ECM5. A 25% reduction in LPD was applied to both stairways and corridors, in compliance with the C406 reduced LPD measure selected. An additional reduction in LPD was applied to stairways in compliance with section C405.2.5 which requires lighting control for stairways. ECM 5 then applies an LPD reduction for corridor lighting control. Lighting controls are estimated as a 35% reduction in LPD for stairways and 25% reduction for corridors per EnergyStar

[6] NEEA Clothes Dryer Field Study, Table 45, https://neea.org/resources/rbsa-laundry-study, 2014
[7] https://rtf.nwcouncil.org/measure/clothes-dryers-sf-mh-and-mf-unit, 'SEEM HVAC' tab

MFHR Simulation guidelines[8]. Then, in the eQUEST, the daylighting controls are applied to corridors, lobby, and stairway which have windows. Table 16 shows the decreases in LPD for stairways and corridors.

Table 16. Variable Changes of ECM5

	SEC 2015 CODE REQUIREMENT	C406 – 25% BOTH	BASELINE - C405.2.5 – 35% STAIRWAYS	ECM5 – 25% CORRIDOR
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

Adding occupancy and daylight sensors reduces the time and amount of lights that are on and results in energy savings of 12,293 kWh/year and electricity savings of $1,106/year. The $9,000 incremental cost of adding these sensors considers the approximate number of sensors required, purchase cost per sensor, and install cost assuming an additional 1 hour install time per sensor.

ECM6: CO2 Heat Pump Water Heater

Domestic hot water savings are attributed to the heating equipment efficiency in ECM6. A CO2 heat pump water heater utilizes a heat pump 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 measured value from previous Ecotope projects[9].

Energy savings are determined from a manual engineering calculation. Distribution pipe heat loss (assumed 60W per unit) was included for both the baseline and ECM6 based on research that Ecotope has performed on multifamily buildings with central recirculation systems. The domestic hot water process flow (GPM) was adjusted between baseline and proposed energy model to achieve the results from the manual calculation. No hot water demand savings were taken for service water heating under ECM6 – both baseline and ECM6 are 19.34 gal/person/day (refer to ECM7).

The CO2 heat pump water heater has the most significant energy savings at 153,571 kWh/year. These energy savings expect to reduce electricity costs by $13,821/year. Replacing the central electric domestic hot water plant with Sanden HPWHs is expected to cost an additional $75,740. Associated maintenance costs are conservatively estimated at $1,000/year to clean the HPWHs coils.

[8] 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

[9] Elizabeth James: https://ecotope.shinyapps.io/MFSandenRetrofit/

Table 17. HPWH 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	68	dwelling units
# of people	158	persons
Volume of Storage	714	Gal
Baseline DHW Heating Efficiency (%/h)	0.338	%/h
Baseline DHW Heating Efficiency (SL)	**1055**	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	**19.34**	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	**1,370,863**	gal/yr
Proposed HW Demand w/ Energy Star	**1,062,434**	gal/yr
Baseline DHW Energy Consumption (w/ recirc)	**927,694,982**	BTU/yr
Proposed DHW Energy Consumption (w/ recirc)	**748,497,971**	BTU/yr
Savings	**179,197,011**	BTU/yr

ECM7: Low-Flow Fixtures

Energy savings 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 and experts' knowledge. 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:

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

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

Low-flow fixtures are the second most energy saving measure and are expected to save 44,495 kWh/year and $4,005/year. There is no incremental cost associated with low-flow fixtures.

