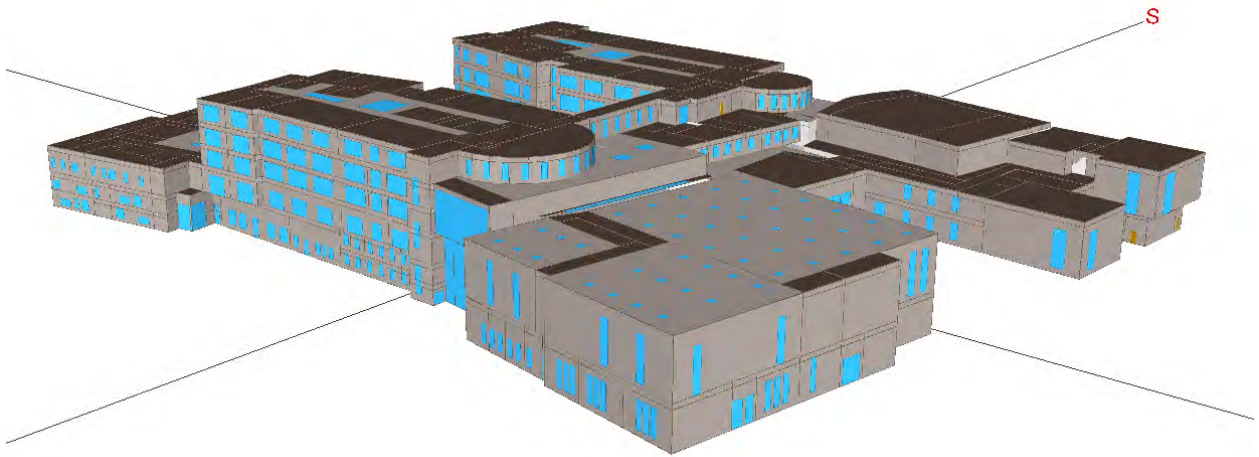




100% CD LEED Submission Energy Model Report

Arlington High School

Massachusetts Avenue
Arlington, MA



January 29, 2021

Project # 181230-000

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1. EXECUTIVE SUMMARY

A series of energy models have been developed for the new Arlington High School building. Arlington High School will be an approximately 423,000 SF high school facility in Arlington, Massachusetts. The building features standard classrooms, maker space, an auditorium, gymnasium, administrative office space, and a central spine with commons/plaza-type areas. In addition to normal school-day occupancy during the week, there will be after-hours usage for community activity and afterschool programs.

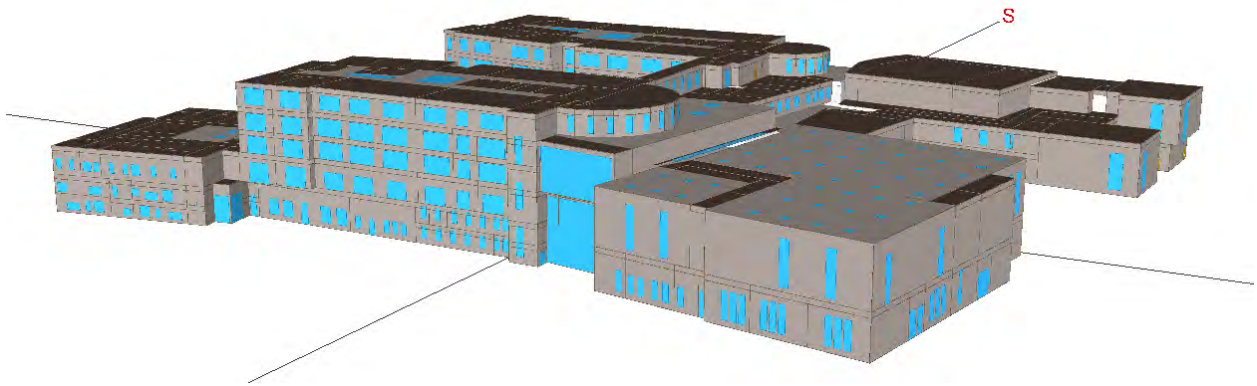
The Proposed Model is based on the 100% CD drawings set, sequence of operations and equipment selections and subsequent discussions with the design team.

A LEED baseline model has been developed under ASHRAE 90.1-2010 Appendix G guidelines to determine the cost savings and potential LEED points for the proposed design. The below table shows the results; the current design saves 33.6% versus the LEED baseline and is potentially eligible for 13 LEED points (not including additional points from any on site PV generation).

