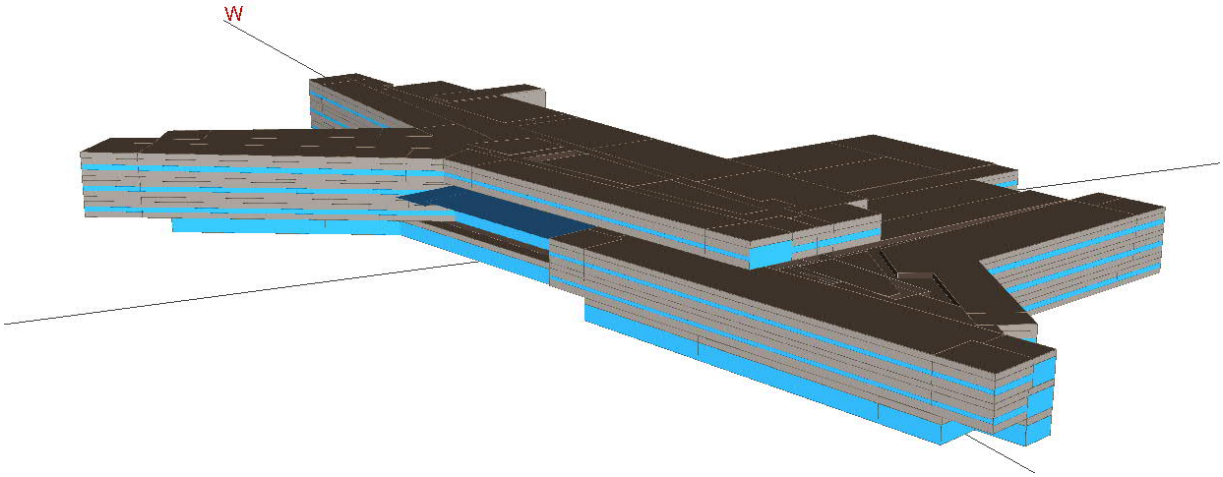
DRAFT – Preliminary Design Energy Model Input Summary

Belmont High School

Belmont, MA



June 1, 2018

AKF Project No. 180358-000

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1. EXECUTIVE SUMMARY

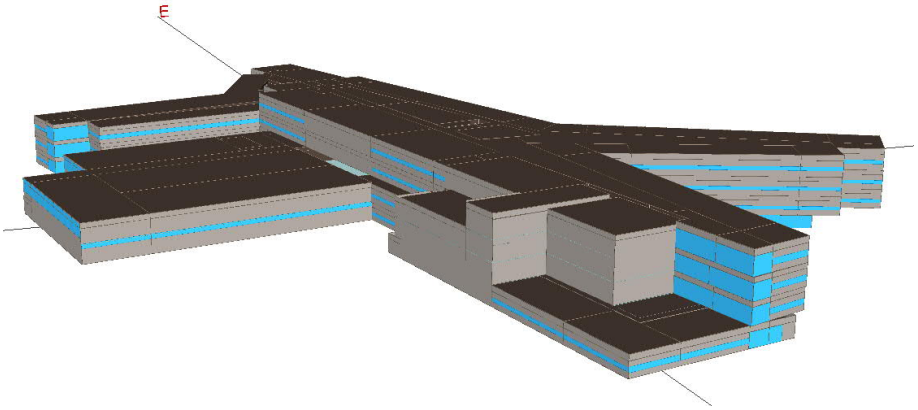
The Belmont High School project contains approximately 480,000 SF of built space, which includes classrooms, maker space, a general purpose gym, a field house, a kitchen/cafeteria, and a variety of auditorium/band/learning commons programmatic area. The purpose of the energy model is to identify the proposed design's performance relative to an ASHRAE 90.1-2013 Appendix G baseline model and demonstrate a 20% improvement in energy consumption as well as to evaluate the performance of several HVAC alternatives on both energy and cost bases.