Table 18. Low-flow Fixtures DHW Calculation

DHW Calcs (EnergyStar appliances)		
Temp		
Entering water temperature (F)	50	F
Hot water setpoint (F)	120	F
Ambient air temperature (F)	67.5	F
# of Units	68	dwelling units
# of people	158	persons
Volume of Storage	714	Gal
Baseline DHW Heating Efficiency (%/h)	0.338	%/h
Baseline DHW Heating Efficiency (SL)	**1055**	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	**19.34**	GPD/person
Fixture	GPM/Fixture	
Faucets	1.00	
Shower Heads	1.50	
Proposed HW Demand	**19.34**	GPD/person
Energy Star Dishwasher Savings		
Baseline	1290.0	gal/year/unit
Proposed	860.0	gal/year/unit
Savings	430	gal/year/unit
Savings	**1.18**	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)	1127.4	gal/year/unit
Savings	1309	gal/year/unit
Savings	**3.59**	gal/day/unit
Baseline HW (In-unit)	6.67	gal/day/unit
Baseline HW Demand	**1,370,863**	gal/yr
Proposed HW Demand w/ Energy Star	**1,252,638**	gal/yr
Baseline DHW Energy Consumption (w/ recirc)	**927,694,982**	BTU/yr
Proposed DHW Energy Consumption (w/ recirc)	**859,006,373**	BTU/yr
Savings	**68,688,609**	BTU/yr

ECM8: High-Efficiency Elevator

The energy use of the baseline elevator was calculated based on default elevator energy usage table from the Energy Star MFHR Simulation Guidelines. The Othello building has one elevator and 68 dwelling units. Therefore, annual energy consumption is 4.12 MWh per the table. 80% of energy savings by the high-performance elevator was suggested for the ECM8 - refer to high-performance elevator literature[10].

Table 19. Variable Changes of ECM8

	BASELINE	ECM8
ELEVATOR ENERGY USE (DIRECT LOAD)	4.12 MWh	0.82 MWh

The high-efficiency elevator chosen is a regenerative model, rather than hydraulic, and has energy savings of 2,821 kWh/year. The high incremental cost of $70,375 is offset not only by energy savings, but through other improvements as well. The model selected requires less maintenance, has increased durability, and operates faster than the baseline hydraulic elevator.

ECM9: Improved Airtightness

The baseline building airtightness level in accordance with SEC2015 C402.5.1.2 is 0.30 cfm/sf at a pressure differential of 0.3 in. w.g. An airtightness level of 0.25 cfm/sf at 0.3 in. w.g. was applied for ECM9. The air leakage rates were converted to air change per hour (ACH) for modeling following Table C407.5.1(1) in the SEC2015.

Table 20. Variable changes of ECM9

	BASELINE	ECM9
INFILTRATION (ACH) FOR DWELLING UNIT	0.17 ACH	0.14 ACH
INFILTRATION (ACH) FOR OTHERS	0.15 ACH	0.12 ACH

Improving the building airtightness is expected to save 1,440 kWh/year. The cost of improving the building airtightness is challenging to quantify but was estimated at $15,000 for the whole building based on input from envelope consultants and general contractors on past buildings.

[10] http://e3tnw.org/ItemDetail.aspx?id=471

ECM10: Improved Fenestration

The baseline building fenestration U-value and SHGC are determined from 2015 Seattle Energy Code Table C402.4. The proposed design includes replacing vinyl windows with fiberglass windows and improving storefront windows. The area-weighted average values were calculated for U-value and SHGC.

Table 21. Variable changes of ECM10

	BASELINE	ECM10
NON-METAL WINDOW U-VALUE	U-0.300	U-0.263
METAL WINDOW U-VALUE (STOREFRONT)	U-0.383	U-0.354
ENTRANCE DOOR	Residential: U-0.600 Others: U-0.600	Residential: U-0.29 Others: U-0.529
SHGC	SEW: SHGC-0.35, N: SHGC-0.53	SEW: SHGC-0.321, N: SHGC-0.288

Improving the building fenestration by replacing vinyl windows with fiberglass and selecting improved storefront windows is expected to save 8,658 kWh/year and will save approximately $779 in electricity costs annually. Fiberglass windows were selected for their lower environmental impact as they require less energy to manufacture, yield higher energy savings, and improved durability.

The cost of improving the non-metal fenestration over the $150,000 vinyl baseline windows is an additional $100,000. Per the window manufacturer, the builder grade vinyl windows are not as durable and last 7-10 years before performance drops off. The fiberglass windows from the same manufacturer have a 20-year performance warranty and can be expected to last well beyond that.

ECM11: Efficient whole house fan

The whole house fan power in the baseline model is set to 0.714 W/cfm in accordance with SEC 2015 Table C403.2.11.4. The selected energy saving efficient fan (Panasonic WhisperGreen FV-05-11VKSL1: 0.13 W/cfm) is applied as a whole house fan measure in the proposed design.

