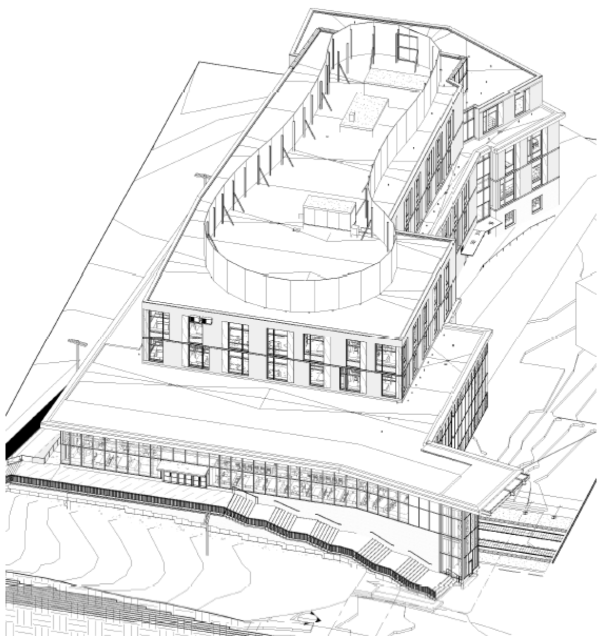
Cypress Building

Brookline High School

Design Development Energy Analysis Report

Revision-2



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Executive Summary

The Cypress Building project consists of a five-story (lower level + 4 floors) new 116,534 SF academic building consisting of classrooms, library, cafeteria, office spaces, and support spaces at the Brookline High School campus in Brookline, MA. The project scope also includes back-of-house and electrical/mechanical support spaces at the lower level.

The Green Engineer (TGE) performed building performance analysis to compare the design with a LEED baseline, modeled in accordance with ASHRAE 90.1-2010, Appendix G. The results of the modeling indicate that the as-designed building is expected to show total energy-cost savings of 35.8%, excluding savings from on-site PV, compared to the Baseline. With savings from on-site PV the cost savings are 39.5% and EUI for the design is 29.8 kBtu/SF-yr. The percentage annual site and source energy savings are estimated at **42.9%** and **37.1%,** respectively. Additionally, the greenhouse gas (GHG) emissions for the proposed design are estimated at **232** MTCO2e, an approximately **39.7%** reduction from the Baseline emissions. Refer to Figure-1 below.

Standard LEEDv4 compliance path uses energy cost metrics for credit achievement. This project has a potential to earn 14 LEED points based on annual energy cost savings. Based on the LEED v4 pilot alternative compliance path (ACP)[1], that allows using alternate metrics such as source energy, GHG emissions, etc., for documenting performance improvement, the estimated savings for the project are 38.42% which is equivalent to 15 LEED points. Summaries of these results are presented in the following sections.