Inputs for this energy model are based on the April 2018 Revit Model, ASHARE 90.1-2013 Appendix G baseline assumptions, the April 2018 BHS Envelope Summary, and the April 2018 HVAC Narratives provided by Bala Consulting Engineers.

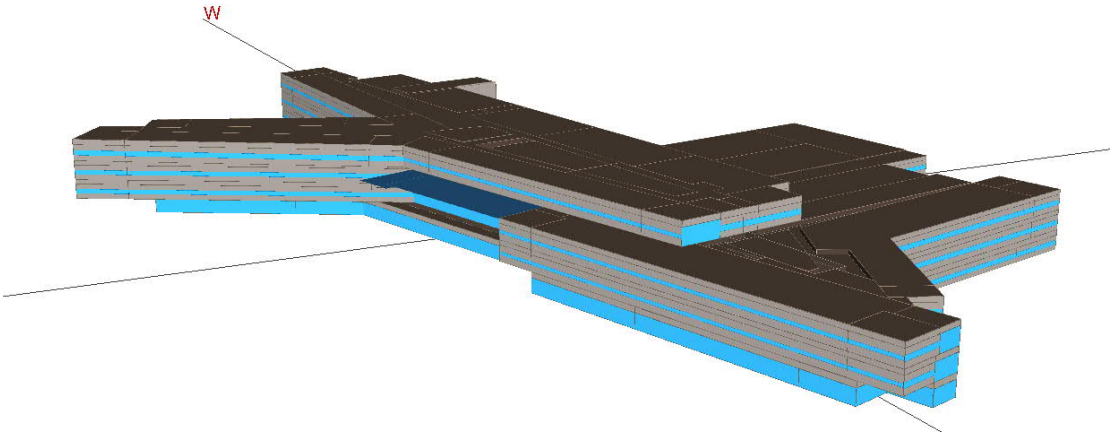
The following table shows the modeled results for total annual energy consumption, site EUI, and annual energy cost changes.

SUMMARY - ENERGY AND COST	TOTAL CONSUMPTION (MMBTU)	EUI (kbtu/sf/yr)	SITE ENERGY SAVINGS (%)	ESTIMATED ANNUAL UTILITY COST ($)	UTILITY COST SAVINGS (%)	ANNUAL UTILITY COST DELTA vs.. PREFERRED/ PROPOSED DESIGN
ASHRAE 90.1-2013 BASELINE	28,039	**58.42**	-	$697,770	-	-
PROPOSED (GEOTHERMAL / INDUCTION UNITS)	12,490	**26.02**	**55%**	$539,431	**23%**	-
PROPOSED - OPT 1 (CHILLER/BOILER/INDUCT)	15,494	**32.28**	**45%**	$563,248	**19%**	**$23,817**
PROPOSED - OPT 2 (CHILLER/BOILER/FAN COIL)	15,894	**33.11**	**43%**	$582,901	**16%**	**$43,469**

Energy Model Images



Northwest Corner View



Southeast Corner View

Energy Modeling Disclaimer

Building energy modeling is a comparative tool used for understanding the relative impact of alternate strategies and systems on annual energy use and cost. Energy modeling is not an absolute predictor of actual energy use or cost and shall not be relied on to predict actual building performance. Changes in construction, variable weather conditions, operational characteristics, end-user input, miscellaneous electrical and gas loads, controls alterations and other unpredictable metrics prevent energy models from predicting the actual annual energy consumption of any facility.