Table 22. Variable changes of ECM11

	BASELINE	ECM11
WHOLE HOUSE FAN POWER	0.714 W/cfm	0.13 W/cfm

Improving the whole house fan is expected to save 15,080 kWh/year and $1,357 in annual energy savings. From the general contractor, improving the whole house fan from baseline to the Panasonic WhisperGreen has an incremental cost of $11,390.

SECTION III. ANALYSIS OF OVERALL PROJECT

Life Cycle Cost Analysis

The Washington State Life Cycle Cost Analysis Tool Version August 2019 was used to perform a life cycle cost analysis per energy conservation measure. From this analysis it is possible to determine the cost effectiveness of each ECM over the anticipated 50-year lifespan of the building. The summary of the analysis in Table 23 shows the net present savings (NPS) for each measure. A positive NPS indicates the ECM is energy saving and cost saving; whereas, a negative NPS predicts that ECM will likely cost more than the baseline over the building's lifespan. The most significant cost saving measure is ECM6 – CO2 Heat Pump Water Heater. This measure alone can be expected to save $486,640. The least cost-effective measure is ECM9 – Air Tightness. The lack of payoff for this measure is due to the high incremental first construction costs and the low energy savings.

Table 23: Washington State Life Cycle Cost Analysis Summary

	EUI (KBTU/SF)	1ST CONSTRUCT. COSTS	PV OF CAPITAL COSTS	PV OF MAINT. COSTS	PV OF UTILITY COSTS	TOTAL LIFE CYCLE COST	NET PRESENT SAVINGS
BASELINE	34.1	$ -	$ -	$ -	$3,442,719	$3,442,719	N/A
ECM1	33.4	$1,400	$2,346	$ -	$3,386,122	$3,388,469	$ 54,250
ECM2	33.6	$21,300	$53,776	$ -	$3,401,938	$3,455,714	$(12,995)
ECM3	32.4	$43,200	$182,393	$ -	$3,300,962	$3,483,355	$ (40,637)
ECM4	33.5	$42,900	$155,112	$(183,904)	$3,394,092	$3,365,299	$77,419
ECM5	33.4	$9,000	$37,999	$ -	$3,390,045	$3,428,044	$14,675
ECM6	25.5	$75,740	$191,220	$55,488	$2,709,371	$2,956,079	$486,640
ECM7	31.6	$ -	$ -	$ -	$3,230,203	$3,230,203	$212,516
ECM8	33.9	$70,375	$117,950	$ -	$3,429,244	$3,547,194	$(104,476)
ECM9	34.0	$15,000	$15,000	$ -	$3,435,843	$3,450,843	$(8,124)
ECM10	33.6	$100,000	$125,168	$ -	$3,401,374	$3,526,542	$(83,823)
ECM11	33.2	$ 11,930	$60,494	$ -	$3,370,665	$3,431,159	$11,560
ALL	**19.9**	**$390,845**	**$941,459**	**$(128,416)**	**$39,892,577**	**$40,705,620**	**$607,005**

Building Energy Use

The modeled baseline and proposed energy use index (EUI) by end use are shown in Table 24. The total energy consumption of the proposed model is 19.9 (1,439,808kBtu/72,205ft^2/yr). The baseline annual energy use is 34.1 (2,458,964kBtu/72,205ft^2/yr). The annual savings are 14.2 kBtu/ft^2/yr or 41%. The largest energy reduction is in domestic water heating. Low-flow fixtures and CO_2 HPWHs reduce the EUI by 9.7 kBTU/sf/yr over baseline.

Table 24: EUI comparison (kBTU/sf/yr)

EUI	MODELED BASELINE	MODELED PROPOSED	REDUCTION %
DHW	12.85	3.14	76%
LIGHTS	2.31	1.60	31%
HEAT	6.87	7.01	-2%
PLUGS	9.26	7.45	20%
FAN	2.65	0.72	73%
COOL	0.11	0.03	73%
SUM (KBTU/SF/YR)	34.06	19.94	41.4%

The donut charts in Figure 1 show the reduction of EUI by end use category. 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.