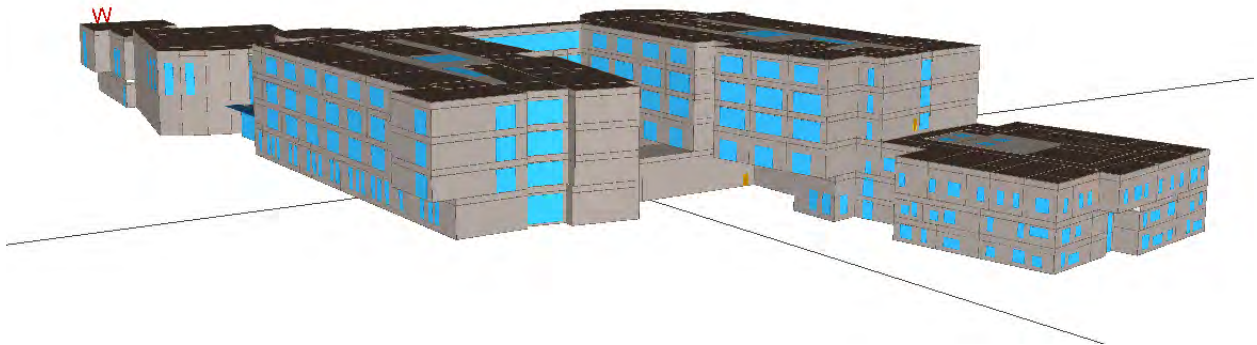
| RESULTS SUMMARY | ANNUAL ELECTRICITY CONSUMPTION (KWH) | ANNUAL ELECTRICITY COST (\$) | EUI (kbtu/sf/yr) | Cost Savings vs. Baseline (\$) | % Cost Savings vs. Baseline | LEED Points |
|-----------------|--------------------------------------|------------------------------|------------------|--------------------------------|-----------------------------|-------------|
| Baseline Model | 4,622,435 | \$987,814 | 37.2 | \$336,422 | 33.6% | 13 |
| Proposed Design | 3,069,611 | \$656,015 | 24.7 | | | |

Energy Model Images

Northwest Corner View



Southeast Corner View



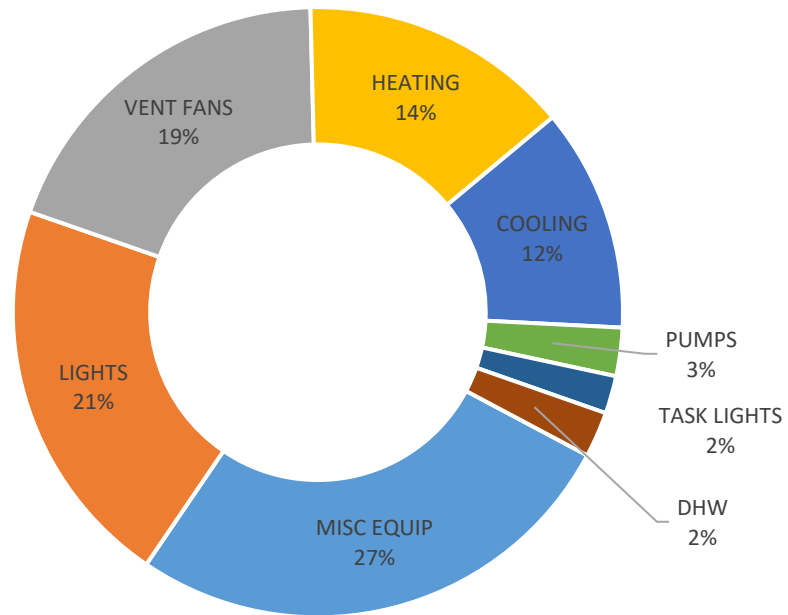
Energy Modeling Disclaimer

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.