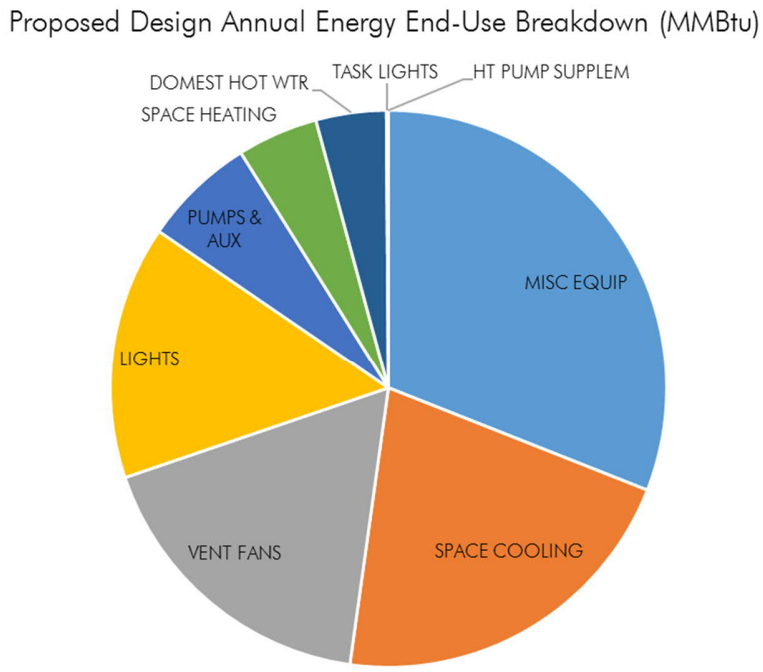
2. ENERGY MODEL RESULTS

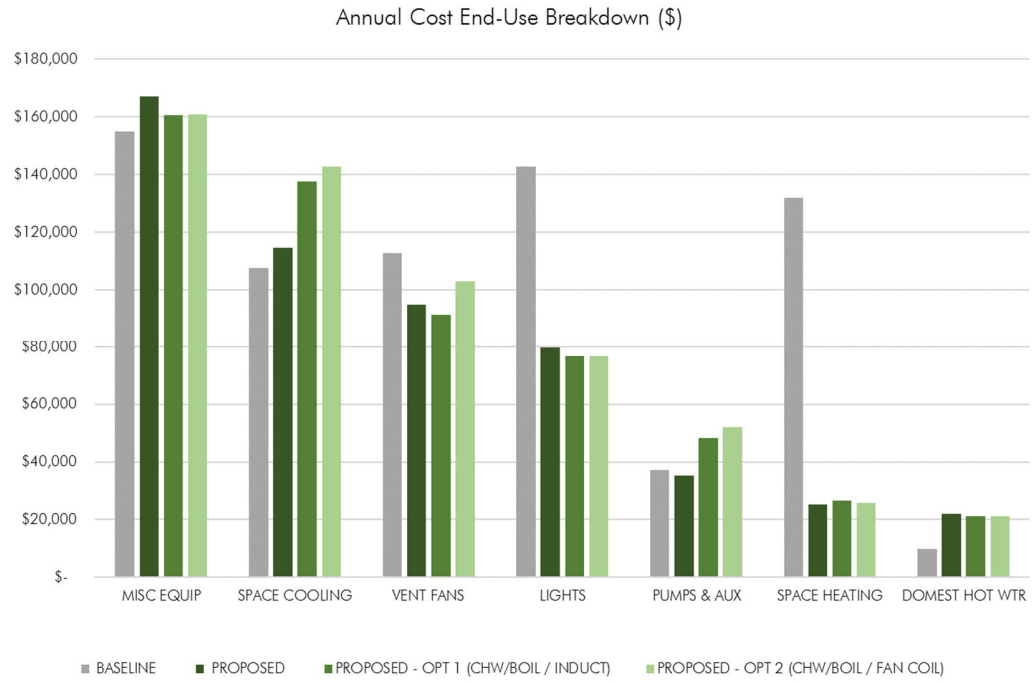
General

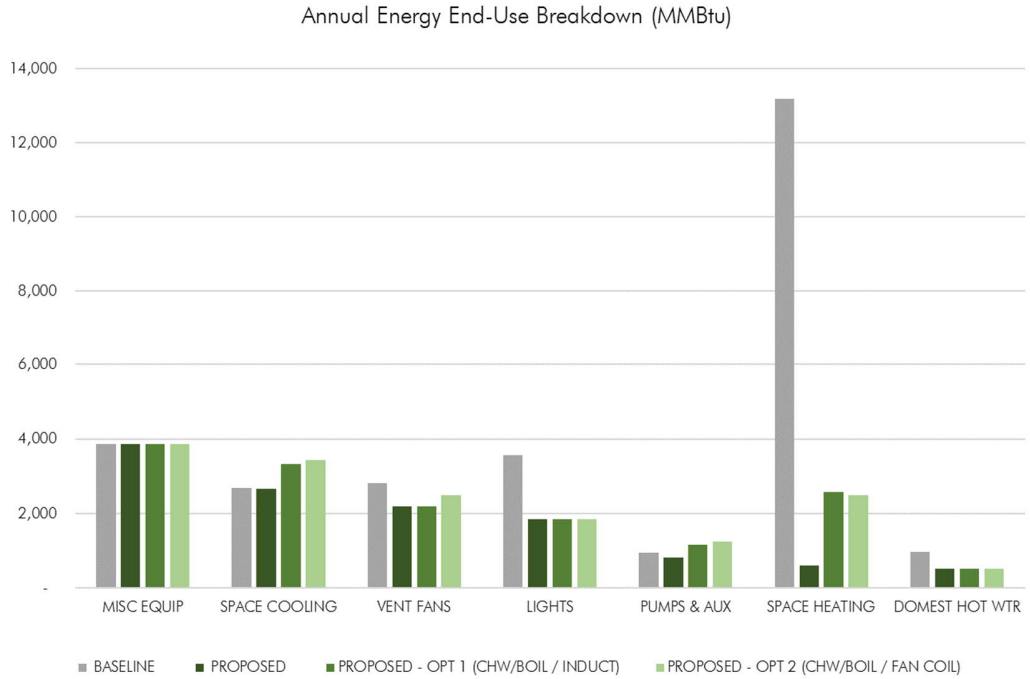
The following charts and tables show a breakdown of energy consumption by end-use for the proposed design, the HVAC alternates, and the ASHRAE 90.1-2013 baseline model.

SUMMARY - COST	ELECTRIC COST ($)	GAS COST ($)	TOTAL COST ($)	COST SAVINGS (%)	COST DELTA VS PREFERRED/PROPOSED DESIGN
ASHRAE 90.1-2013 BASELINE	$556,257	$141,513	$697,770	-	-
PROPOSED (GEOTHERMAL / INDUCTION UNITS)	$539,431	$-	$539,431	23%	-
PROPOSED - OPT 1 (CHILLER/BOILER/INDUCT)	$537,861	$25,387	$563,248	19%	$23,817
PROPOSED - OPT 2 (CHILLER/BOILER/FAN COIL)	$558,349	$24,552	$582,901	16%	$43,469

SUMMARY - ENERGY	TOTAL CONSUMPTION MMBTU)	EUI (kbtu/sf/yr)	SITE ENERGY SAVINGS (%)
ASHRAE 90.1-2013 BASELINE	28,039	58.42	-
PROPOSED (GEOTHERMAL / INDUCTION UNITS)	12,490	26.02	55%
PROPOSED - OPT 1 (CHILLER/BOILER/INDUCT)	15,494	32.28	45%
PROPOSED - OPT 2 (CHILLER/BOILER/FAN COIL)	15,894	33.11	43%




Annual Cost End-Use Breakdown ($)
$180,000
$160,000
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$-
MISC EQUIP
SPACE COOLING
VENT FANS
LIGHTS
PUMPS & AUX
SPACE HEATING
DOMEST HOT WTR
BASELINE
PROPOSED
PROPOSED - OPT 1 (CHW/BOIL / INDUCT)
PROPOSED - OPT 2 (CHW/BOIL / FAN COIL)