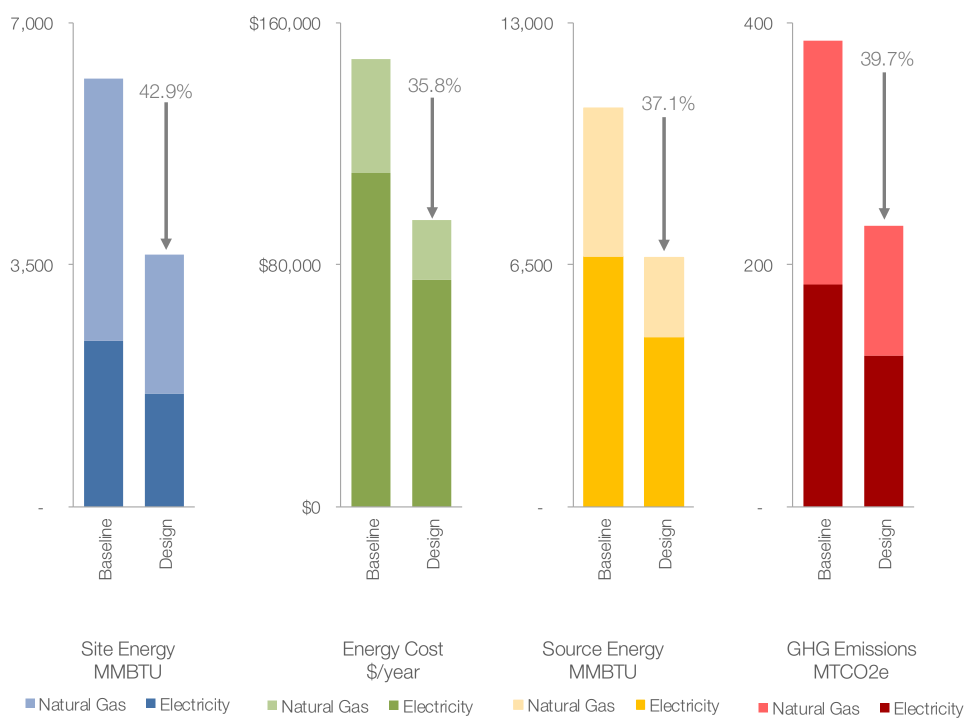


Figure 1: Baseline and Design Case Energy Use, Energy Cost, Source Energy and GHG Emissions Comparison

[1] Source: LEEDv4 BD+C Alternate Energy Performance Metric

I. Description of Alternatives

ASHRAE 90.1-2010 Baseline: The building as-designed, except that the envelope constructions, mechanical equipment, and lighting meet the minimum requirements of ASHRAE 90.1-2010.

Design Case: The building as-designed. The design inputs are based on the Design Development Pricing Set drawings and documents, and information provided by the design team.

Every effort has been made to use reasonable assumptions for building components and systems where details were not available.

Design Case-Alternate Options: The team wanted to investigate the impact extended hours of operation (evenings, Saturdays and summer) for Floors 1 & 2 will have on the annual energy use. A version of the model was run when the school is only used for academic purposes (Monday-Friday, 8:00 a.m. – 3 p.m., all other dates/times-including summer: closed). Details for occupancy and hours of operation included in the energy model are provided in Section-V of this report.

Simulation results for the extended academic schedule as well as the alternate schedule (standard school hours) are provided in Section-III of this report.

Please refer to Appendix-A for detailed model inputs.

II. Energy Conservation Measures

The following ECM's have been identified for the project:

- Improved envelope assemblies and fenestration
- Reduced interior lighting through use of high-efficiency LED fixtures
- High efficiency VAV units with energy recovery effectiveness better than ASHRAE 90.1 requirements
- The design includes partial cooling for all areas, except the offices, specialty spaces, library, White Box, and admin areas. This results in a lower overall energy use for the project.
- Supply air temperature reset
- Perimeter finned tube radiators (FTR's) and radiant panels with hot water heating. Perimeter FTR's meet space loads during unoccupied periods eliminating the need for RTUs to cycle on at night and unoccupied periods. RTU's are modeled to remain off during unoccupied hours.
- High efficiency condensing boilers and optimized hot water loop parameters
- High efficiency air-cooled chiller and optimized chilled water loop parameters
- High efficiency VRF-HPs in spaces with full cooling
- On-site renewables: roof top photo-voltaic (PV)