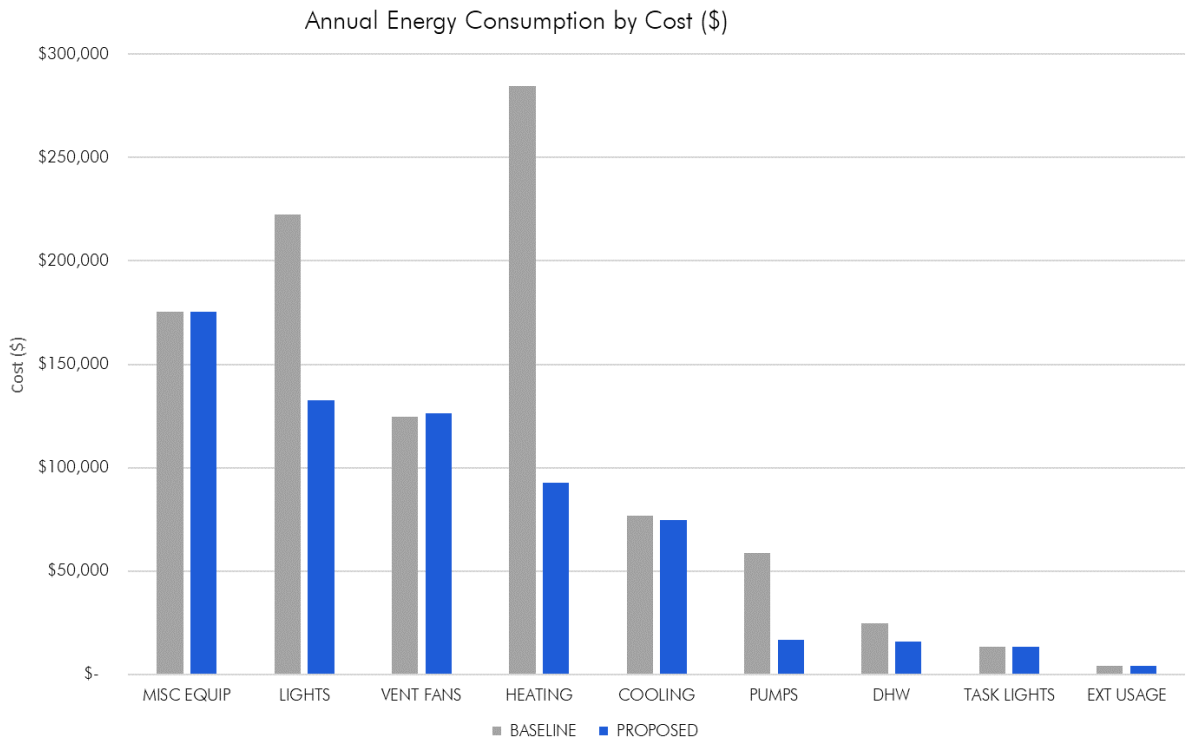
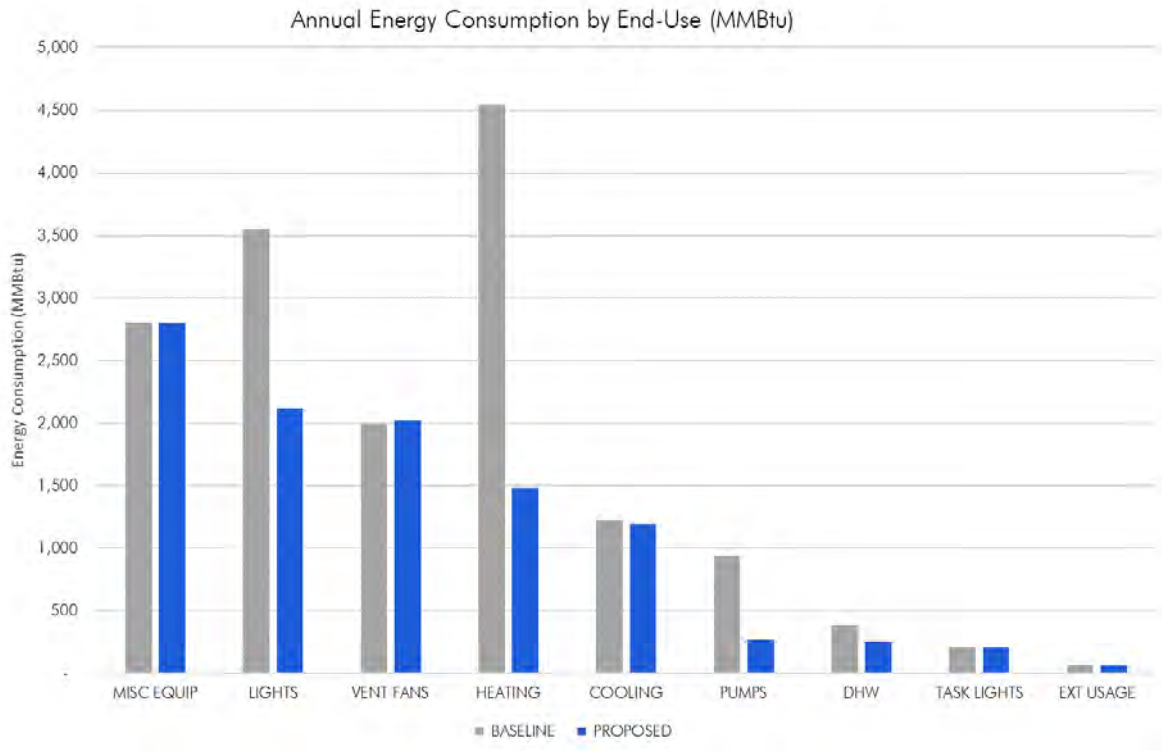
ENERGY MODEL RESULTS

The following chart show a breakdown of energy consumption by end use for the proposed design

Energy Consumption by End-Use (MMBtu)



The below charts show annual energy end-use breakdown for the Proposed Design and the ASHRAE 90.1-2010 Appendix G Baseline, broken out Annual Cost and Site Energy Consumption:



ENERGY MODEL INPUTS

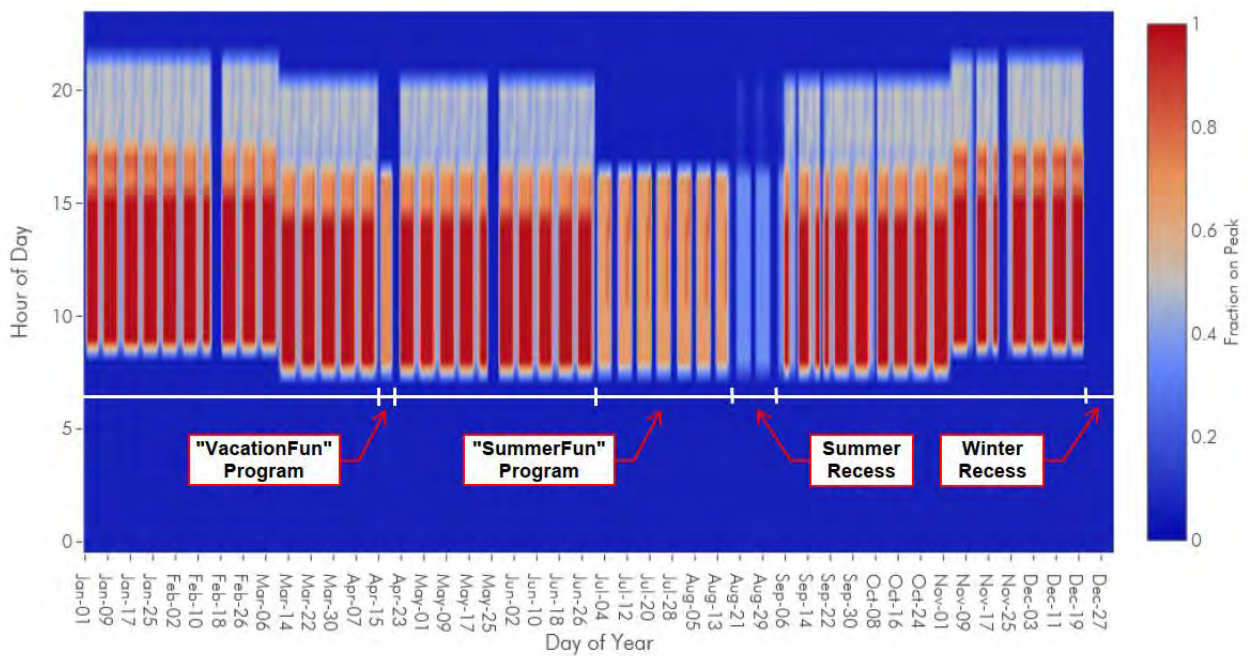
Project and Site Information

| | |
|----------------------|-----------------------------|
| Weather | Boston, MA – TMY3 format |
| Orientation | Plan North = True North |
| Electric Rate | Energy Charge: \$0.2137/kWh |
| Gas Rate | Gas Charge: \$1.036/therm |

Schedule and Occupancy

A detailed annual schedule has been incorporated into the energy model based on Arlington High School’s actual operational schedule and projected building occupation. The below heatmap describes the overall program intensity throughout the year and by time of day. Building program intensity is positively correlated with the intensity of red in the diagram.

Annual Building Program Intensity



Occupancy schedules include “VacationFun” and “SummerFun” programs, winter and summer recess, as well as scheduled holidays outlined in the following section. Additional major program types include schedules for regular classrooms, extended classrooms, gym spaces, auditorium spaces, community school offices and district admin offices. Extended hour programs use designated spaces scattered throughout the building including both classroom wings in addition to the Athletic and Performing Arts wings. These spaces by floor include:

- 1st floor spine and FACS classrooms
- All classrooms and corridors on the second floor including the auditorium and gymnasium
- Half of the classrooms in the Humanities Wing on the third floor and classrooms in the music wing
- Half of the classrooms in the Humanities Wing on the 4th and 5th

Refer to the Appendix section of this report for similar heatmaps for each major program type.

Program Specific Schedule and Occupancy

From September through June, the building is open during the week to staff and students from 6:00 am to 10:00 pm and closed on weekends. Typical school day hours are from 8:00 am to 3:00 pm at peak student, faculty and staff occupancy with modified occupancy from 3:00 pm to 5:00 pm for lingering occupants. Typical after school hours are from 5:00 pm to 10:00 pm at reduced occupancy from community school students/faculty, in addition to athletes and performing arts students using the gymnasium and auditorium. Adult evening classes take place during after school hours on some weekdays from 5:00 to 10:00 pm. District admin and Community school offices are open year round from 8:00 am to 5:00 pm during the week, including during vacation programs. Additionally, the building is occupied for five weeks from July to mid-August for the “SummerFun” program and a vacation week in April for the “VacationFun” program. Vacation programs run from 8:00 am to 5:00 pm on weekdays, using extended-hour classrooms, gyms, and auditoriums as mentioned in the previous section.