Annual Energy End-Use Breakdown (MMBtu)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
MISC EQUIP
SPACE COOLING
VENT FANS
LIGHTS
PUMPS & AUX
SPACE HEATING
DOMEST HOT WTR
BASELINE
PROPOSED
PROPOSED - OPT 1 (CHW/BOIL / INDUCT)
PROPOSED - OPT 2 (CHW/BOIL / FAN COIL)

3. ENERGY MODEL INPUTS

Code Assumptions for Proposed Model

Unless otherwise noted, proposed design assumptions for unknown model inputs are set to ASHRAE 90.1-2013 requirements.

Project and Site Information

Energy Baseline	ASHRAE 90.1-2013 Appendix G
Weather	TMY3\MA_Boston_Logan_Intl_Arp.bin
Orientation	Plan North = North
ASHRAE Climate Zone	5A

Utility Rate Structure

Electricity	Belmont Large Municipal with Demand Rate. Distribution Charge: $190.8 / month Sum of Energy Charges: $0.113/kWh Sum of Demand Charges: $6.36/kW Winter, $8.48/kW Summer
Natural Gas	EIA State Average: $0.986 / Therm

Geometry and Architecture

	Proposed Design
Zoning	Based on April 18, 2018 Revit Model
Gross Area	▪ Total Conditioned Space: ~445,000 ▪ Modeled Area by Floor: - 1: 159,600 SF - 2: 113,000 SF - 3: 102,100 SF - 4: 70,200 SF
Floor to Floor Heights	▪ Floor-to-Floor Height: - 1: 13'-8" - 2: 14'-3" - 3: 14'-3" - 4: 16'-0"

Occupancy and Load Profiles

The table at the last page of this document provides a detailed analysis of modeling assumptions made for occupancy scheduling, population density, lighting w/sf and equipment w/sf for specific spaces.

Building Envelope Performance

	Baseline Design	Proposed Design
Window-to-Wall Ratio (Gross wall - floor-to-floor)	Window-to-Wall Ratio: 22% per 90.1-2013 Appendix G Guidelines	Window-to-Wall Ratio: 28% per April 11, 2018 Belmont Envelope Summary and April 11, 2018 BHS Façade Analysis showing Glazing/Curtainwall Façade and Academic Mass (Combo Glazing/Solid)
Glazing Performance (assembly values)	ASHRAE 90.1-2013. Vertical Glazing: - U-assembly: 0.42 - SHGC: 0.4	Per 04/11/2018 Belmont Envelope Summary: Glass Type 1: U-0.29 / SHGC-0.29 Glass Type 2: U-0.28 / SHGC-0.29 Glass Type 3: U-0.74 / SHGC-0.42
External Shades	N/A	Various shades throughout building, based on April 2018.
Above Grade Walls, Steel Frame	ASHRAE 90.1-2013: U-assembly: 0.055	Per 04/11/2018 Belmont Envelope Summary: Wall Type 1: U-0.042 Wall Type 2: U-0.036 Wall Type 3: U-0.036
Sub-grade Walls	N/A	N/A
Slab-on-Grade	N/A	N/A
Roof – Insulation entirely above deck	ASHRAE 90.1-2013: U-assembly: 0.032	Per 04/11/2018 Belmont Envelope Summary: U-assembly: 0.024

Equipment Loads (same for baseline and proposed)

Equipment (Includes Diversity)	Hourly Average EPD
General Space	0.5 w/sf peak load
Kitchen	141 kW peak load estimated for kitchen electric load
IT Closets	11 kW peak load estimated for IT Loads