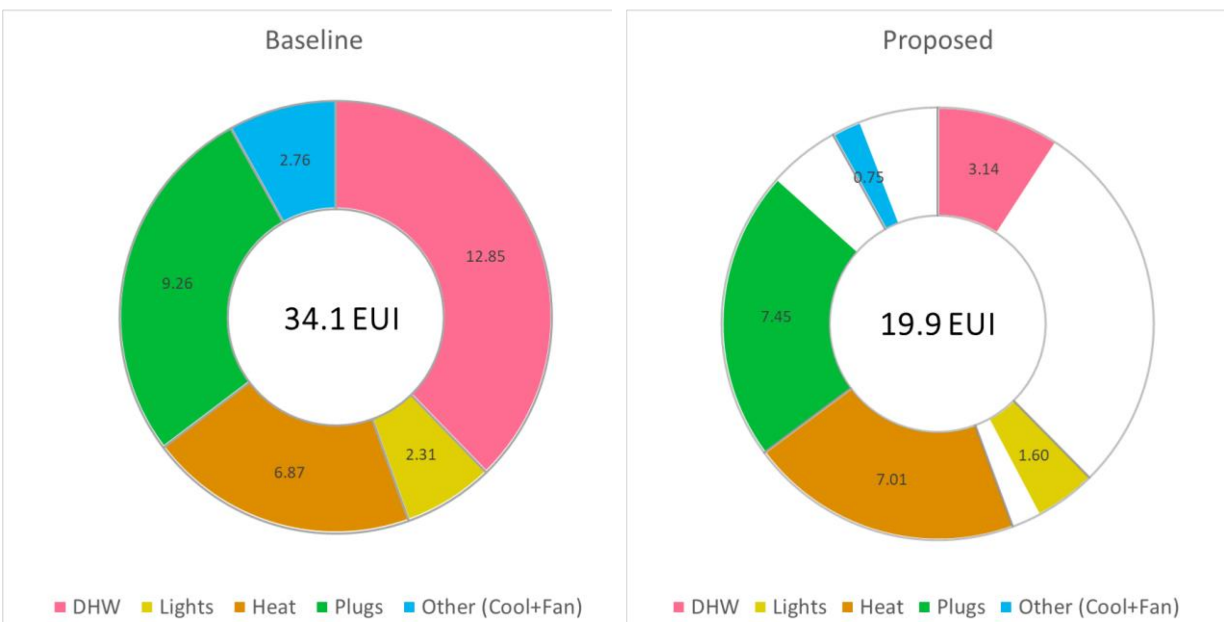

Figure 1: EUI comparison between Baseline and Proposed Building Models (w/o PV generation)

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 25,000 kWh each month.

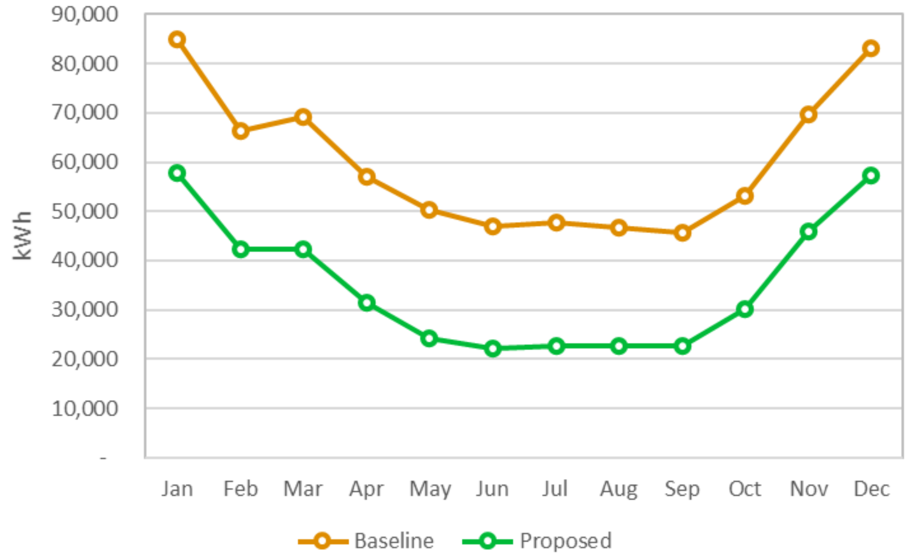

Figure 2: Total monthly kWh consumption

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 25 shows the energy usage by end use in the parking garage, with a detailed explanation in the sections below.