Scheduled Holidays

The below table represents scheduled holidays in which the school building is assumed to be completely closed. Assumptions for holiday closings were taken from Arlington Public High School’s online school calendar. HRU’s/ventilation units and building occupancy/internal loads are assumed to be off (or, in the case of lighting and plug loads, at minimums values), and space temperature setpoints are assumed to be set back for the entirety of the following scheduled days:

| Date | Holiday |
|--|----------------------|
| Jan 1 st | New Year’s Day |
| Feb 15 th – 18 | Presidents Day |
| Apr 20 th – 22 nd | Spring recess |
| May 24 th – 27 th | Memorial Day weekend |
| Aug 17 th – Sep 5 th | Summer recess |
| Sep 3 rd | Labor Day |
| Sep 10 th | Rosh Hashanah |
| Sep 19 th | Yom Kippur |
| Oct 8 th | Columbus Day |
| Nov 12 th | Veterans Day |
| Nov 21 st – 23 rd | Thanksgiving recess |
| Dec 21 th – Jan 1 st | Winter recess |

Occupant Density

Occupant quantities are calculated per ASHRAE 90.1-2007 User's Manual, ASHRAE 62.1-2010 default occupant density, and where specific information was available, based on discussions about projected occupancy of Arlington Public High School.

| Space Type | Proposed (sf/person) |
|------------------------|----------------------|
| Office/Admin | 275 |
| Corridor | 750 |
| MER/BOH | 1000 |
| Classroom | 29 |
| Science/Art Classrooms | 75 |
| Lobby | 500 |
| Auditorium | 50 |
| Cafeteria | 150 |
| Gym | 225 |

Geometry and Architecture

| Zoning | Based on June 2020 60%CD Revit Model |
|------------------------|--|
| Gross Area | <ul style="list-style-type: none"> ▪ Classrooms: 147,600 <u>sf</u> ▪ Administrative Office: 49,000 <u>sf</u> ▪ Gym: 30,400 <u>sf</u> ▪ Auditorium: 12,600 <u>sf</u> ▪ Cafeteria: 12,700 <u>sf</u> ▪ Corridors: 105,700 <u>sf</u> ▪ Back of House: 65,800 <u>sf</u> <p>Total: 423,800 <u>sf</u></p> |
| Floor to Floor Heights | <ul style="list-style-type: none"> ▪ 1st Floor: 12'- 0" ▪ 1st Floor Mezzanine: 12'- 0" ▪ 2nd Floor: 18'- 0" ▪ 3rd Floor: 14'- 0" ▪ 4th Floor: 14'- 0" ▪ 5th Floor: 15'- 0" |

| | Baseline Design (ASHRAE 901-2010 values) | Proposed Design |
|---|--|---|
| Window-to-Wall Ratio | Same as Proposed | 18.1% |
| Curtainwall Glazing Performance (assembly values) | U-assembly = 0.45 (curtainwall) U-assembly = 0.8 (entrance door) U-assembly = 0.55 (metal framing (all other)) SHGC = 0.4 VLT = 0.44 | Values based off 100%CD drawings: U-assembly = 0.35 (curtainwall) U-assembly = 0.74 (entrance door) U-assembly = 0.27 (windows, fixed) U-assembly = 0.29 (windows, operable) U-assembly = 0.31 (large Curtainwall) SHGC = 0.37 (CW - South, East, West facing) SHGC = 0.51 (CW - North facing) SHGC = 0.22 (Fixed windows) SHGC = 0.18 (Operable windows) SHGC = 0.355 (Large CW - South, East, West facing) SHGC = 0.31 (Large CW – North facing) VLT = 0.68 (all windows) |
| Sunshades | None | None |
| Skylight Performance | U-assembly = 1.17 SHGC = 0.39 | U-assembly = 0.45 SHGC = 0.37 VLT = 0.43 |
| Above Grade Walls, Steel Frame | U-assembly = 0.064 | U-assembly (Gym & Performing Arts wing) = 0.034 U-assembly (All other) = 0.048 |
| Roof – Insulation entirely above deck | U-assembly = .048 | U-assembly = 0.025 |
| Opaque Doors | U-assembly = 0.7 (swinging) | U = 0.37 |