Internal Electrical Loads

	Baseline Design	Proposed Design
Lighting	ASHRAE 90.1-2013 building area method LPD. School/University: 0.87 w/sf	0.45 w/sf for entire building
Exterior Lighting	tbd	tbd
Daylighting	Automatic Daylighting Controls for Primary Sidelighted Areas as per ASHRAE 90.1-2013 section 9.4.1.4, with one control step at 60% of design lighting power and another control step at 30% of design lighting power.	Automatic Daylighting Controls for Primary Sidelighted Areas as per ASHRAE 90.1-2013 section 9.4.1.4, with power ramped linearly to 18% and turned off when possible.
Lighting Controls	Same as Proposed	Occupancy Sensors in all areas required by code

HVAC

General HVAC

	Proposed Design
ASHRAE Climate Zone	Climate Zone 5A
Thermostat Setpoints	75°F / 70°F occupied, 64°F heating setback with no cooling after hours. Field House/Pool: Heated Only

Airside HVAC

Proposed System Sizing Summary:

SYSTEM NAME	Supply CFM	OA CFM	EXHAUST CFM	AREA SERVED (SF)	Supply Static (in wg)	Return Static (in wg)	Exhaust Static (in wg)
H&V - Pool	4,300	4,310		7,183	2.5		
RTU - Small Gym	5,208	1,590		7,868	5	3	
RTU - Field House	21,813	21,813		32,506	5	3	
RTU - Auditorium	9,003	3,444		9,216	5	3	
RTU - Band/Chorus	6,559	5,538		11,677	5	3	
RTU - Black Box	4,391	2,892		5,720	5	3	
RTU - Dining Commons	18,348	10,369		29,417	5	3	
RTU - Media Center	7,055	5,311		13,156	5	3	
DOAS - Classrooms	133,508	133,508		338,627	6	3.5	
ERV - Admin Offices	920	920		7,353	6	3.5	
Kitchen MUA Sys	2,500	2,500	5000	9,255	2.5		1.5

	Baseline Design	Proposed Design
System	- ASHRAE 90.1-2013 Appendix G System 7 – VAV with Reheat and purchased chilled water/hot water coils. - Air Handlers are modeled as separate floor-by-floor units with the exception of special-use spaces - Average fan power: 0.001 kW/cfm	- Classrooms: DOAS Units for Classroom Ventilation, Induction Units (perimeter) and chilled beams (core) for space conditioning - Special use spaces: RTU's with HW/CHW coils - Office Space: VRF units for space conditioning and ERV for ventilation
DCV	n/a (not required)	DCV on all DOAS and RTU air handlers.
Energy Recovery	50% sensible/50% latent energy recovery on all air handlers	76% sensible/74% latent energy recovery on all DOAS and RTU air handlers
Airside Economizer	Drybulb Economizer with 70°F high limit shutoff	Dual Enthalpy economizer with 70°F high limit shutoff on RTUs
Exhaust Systems	same as proposed	Kitchen: 5,000 cfm exhaust

Waterside HVAC

	Baseline Design	Proposed Design
Chilled Water (CHW) Source	Same as Proposed	Heat recovery chillers, COP-6.0, fed from geothermal well loop
CHW Temperatures	44°F with 12°F delta T	45°F supply primary / 57°F supply secondary for induction units.
CHW Flow	Variable Primary	Variable Primary/Secondary pumps
CHW Pump	65 ft head	85 ft head
Hot Water (HW) Source	Same as Proposed	Heat recovery chillers, COP-6.0, fed from geothermal well loop
HW Temperatures	180°F supply with 50°F delta T	180°F supply with 40°F delta T
HW Flow	Variable Secondary (on-site) pumps	Variable Primary
HW Pump	60 ft head	85 ft head
Well Loop Flow		Variable Primary
Well Loop Pump		100 ft head

Domestic Hot Water

	Proposed Design
General Usage	School Load: 172 kBtu, modulating according to school general occupancy profile
Heaters	Proposed Design: Electric Resistance Baseline Design: Gas Storage