Table 25: Energy Consumption for Proposed Garage

ESTIMATION FOR GARAGE	PROPOSED ENERGY (KWH)
GARAGE LIGHTING (KWH/YR)	10,372
GARAGE FAN (KWH/YR)	1,909

The total parking garage energy consumption of 12,281 kWh/yr increases the proposed modeled building EUI by 0.56 kBtu/sf/yr.

Garage Lighting Energy

Estimated floor area for the proposed garage is 9,397 sf. The interior lighting power allowances for interior parking garage is 0.14 in accordance with SEC2015-Table C405.4.2(2). The 10% of lighting energy savings due to the occupancy sensor (OS) refer to Energy Star Multifamily High-Rise Program Simulation Guidelines V1.0 R03 Table 3.

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

$$9{,}397\ \text{sf} \times 0.14\ \text{W/sf} \times (1 - 0.1) \times 8760\ \text{hrs} = 10{,}372\ \text{kWh}$$

Garage Fan Energy

In the proposed design, garage ventilation is performed by 7,600 cfm, 1.5 HP exhaust fan (Greenheck SBE-3H36-15). The control modulates 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 fan is assumed to operate 100 percent in the morning and evenings (4 hrs.)

$$\left\{1.5\ hp\ \times 735.5\frac{W}{hp}\times 4\ hrs\ \times 365\frac{days}{yr}\times\frac{1\ kW}{1000\ W}\right\}+\left\{1.5\ hp\ \times 735.5\frac{W}{hp}\times(24-4)\ hrs\ \times 365\frac{days}{yr}\times\frac{1\ kW}{1000\ W}\times\left(\frac{7600\ cfm\times(\frac{20}{60})}{7600\ cfm}\right)^3\right\}=1{,}909\ \text{kWh/yr}$$

SECTION IV. POST-CONSTRUCTION MONITORING RECOMMENDATIONS

To ensure maximum long-term effectiveness in energy efficiency, thermal comfort, and indoor air quality, post-construction monitoring can be performed. Two areas where monitoring would be especially beneficial are in corridors and on the heat pump water heaters (HPWH).

Installing temperature and CO2 sensors in the corridors would allow for long-term monitoring of corridor temperature and indoor air quality. Naturally ventilated and unconditioned corridors are potentially significant energy savers compared to the baseline mechanically ventilated and conditioned corridor; however, popular belief is that removing mechanical ventilation and heating from the corridor will lead to a less comfortable indoor environment. Monitoring corridor temperature and CO2 levels would be beneficial not only for this project but could also potentially prove that naturally ventilated and unconditioned corridors substantially reduce energy usage, initial install and maintenance cost, and do not negatively impact the quality of the indoor environment. Veris wireless combined CO2/temperature sensors could be installed in three of the corridors. These sensors cost about $500 each. 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 $30,000.

The functioning of the CO2 Sanden HPWHs is 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.

SECTION V. APPENDICES

Appendix A. PV Calculation

SEC C406.5 requires on-site renewable energy system shall not be less than 0.25 watts per square foot of conditioned space. C411 requires new building larger than 5000 square feet of gross conditioned floor area shall include a renewable generation system of at least 70 Watts per 1000 square feet of conditioned space.

$$\text{C406.5 required PV capacity} = 74103 \times 0.25 = 18{,}526\ \text{W}$$

$$\text{C411 required PV capacity} = \frac{74103}{1000} \times 70 = 5{,}187\ \text{W}$$

$$\text{Total required PV capacity} = 23.7\ kW\ \approx 25\ kW$$

PVWatts[11] calculator was used to obtain the PV generation energy. The result of the calculation is as follow. Assumption for performance value and PV system array are also shown in the result. As a result, 25kW PV system of the building can generate 26,676 kWh/year.