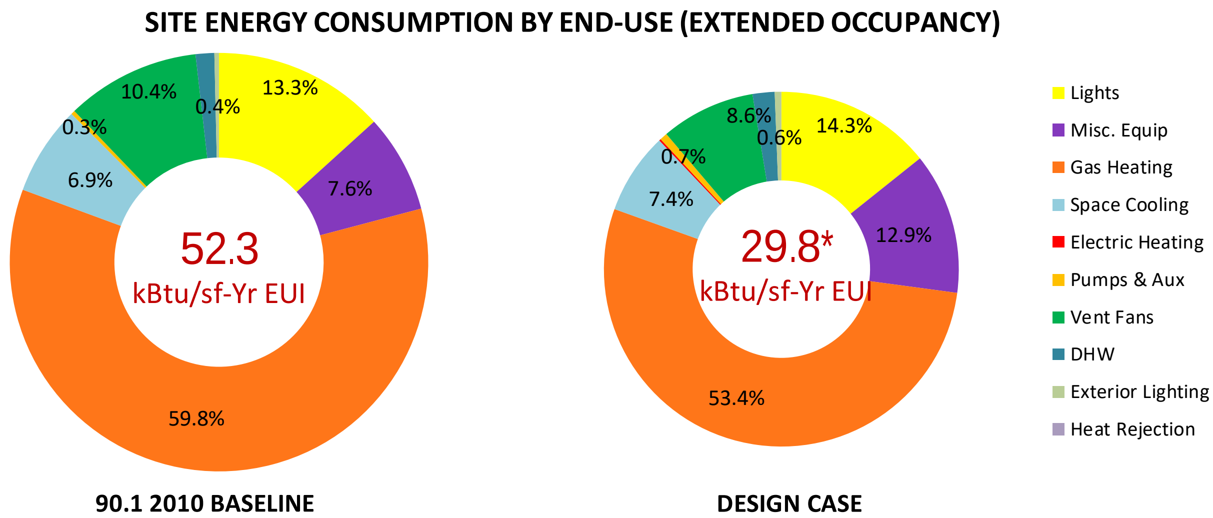
III. Simulation Results

a. Baseline Schedule – Extended Occupancy

Following are the simulation results obtained from the energy model iterations. The annual energy use and cost savings for the proposed design are based on energy efficiency strategies incorporated in the design to reduce the energy consumption in the building. The following tables summarize energy use and cost results for the Baseline and the Proposed Design based on extended hours of operation. Also included are the estimated source energy savings and GHG emissions reduction for the Design compared to the Baseline.

Site Energy Use Savings (MMBtu/Yr)														EUI (kBtu/SF-yr)
Description	Lights	Misc. Equip	Gas Heating	Space Cooling	Electric Heating	Pumps & Aux	Vent Fans	DHW	Exterior Lighting	Heat Rejection	Solar PV Offset	Total	% Savings	
LEED Baseline	821.1	469.7	3694.0	426.9	0.0	18.9	640.8	89.0	21.8	0	-	6,182	-	52.3
Design Case	520.1	469.7	1946.0	270.3	6.2	25.0	314.4	73.4	21.8	0	-119	3,528	42.9%	29.8

Energy Use, GHG Reduction and Cost Summary			
Description		LEED Baseline	Design Case
Annual Site Energy Summary			
Electricity	kWh	702,966	476,970
Natural Gas	MMBtu	3,783	2,019
^Total Site Energy use	MMBtu	6,182	3,647
Annual Energy Cost Reduction			
Electricity	$/year	$110,366	$74,884
Natural Gas	$/year	$37,414	$19,972
^Total Energy Cost	$/year	$147,779	$94,856
		Site Energy Cost Savings (%)	35.8%
Total Energy Cost with On-site PV	$/year	$147,779	$89,391
		Site Energy Cost Savings (including PV) (%)	39.5%
Annual Source Energy Reduction			
Total Source Energy use	MMBtu	10,690	6,678
		Source Energy Savings (%)	37.5%
Green House Gas (GHG) Reduction			
Total GHG Emissions	MTCO2e	384.7	232.0
		GHG Reduction(%)	39.7%
^Estimated Annual Energy Use and Cost excluding savings from on-site PV			



*Design Case *EUI includes energy use savings from On-Site PV*

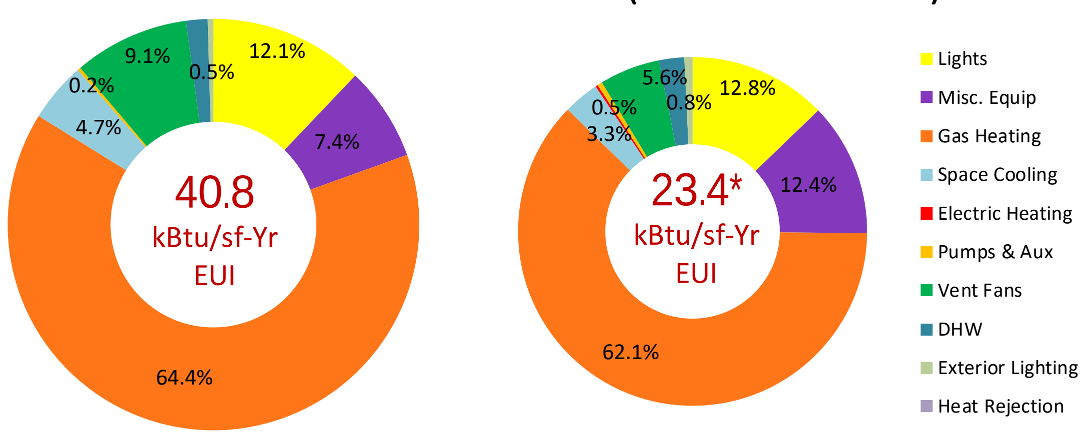
b. Alternate Schedule – Standard School Hours Only