HVAC Design Alternates

The following design alternates have been developed. Values that differ from the values in the General/Air-Side/Water-Side tables, which describe only the Proposed Design, are broken out specifically in the following table:

Design Alternate	Description
HVAC Option 1	Chillers and Boilers in lieu of Geothermal Loop and Heat Recovery Chillers - Chillers: COP 5.9, Electric Centrifugal - Boilers: 96%, Gas-Fired Condensing - CW Pump Head: 75 ft
HVAC Option 2	Chillers/Boilers with Fan Coil Units in perimeter and interior classrooms - Chillers/Boilers/Pump Heads: same as Option 1 - Fan Coil Units: 0.75” wg static, no displacement ventilation in classrooms - 57°F Secondary CHW Loop for Perimeter Induction Units removed, all CHW supplied at 45oF.

Occupancy and Load Profiles:

Occupancy and Load Matrix	Occupancy Schedules				Peak Loads		
Program Category	Weekday Profile	Weekend Profile	Holiday/Break Profile*	Events Profile	Occupancy (sf/person unless otherwise noted)	Equipment (w/sf)	Lighting (w/sf)
Lower School	7:00 am start M T R F : 2:25pm dismissal W: 1:15pm normal / 11:00am early dismissal	Sunday: Lexington Chinese School: 10 classrooms	Unoccupied	-	29	0.5	0.45
Upper School	7:00 am start M T R F : 2:25pm W: 1:25pm normal / 10:30am early dismissal	Unoccupied	Unoccupied	-	29	0.5	0.45
Maker Space	8:00am - 2:30pm, two blocks of two hours through day	Unoccupied	Unoccupied	-	40	0.8	0.45
Band/Rehearsal	8:00am - 2:30pm, two blocks of two hours through day	Unoccupied	Unoccupied	-	40	0.1	0.45
Field House	School Day: 8:00am - 2:30pm, two blocks of two hours through day Afterschool: 3pm - 9pm Monday thru Thursday, 3pm-7pm Friday	12:00pm - 5:00pm Saturday/Sunday	Summer/Winter Recess: Saturday Schedule	Pep Rallies: 2x/yr Misc assemblies: 5x/yrpeople	28 students in normal gym class Pep Rallies: 1,500 people Misc assemblies: /1,000 people	Normal Occupancy: 0.2 w/sf Full Occupancy: 0.5 w/sf	0.45
Small Gym	8:00am - 2:30pm, two blocks of two hours through day Nov-March: Afterschool Use 3-5pm Monday-Thursday All Year: Thursday: 7pm-9pm (pickleball)	Unoccupied	Unoccupied	-	75	0.1	0.45
Pool	Schoolday: 2 2hr blocks throughout day, 8am-2:30pm Afterschool: Monday-Friday 3:00pm - 7:00pm	12:00pm - 5:00pm Saturday/Sunday	Summer/Winter Recess: Saturday Schedule	-	100	0.1	0.45
Kitchen	6:00am - 9:30am kitchen active for hot breakfast 10am - 1pm kitchen active for lunch	Unoccupied	Unoccupied	-	50	50	0.45
Cafeteria	6:00am - 9:30am kitchen active for hot breakfast 10am - 1pm kitchen active for lunch, conditioned until 3pm	Sunday: Lexington Chinese School	Unoccupied	-	75 students from 7am thru 9pm 400 students from 10am thru 1pm	0.1	0.45
Office/Admin Space	7am - 4pm	12:00pm - 4:00pm Saturday	Summer/Winter Recess: Weekday/Weekend Schedule	-	200	0.75	0.45
Auditorium	3 hrs/day occupied	Sunday: Lexington Chinese School	Unoccupied	~15 full occupancy events/year	Normal Occupancy: 219 Full Occupancy: 8	0.2	0.45
Corridor/Lobby	M T R F: 7am - 8pm	Same as Weekday Schedule	Same as Weekday Schedule	-	400	0.1	0.45