[11] https://pvwatts.nrel.gov/pvwatts.php

NREL

NATIONAL RENEWABLE ENERGY LABORATORY

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at https://sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data for nearby , and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

26,676 kWh/Year*

System output may range from 25,457 to 27,575 kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	1.54	950	74
February	2.50	1,382	107
March	3.44	2,073	161
April	5.01	2,823	219
May	5.45	3,181	247
June	5.95	3,228	250
July	6.41	3,511	272
August	6.19	3,386	262
September	4.69	2,578	200
October	2.91	1,718	133
November	1.71	1,025	79
December	1.31	821	64
Annual	**3.93**	**26,676**	**$ 2,068**

Location and Station Identification

Requested Location	7343 MARTIN LUTHER KING JR WAY S SEATTLE, WA
Weather Data Source	Lat, Lon: 47.53, -122.3 1.0 mi
Latitude	47.53° N
Longitude	122.3° W

PV System Specifications *(Residential)*

DC System Size	25 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	20°
Array Azimuth	180°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2

Economics

Average Retail Electricity Rate	0.078 $/kWh

Performance Metrics

Capacity Factor	12.2%

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	166.6	0.0	668.9	493.8	8.0	0.0	0.0	191.0	0.0	2.6	928.0	0.0	2458.9
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	166.6	0.0	668.9	493.8	8.0	0.0	0.0	191.0	0.0	2.6	928.0	0.0	2458.9

TOTAL SITE ENERGY 2458.94 MBTU 36.1 KBTU/SQFT-YR GROSS-AREA 36.1 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7376.82 MBTU 108.2 KBTU/SQFT-YR GROSS-AREA 108.2 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.88
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 23
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 142

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	166.6	0.0	668.9	505.0	2.8	0.0	0.0	138.4	0.0	1.5	928.0	0.0	2411.2
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	166.6	0.0	668.9	505.0	2.8	0.0	0.0	138.4	0.0	1.5	928.0	0.0	2411.2

TOTAL SITE ENERGY 2411.20 MBTU 35.4 KBTU/SQFT-YR GROSS-AREA 35.4 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7233.61 MBTU 106.1 KBTU/SQFT-YR GROSS-AREA 106.1 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.68
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 147

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	166.6	0.0	668.9	483.1	8.3	0.0	0.0	166.5	0.0	3.0	928.0	0.0	2424.6
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	166.6	0.0	668.9	483.1	8.3	0.0	0.0	166.5	0.0	3.0	928.0	0.0	2424.6

TOTAL SITE ENERGY 2424.55 MBTU 35.6 KBTU/SQFT-YR GROSS-AREA 35.6 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7273.67 MBTU 106.7 KBTU/SQFT-YR GROSS-AREA 106.7 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.89
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 58
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 108

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	166.6	0.0	596.4	516.6	7.7	0.0	0.0	189.0	0.0	3.7	859.3	0.0	2339.4
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	166.6	0.0	596.4	516.6	7.7	0.0	0.0	189.0	0.0	3.7	859.3	0.0	2339.4

TOTAL SITE ENERGY 2339.36 MBTU 34.3 KBTU/SQFT-YR GROSS-AREA 34.3 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7018.08 MBTU 102.9 KBTU/SQFT-YR GROSS-AREA 102.9 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.89
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 17
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 149

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

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	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	166.6	0.0	617.7	505.9	8.9	0.0	0.0	188.2	0.0	2.6	928.0	0.0	2418.0
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	166.6	0.0	617.7	505.9	8.9	0.0	0.0	188.2	0.0	2.6	928.0	0.0	2418.0

TOTAL SITE ENERGY 2417.95 MBTU 35.5 KBTU/SQFT-YR GROSS-AREA 35.5 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7253.86 MBTU 106.4 KBTU/SQFT-YR GROSS-AREA 106.4 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.86
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 20
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 143

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	115.3	0.0	668.9	505.0	6.2	0.0	0.0	182.7	0.0	3.3	928.0	0.0	2409.4
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	115.3	0.0	668.9	505.0	6.2	0.0	0.0	182.7	0.0	3.3	928.0	0.0	2409.4