Internal Electrical Loads

| | Both Models (unless otherwise noted) |
|--------------------|--|
| Lighting | Overall Building LPD <ul style="list-style-type: none"> ▪ Proposed Design: 0.61 W/sf ▪ Baseline Design: 1 W/sf See below table for detailed lighting summary using space-by-space method |
| Specialty Lighting | <ul style="list-style-type: none"> ▪ Auditorium stage lighting: 80 kW peak, assumed diversity 5% mon-thur, 100% from 3 – 7 pm fri and 4 – 6pm sat, 0% otherwise ▪ Blackbox stage lighting: 15 kW peak, assumed diversity same as auditorium ▪ Exterior lighting: 3.8 kW peak, 0% from 8 am – 9pm, 100% during unoccupied hours |

| | |
|---------------------------------------|--|
| Daylighting | Daylighting in all primary sidelighted areas |
| Equipment (includes diversity) | <ul style="list-style-type: none"> ▪ Classroom/Science/Art spaces: 0.5 W/sf ▪ CAD Lab: 0.75 W/sf ▪ Office/Admin spaces: 0.75 W/sf ▪ Gym/Auditorium/Corridor: 0.5 W/sf ▪ BOH spaces: 0.25 W/sf |
| Specialty Equipment | <ul style="list-style-type: none"> ▪ Kitchen Load: 135 kW peak, assumed diversity 55% during weekdays from 8am – 2pm, 5% after hours, 0% during weekends and holidays ▪ Elevator Load: 10 kW peak, assumed diversity 30% during day, 0% at night (off fully during holidays) ▪ IT Load: 10 kW peak, assumed diversity 80% during day and 40% at night (year round) |

| Lighting Summary Table - Space-by-Space Method | | | | |
|--|---------|---------|---------------|---------------|
| Space Type | WATTS | AREA | Proposed W/SF | Baseline W/SF |
| Auditorium Seating | 38,182 | 12,977 | 2.94 | 0.79 |
| Classroom | 57,880 | 114,099 | 0.51 | 1.24 |
| Conference/Meeting/Multipurpose | 20,297 | 31,610 | 0.64 | 1.23 |
| Corridor < 8 ft | 37,210 | 81,098 | 0.46 | 0.66 |
| Dining Area | 15,299 | 21,657 | 0.71 | 0.65 |
| Dressing/Fitting Room for Theater | 456 | 674 | 0.68 | 0.4 |
| Electrical/Mechanical | 4,473 | 10,491 | 0.43 | 0.95 |
| Food Preparation | 2,388 | 3,090 | 0.77 | 0.99 |
| Classroom Lab | 5,022 | 9,744 | 0.52 | 1.28 |
| Lobby | 9,503 | 21,502 | 0.44 | 0.9 |
| Performing Arts Lobby | 2,328 | 3,435 | 0.68 | 2 |
| Locker Room | 3,118 | 6,809 | 0.46 | 0.75 |
| Open Office | 1,444 | 3,662 | 0.39 | 0.98 |
| Closed Office | 4,738 | 7,699 | 0.62 | 1.11 |
| Restroom | 5,549 | 8,852 | 0.63 | 0.98 |
| Stairway | 3,595 | 14,638 | 0.25 | 0.69 |
| Storage | 10,068 | 19,852 | 0.51 | 0.63 |
| Workshop | 13,756 | 12,627 | 1.09 | 1.59 |
| Fitness Area | 3,334 | 6,380 | 0.52 | 0.72 |
| Gym Court | 14,600 | 24,041 | 0.61 | 1.2 |
| Library - Reading Area | 1,731 | 3,794 | 0.46 | 0.93 |
| Sorting Area | 450 | 885 | 0.51 | 0.94 |
| Exam/Treatment | 1,949 | 3,457 | 0.56 | 1.66 |
| NA | 0 | 681 | | |
| | 257,372 | 423,756 | 0.61 | 1.00 |