The following tables summarize energy use and cost results for the Baseline and the Proposed Design with standard hours of operation i.e. Monday - Friday 8a.m. – 3p.m. The school is assumed to remain closed on weekends and during summer / winter breaks. Also included are the estimated source energy savings and GHG emissions reduction for the Design compared to the Baseline.

Site Energy Use Savings (MMBtu/Yr) - Alternate Schedule														EUI (kBtu/SF-yr)
Description	Lights	Misc. Equip	Gas Heating	Space Cooling	Electric Heating	Pumps & Aux	Vent Fans	DHW	Exterior Lighting	Heat Rejection	Solar PV Offset	Total	% Savings	
LEED Baseline	584.0	356.9	3106.0	226.3	0.0	11.6	438.2	81.2	21.8	0		4,826.0	-	40.8
Design Case	369.7	356.9	1795.0	96.1	6.3	13.4	161.8	67.4	21.8	0	-119	2,769.4	42.6%	23.4

Energy Use, GHG Reduction and Cost Summary - Alternate Schedule			
Description		LEED Baseline	Design Case
Annual Site Energy Summary			
Electricity	kWh	480,168	300,618
Natural Gas	MMBtu	3,187	1,862
Total Site Energy use	MMBtu	4,826	2,888
Annual Energy Cost Reduction			
Electricity	$/year	$75,386	$47,197
Natural Gas	$/year	$31,521	$18,419
^Total Energy Cost	$/year	$106,908	$65,616
		Site Energy Cost Savings (%)	38.6%
Total Energy Cost with on-site PV	$/year	$106,908	$60,151
		Site Energy Cost Savings (including PV) (%)	43.7%
Annual Source Energy Reduction			
Total Source Energy use	MMBtu	7,935	4,828
		Source Energy Savings (%)	39.2%
Green House Gas (GHG) Reduction			
Total GHG Emissions	MTCO2e	294.8	177.5
		GHG Reduction(%)	39.8%
^Estimated Annual Energy Use and Cost excluding savings from on-site PV			

SITE ENERGY CONSUMPTION BY END-USE (REDUCED OCCUPANCY)



90.1 2010 BASELINE **DESIGN CASE**

*Design Case *EUI includes energy use savings from On-Site PV*

IV. Discussion of Results:

- The design includes several energy efficiency measures that provide annual energy use savings for the project. Interior lighting, space heating, space cooling, and fan energy are the largest end-uses contributing towards overall savings for the project.

- The Site EUI for the design, based on the current model inputs, is estimated at 29.8 kBtu/sf-yr. The GHG emissions for the Proposed Design are estimated at 232 MTCO2e, an approximately 39.7% reduction from the Baseline GHG emissions estimated at 384 MTCO2e.

  This preliminary analysis shows that pursuing the pilot LEED ACP and using alternate performance metric such as source energy, GHG emissions, etc., to document savings can potentially provide up to 15 LEED points for this project. *Note that achieving additional credit using this ACP requires project teams to calculate and document all required energy metrics and is subject to approval by the GBCI.*

- The design includes partial cooling for all areas except the faculty spaces, offices, library, White Box and admin spaces that have full air-conditioning. This results in a lower overall energy use for the project.

- Alternate Building Operation Schedule: The iteration of the energy model in which hours of operation are limited to academic hours only shows an EUI of 23.4 kBtu/SF-yr compared to 29.8 kBtu/SF-year for the anticipated extended operating hours.