TOTAL SITE ENERGY 2409.41 MBTU 35.3 KBTU/SQFT-YR GROSS-AREA 35.3 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7228.24 MBTU 106.0 KBTU/SQFT-YR GROSS-AREA 106.0 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.66
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 3
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 142

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	166.6	0.0	668.9	493.8	8.0	0.0	0.0	191.0	0.0	2.6	309.3	0.0	1840.3
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	166.6	0.0	668.9	493.8	8.0	0.0	0.0	191.0	0.0	2.6	309.3	0.0	1840.3

TOTAL SITE ENERGY 1840.28 MBTU 27.0 KBTU/SQFT-YR GROSS-AREA 27.0 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 5520.85 MBTU 81.0 KBTU/SQFT-YR GROSS-AREA 81.0 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.88
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 23
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 142

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	166.6	0.0	668.9	493.8	8.0	0.0	0.0	191.0	0.0	2.6	748.7	0.0	2279.7
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	166.6	0.0	668.9	493.8	8.0	0.0	0.0	191.0	0.0	2.6	748.7	0.0	2279.7

TOTAL SITE ENERGY 2279.67 MBTU 33.4 KBTU/SQFT-YR GROSS-AREA 33.4 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 6839.03 MBTU 100.3 KBTU/SQFT-YR GROSS-AREA 100.3 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.88
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 23
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 142

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	166.6	0.0	657.6	493.8	8.0	0.0	0.0	191.0	0.0	2.6	928.0	0.0	2447.6
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	166.6	0.0	657.6	493.8	8.0	0.0	0.0	191.0	0.0	2.6	928.0	0.0	2447.6

TOTAL SITE ENERGY 2447.56 MBTU 35.9 KBTU/SQFT-YR GROSS-AREA 35.9 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7342.70 MBTU 107.7 KBTU/SQFT-YR GROSS-AREA 107.7 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.88
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 23
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 142

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	166.6	0.0	668.9	488.1	8.0	0.0	0.0	190.9	0.0	2.6	928.0	0.0	2453.1
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	166.6	0.0	668.9	488.1	8.0	0.0	0.0	190.9	0.0	2.6	928.0	0.0	2453.1

TOTAL SITE ENERGY 2453.13 MBTU 36.0 KBTU/SQFT-YR GROSS-AREA 36.0 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7359.40 MBTU 107.9 KBTU/SQFT-YR GROSS-AREA 107.9 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.92
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 26
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 142

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	166.6	0.0	668.9	466.6	7.2	0.0	0.0	184.1	0.0	2.6	928.0	0.0	2424.1
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	166.6	0.0	668.9	466.6	7.2	0.0	0.0	184.1	0.0	2.6	928.0	0.0	2424.1

TOTAL SITE ENERGY 2424.06 MBTU 35.5 KBTU/SQFT-YR GROSS-AREA 35.5 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7272.19 MBTU 106.6 KBTU/SQFT-YR GROSS-AREA 106.6 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.85
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 17
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 145

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	166.6	0.0	668.9	493.8	8.0	0.0	0.0	130.3	0.0	2.6	928.0	0.0	2398.2
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	166.6	0.0	668.9	493.8	8.0	0.0	0.0	130.3	0.0	2.6	928.0	0.0	2398.2

TOTAL SITE ENERGY 2398.18 MBTU 35.2 KBTU/SQFT-YR GROSS-AREA 35.2 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7194.53 MBTU 105.5 KBTU/SQFT-YR GROSS-AREA 105.5 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.88
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 23
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 142

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	115.3	0.0	538.1	504.2	2.2	0.0	0.0	51.7	0.0	1.6	226.7	0.0	1439.8
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	115.3	0.0	538.1	504.2	2.2	0.0	0.0	51.7	0.0	1.6	226.7	0.0	1439.8

TOTAL SITE ENERGY 1439.80 MBTU 21.1 KBTU/SQFT-YR GROSS-AREA 21.1 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 4319.39 MBTU 63.3 KBTU/SQFT-YR GROSS-AREA 63.3 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 2.69
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 155

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