Airside HVAC Performance Details

| Airside Systems | Baseline Design | Proposed Design |
|------------------------------------|---|--|
| <p>Thermostat Setpoints</p> | <p>Same as Proposed</p> | <p>75°F Cooling / 70°F Heating Setback: 80°F Cooling / 65°F Heating during unoccupied hours</p> |
| <p>Air Systems</p> | <p><u>1st Floor PIU System</u></p> <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 7,266 cfm ▪ Ventilation: 5,020 cfm <p><u>2nd Floor PIU System</u></p> <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 21,761 cfm ▪ Ventilation: 10,075 cfm <p><u>3rd Floor PIU System</u></p> <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 26,786 cfm ▪ Ventilation: 12,401 cfm <p><u>4th Floor PIU System</u></p> <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 34,733 cfm ▪ Ventilation: 16,081 cfm <p><u>5th Floor PIU System</u></p> <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 32,051 cfm ▪ Ventilation: 14,839 cfm <p><u>Auditorium PIU System</u></p> | <p><u>Classroom Wings:</u></p> <ul style="list-style-type: none"> ▪ (4) 100% outside air Heat Recovery Units (HRU's #1,2,4,5), CHW from chillers, HW from heat pump loop) with secondary air Fan Coil Boxes or Fan Powered Boxes (CHW/HW from heat pump loop) ▪ Total Design Flow: 63,200 cfm ▪ Average heat recovery effectiveness: 70% ▪ Total Fan Static (supply/return): 8"/5.5" <p><u>Athletics Wing:</u></p> <ul style="list-style-type: none"> ▪ (4) 100% outside air Heat Recovery Units (HRU's #11,12,13,14), CHW/HW from heat pump loop (primary air only) ▪ Total Design Flow: 44,640 cfm ▪ Average heat recovery effectiveness: 70% ▪ Total Fan Static (supply/return): 6.6"/4.1" <p><u>Performing Arts Wing:</u></p> <ul style="list-style-type: none"> ▪ (3) 100% outside air Heat Recovery Units (HRU's #6,7,8), CHW/HW from heat pump loop (primary air only serving auditorium), with VRF serving music classrooms ▪ Total Design Flow: 21,510 cfm ▪ Average heat recovery effectiveness: 83% ▪ Total Fan Static (supply/return): 6.2"/4.7 <p><u>All other regularly-occupied spaces:</u></p> <ul style="list-style-type: none"> ▪ (4) 100% outside air Heat Recovery Units (HRU's #3,9,10,15), CHW/HW from heat pump loop (primary air only) ▪ HRU Total ventilation: 21,790 cfm |

| | | |
|--|--|--|
| | <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 9,931 cfm ▪ Ventilation: 3,138 cfm <p><u>Auditorium PSZ (stage, seating and per arts room) System</u></p> <ul style="list-style-type: none"> ▪ App. G System 4: Packaged Single Zone Heat Pump ▪ Fan Power: 0.000768 kW/CFM ▪ Total Flow: 16,555 cfm ▪ Ventilation: 7,531 cfm <p><u>Gym PIU System</u></p> <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 18,040 cfm ▪ Ventilation: 18,040 cfm <p><u>Spine PIU System</u></p> <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 7,534 cfm ▪ Ventilation: 2,561 cfm <p><u>Locker PIU System</u></p> <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 4,069 cfm ▪ Ventilation: 2,787 cfm <p><u>Library PIU System</u></p> <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 6,004 cfm ▪ Ventilation: 2,779 cfm <p><u>Cafeteria PIU System</u></p> | <ul style="list-style-type: none"> ▪ Average heat recovery effectiveness: 73% ▪ Total Fan Static (supply/return): 5.5"/4.9" <p><u>Administrative Office / Preschool / Community Spaces</u></p> <ul style="list-style-type: none"> ▪ Air-cooled VRF System with Heat Recovery, 100% OA Energy Recovery Unit (heat pump loop) ▪ VRF Systems supply fan static: 1.25" (assumed) ▪ ERU Average Total Fan Static(supply/return): 7"/5.2" ▪ Ventilation: 19,910cfm <p><u>Kitchen Space (HV-1)</u></p> <ul style="list-style-type: none"> ▪ Heating and Ventilation System, 100% OA ▪ HV System supply fan static: 2.5" ▪ Ventilation: 5,200 cfm <p><u>Radiant Slab</u></p> <ul style="list-style-type: none"> ▪ 11.5 Btu/h/ft2 Cooling ▪ 36 Btu/h/ft2 Heating <p><u>BOH Spaces:</u></p> <ul style="list-style-type: none"> ▪ Electric Unit Heaters or HW heaters |
|--|--|--|

| | | |
|------------------------|---|---|
| | <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 3,652 cfm ▪ Ventilation: 2,497 cfm <p><u>Admin/Community Office & Preschool PIU System</u></p> <ul style="list-style-type: none"> ▪ App. G System 8: VAV with Parallel Fan Powered Boxes and Reheat ▪ Fan Power: 0.00102 kW/CFM ▪ Total Flow: 26,671 cfm ▪ Ventilation: 10,027 cfm <p><u>Kitchen System</u></p> <ul style="list-style-type: none"> ▪ App. G System 4: Packaged Single Zone Heat Pump ▪ Fan Power: 0.000783 kW/CFM ▪ Total Flow: 5,200 ▪ Ventilation: 5,200 cfm <p><u>BOH Spaces:</u></p> <ul style="list-style-type: none"> ▪ Electric Unit Heaters | |
| Economizer | <p>OA Temperature Economizer on all systems (except Unit Heaters)</p> <p>High limit: 70°F</p> | <p>Dual Enthalpy Economizer on recirculating units (RTU's)</p> <p>High limit: 65°F</p> |
| Energy Recovery | <p>Enthalpy wheel on Baseline systems where required.</p> <p>50% Sensible / 50% Latent Effectiveness</p> | <p>Enthalpy Wheel on all 100% OA Heat Recovery Units serving class wings and 100% OA Energy Recovery Units serving Admin/Community/Pre K spaces</p> |