- The design will include roof top PV to provide on-site renewable energy. The available roof area for PV panels is currently estimated at 3,065 SF. Based on assumptions outlined in Appendix-B of this report, a 27 pkW PV system can be installed in the available roof area with annual production potential of 34,873 kWh/yr and an annual energy value of $5,475 for on-site electricity.

V. Modeling Methodology

This phase of the energy modeling, based on the Design Development pricing set dated 30th November 2018, and information provided by the design team, evaluates the performance of the proposed design against an ASHRAE 90.1-2010 compliant Baseline building for LEEDv4. The modeling was performed in accordance with ASHRAE Standard 90.1-2010, Appendix-G guidelines.

The purpose of presenting this information is to provide a gauge for the project in terms of energy performance and an opportunity for the design team to review the energy model assumptions for accuracy. The overall energy savings and estimated annual energy consumption for the project is likely to change as the design gets further refined, and the energy model inputs are reviewed and finalized.

The annual energy cost estimates are based on energy modeling results, using eQUEST version 3.65 modeling software. The eQUEST software uses DOE-2 calculation engine to estimate annual energy consumption by simulating a year of building operations based on a typical weather year and user inputs.

The geometry of the building is based on the AutoCAD floor plans, except that window positions are simplified based on a percentage glazing in each zone and exposure. It is important to keep in mind the limitations of energy models when reviewing this information. The results are based on the current design assumptions and utility rates described within this report.

Further, energy consumption is highly dependent on weather conditions and the actual operating schedule of the building. The numbers generated will not necessarily be an accurate projection of actual energy costs but should serve as an accurate comparison between alternatives.

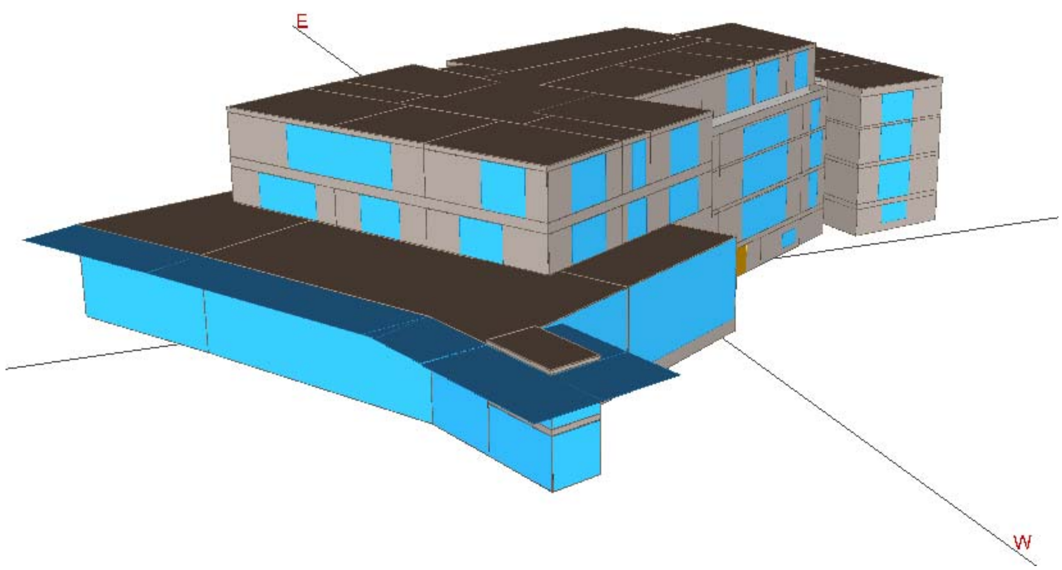


Image 1: Cypress Building – Energy Model 3D View

Occupancy and building operation:

The estimated annual energy use is based on the following hours of operation:

Academic School Year: Building in Full Use
School Day: 8am – 3pm
After Hours: 3pm – 10pm (floors 1 & 2 only)
Saturdays: Partial Use between 9am & 3pm (floors 1 & 2 only)
Sundays: Closed
Holidays, Winter Break, Spring Break: Closed

Summer
Building in Full Use:
School Day: 8am – 3pm
Saturdays: Partial Use between 9am & 3pm (floors 1 & 2 only)

The annual energy use for the following Alternate Schedule has also been included in the result summary.

Academic School Year Only: Building in Full Use
School Day: 8am – 3pm
All other dates/times (including summer): Closed

Utility Rates:

The following EIA State Average Rates for electricity and natural gas have been used for estimating annual energy cost savings for the project:

- Electricity: $ 0.157 /kWh (2017 EIA Average for MA)
- Gas: $9.89 /MBTU (2017 EIA Average for MA)

VI. LEEDv4 Pilot ACP: Alternative Energy Performance Metric

Under the LEED v4 Rating System project teams may use the pilot alternative compliance path (ACP) for documenting savings under the EA Optimize Energy Performance Credit. The intent of this ACP is to allow project teams to use performance metrics other than cost for documenting performance improvement. The ACP requires project teams to calculate and report a metric from each of the required categories:

- Site Energy Cost
- Source Energy
- Greenhouse gas emissions
- Time Dependent Valuation (TDV) Energy (if available)

The average percent savings of the two highest-performing metrics, using equal weighting, is then used to determine percentage energy savings for the project.

For this project, the average percent savings for the two highest-performing metrics i.e. greenhouse gas emission reduction and source energy use reduction are estimated at 38.6% which earns the project 15 LEED credit points.

Note that the following Energy Star Portfolio Manager GHG emissions factors were used for this analysis:

- Electricity: 0.0767 MTCo2e / MMBTU for New England
- Natural gas: 0.05311 MT Co2e /MMBtu (US Average)

APPENDIX-A: MODEL INPUT SUMMARY

The envelope, internal load assumptions and HVAC system inputs in the energy model are based on the drawings and documents available to us and inputs from the design team.

Brookline Cypress Building: Design Development Model Inputs		
Project Area	116,534 SF	
Building Envelope	Baseline Case (ASHRAE 90.1 2010)	Design Case
Roofs	ASHRAE 90.1 2010, Table 5.5-5 (CZ 5A): Insulation entirely above Deck. R-20 c.i. Assembly U-Value: 0.048	Insulation entirely above Deck: R-45.6 c.i. (6" min Polyiso insulation @R 5.7/inch) Assembly U-Value: 0.028
Walls - Above Grade	ASHRAE 90.1 2010, Table 5.5-6 (CZ 5A): Steel-framed Construction. R-13.0 + 7.5 c.i. Assembly U-Value: 0.064	Brick Veneer Wall: R-27.62 Effective R-Value Assembly U-0.035 Spandrel Assembly U-0.45
Slab on Grade	Unheated, 6" slab on grade floor F-0.73	Modeled same as Baseline
Fenestration and Shading	Baseline Case (ASHRAE 90.1 2010)	Design Case
Vertical Glazing Description	Curtain Walls and Punched Windows	Curtain Walls and Punched Windows
Vertical Glazing U-factor	ASHRAE 90.1 2010, Table 5.5-5 Metal Framing (Curtain Wall): Assembly U-value: 0.45 Metal Framing (Punched): Assembly U-Value: 0.55	Solarban 60 + Kawneer Sys-3 Assembly U-0.39
Vertical Glazing SHGC	0.4	0.38
Visual Light Transmission	0.9	0.7
Lighting and Equipment	Baseline Case (ASHRAE 90.1 2010)	Design Case
Lighting Power Calc Method	Building Area Method	Building Area Method
Lighting Power Density	0.99W/SF	0.63 W/SF
Occupancy Sensor	-	Yes
Lighting Controls	Included where required by ASHRAE 90.1 2013	Daylight controls in perimeter Zones: Stepped dimming to 70% and 35% of full power Lighting controls as per Section 9.4.1 of ASHRAE 90.1 2013
Equipment Power Density	Same as design	Kitchen: 5 W/SF (incl appropriate diversity) Servery: 4W/SF (incl appropriate diversity) Office: 1.5 W/SF Classroom: 0.75 W/SF

HVAC - Air Side	Baseline Case (ASHRAE 90.1 2010)	Design Case
Primary HVAC Type	System #5: Packaged VAV with Reheat (DX/HW)	VAV with Reheat Supplemental VRFs in spaces with full cooling (FCUs) Offices, specialty spaces, white box, library and admin areas are being provided full cooling. Other spaces will include humidity control and heating when occupied.
Cooling Capacity / Efficiency	Cooling equipment capacities auto-sized and oversized by 15%. Min DX Cooling Efficiency as per ASHRAE 90.1 2010 9.8-10.8 EER	Air cooled chiller in design Unit: Total / Sensible MBH AHU-1: 182.5/ 124.8 MBH AHU-2: 179.9/74.1 MBH AHU-3 (CC-1): 124.3/50.6 MBH AHU-4: 339.4 /115.7 MBH AHU-5: 82.3 / 41.3 MBH AHU-6: 82.3 / 41.3 MBH AHU-7: 274.1 / 122.1 MBH AHU-8: 213.2 / 97.8 MBH
Heating Capacity / Efficiency	Heating capacities auto-sized and oversized by 25%. Heating source modeled as HW Plant with natural draft boilers.	Heating source modeled as HW Plant with boiler efficiency condensing boilers. AHU-1: 144 MBH AHU-2: 95 MBH AHU-3: 532.7 MBH AHU-4: 112 MBH AHU-5: 55 MBH AHU-6: 55 MBH AHU-7: 202 MBH AHU-8: 164 MBH
Fan System Operation	Variable volume fans, 30% min turn-down or ventilation requirement, whichever is higher. Supply and return fans operate continuously whenever spaces are occupied and cycle to meet loads during unoccupied periods.	Supply and return fans operate continuously whenever spaces are occupied. Perimeter FTR meets loads during unoccupied periods.
Supply Air	System design supply air flow rates based higher of a supply-air-to-room-air temperature difference of 20 degF, or min ventilation requirements.	AHU-1: 12,000 CFM AHU-2: 7,500 CFM AHU-3: 5,500 CFM AHU-4: 7,000 CFM AHU-5: 3,500 CFM AHU-6: 3,500 CFM AHU-7: 13,000 CFM AHU-8: 10,500 CFM
Outdoor Air Design Min Ventilation	Same as design *Note: There is energy penalty from increased ventilation under LEEDV4. This iteration of the model assumes that the ventilation is in line with ASHRAE 62.1 2010 minimum requirements.*	AHU-1: 5,000 CFM AHU-2: 2,750 CFM AHU-3: 5,500 CFM AHU-4: 7,000 CFM AHU-5: 3,500 CFM AHU-6: 3,500 CFM AHU-7: 13,000 CFM AHU-8: 10,500 CFM

Economizer	Economizer with high-limit shutoff of 70 deg F	Economizer mode when outside relative humidity is less than return/ exhaust air relative humidity and outside dew point is lower than 60F.
System Fan Power	As per ASHRAE 90.1 2010 Fan Allowance: Supply: 0.9 W/CFM Return: 0.5 W/CFM Pressure credit: Fully ducted return/exhaust; MERV 13 filter on OA; energy recovery; sound attenuation.	Supply / Exhaust / Total (W/CFM) AHU-1: 1.48 / 0.74 W/CFM AHU-2: 1.58 / 0.83 W/CFM AHU-3: 0.91 W/CFM (Hood Exhaust) AHU-4: 1.19 / 0.883 W/CFM AHU-5: 1.24 / 0.762 W/CFM AHU-6: 1.24 / 0.762 W/CFM AHU-7: 1.36 / 0.876 W/CFM AHU-8: 1.32 / 0.874 W/CFM
Supply Air Temperature Reset Parameters	The air temperature for cooling shall be reset higher by 5F under minimum cooling load conditions	Included identical to Baseline
High Efficiency VAV Controls	NA	VAV AHUs will static pressure reset control logic.
VAV Min Flow Ratio	30%	25%
ERV	50% Recovery Effectiveness, where applicable	Enthalpy Wheel, 70% effective efficiency
Exhaust Fans	Modeled same as design	KEF-1 Basement Grease Hood, 500-4,485 CFM, VFD control KEF-2 Level-1 Grease Hood, 625-1900 CFM, VFD control EF 1-3 Mech Rm, Kitchen, Loading dock general exhaust (3.1 W) DEF-1 Basement Condensate Hood (0.33 W)
HVAC - Water Side	**Baseline Case**	**Design Case**
Number of Boilers	Two - Natural Draft Boilers Thermal Efficiency: 80%	Three (3) 3,000 MBH input/2,760 MBH output condensing boilers with an efficiency of 92%
Hot Water Loop Temperatures	Design HW Temp: 180 F Loop Design DT: 50 F	Design HW Temp: 140 F Loop Design DT: 30 F
HHW Loop Reset	180F @ 20F outdoor, 150F @ 50F outdoor	Linear reset based on outside air temperature: 140F @ ≤0F outdoor, 110F @ ≥60F outdoor
Primary HW pump parameters	One @ 19W/gpm	Three (3) boiler pumps @ 200 gpm, 1.45 BHP/2HP each, VFD
Secondary HW pump parameters	NA	Three (3) HW loop pumps @ 200 gpm, 5.75 BHP/7.5 HP each, VFD
Pump Speed Control	VSD on Pumps	VSD on Pumps
Number of Chillers	NA	One 150-ton air-cooled scroll chiller with 9.912 EER /16.66 IPLV
Chilled Water Supply Loop Temp	-	42F
Chilled Water Loop Delta T	-	12F
CHW Loop Reset	-	Reset based on load
Number of CHW Loop Pumps	-	Three (3) chilled water system pumps. 160 gpm, 8.58 BHP/10HP each, VFD

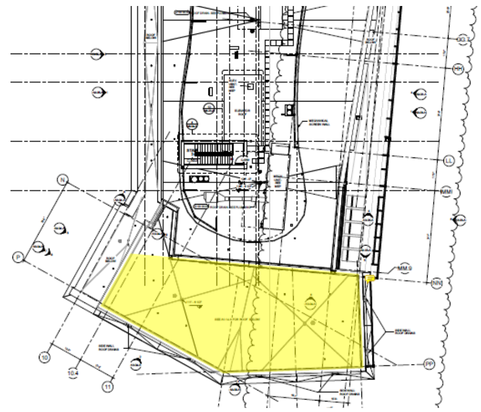
Number of Cooling Towers / Fluid Coolers	NA	NA
Domestic Hot Water	**Baseline Case**	**Design Case**
DHW System Type	Two (2) Gas Storage Water Heaters	Two (2) Gas Storage Water Heaters DWH-1 &2 Basis of Design: Lochnivar SIT119
Storage capacity	Same as design	119 Gallons each
Equipment Efficiency & Temp Controls	80% Et	92% Et
DHW Flow	0.44 gpm (preliminary estimate based on LEED WEp)	0.39 gpm (preliminary estimate based on LEED WEp)

APPENDIX-B: PHOTOVOLTAIC ANALYSIS

The project will include rooftop photovoltaic (PV) arrays to offset electricity use. The roof area available for installing PV panels is currently estimated at 3,065 SF.

If panels were installed on the available portions of the roof, a 27 pkW PV system could be installed. This system would generate an estimated 34,873 kWh of electricity per year. The value of the electricity generated would be approximately $5,475 per year based on an electric rate of 0.157/kWh.

The installed cost of the system is estimated at $94,691. Installation cost estimates do not include any tax or other incentives.



Roof Area Available for On-site PV

Assumptions:

Assumed PV performance:	15.4 watts (peak)/sf
Estimated installation cost:	$3.50/Watt (Peak), excl. any taxes or incentives
Electric utility rate:	$0.157/ kWh
Available roof space after setbacks:	85%
Estimated coverage of available space:	50% (to avoid self-shading)
Panel Tilt:	42-degrees to the horizontal
Panel Orientation:	180 degrees i.e. facing south

Table-1: Rooftop PV Summary

Cypress Building: On Site PV Estimate								
Panel Orientation	Roof Area	Net Roof Area for PV	PV Panel Surface Area	Array Size	Azimuth	Tilt	Annual Production	Annual Value
	SF	SF	SF	kW	(Deg)	(Deg)	kWh/yr	($)
42 Degree Panel Tilt	3,065	2,605	1,759	27	180	42	34,873	$ 5,475

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