Waterside HVAC Performance Details

| <u>Waterside Systems</u> | <u>Baseline Design</u> | <u>Proposed Design</u> |
|--------------------------|--|---|
| CHW Source | <p>(2) Water-cooled electric screw chillers, COP-6.1, with cooling tower</p> | <p>(2) air-cooled multistack chillers serving HRU-1,2,4,5, COP-3.04 (NPLV), (6) compressors per module</p> <p>Simultaneous Heating/Cooling Air-cooled heat pumps, 4.99 annual COP in cooling mode, Simultaneous mode 7.32 COP</p> |



| | | |
|---------------------------------|--|---|
| CHW Temperatures | 44°F supply, 56°F return | 44°F supply, 56°F return served by chillers 57°F supply, 63°F return served by air-source heat pumps |
| CHW Flow | Variable Primary | Variable Primary pumps |
| CHW Pump | Primary / Secondary: 22 W/GPM Total | 40 ft. head serving chiller loop 80 ft. head serving heat pump loop |
| CHW Reset | 44°F supply at 80°F and above, 54°F supply at 60°F and below; ramped linearly in between | 45°F supply at 80°F and above, 55°F supply at 60°F and below; ramped linearly in between |
| HW Source | None | Simultaneous Heating/Cooling Air-cooled heat pumps, 2.71 annual COP in heating mode. Electric Boilers when Heat pump is unable to handle entire load. |
| HW Temperatures | n/a | 120°F supply, 100°F return served by air-source heat pumps |
| HW Flow | n/a | Variable Primary |
| HW Pump | n/a | 90 ft. head |
| Heat Rejection | Cooling Tower (two-speed fan) | None |
| Heat Rejection Flow/Pump | 19 W/GPM | n/a |

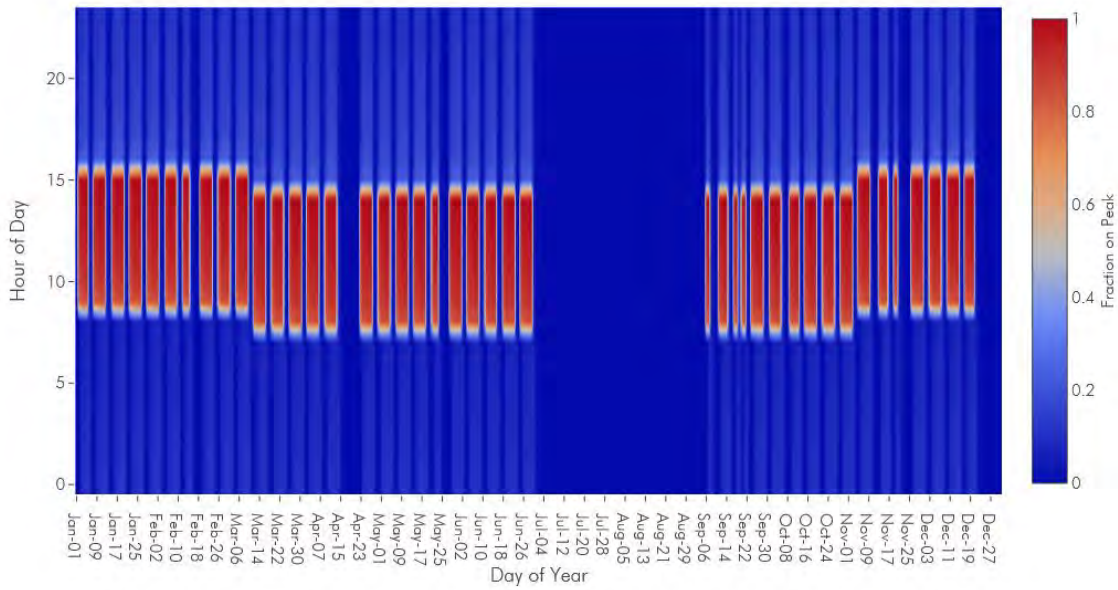
Domestic Hot Water

| | Baseline Design | Proposed Design |
|----------------------|---|---|
| General Usage | Peak values are taken from ASHRAE 90.1-2007 User's Manual, and are based on anticipated occupancy and Btu/person hot water demand: <ul style="list-style-type: none"> School Peak Load: 1.368 MBtu/h | Peak values are taken from ASHRAE 90.1-2007 User's Manual, and are based on anticipated occupancy and Btu/person hot water demand: <ul style="list-style-type: none"> School Peak Load: 1.368 MBtu/h |
| Heaters | Domestic Hot Water Heater: Electric Resistance | Domestic water preheat by HW heat pump loop, 2.71 annual COP, remainder of load handled by electric boiler |

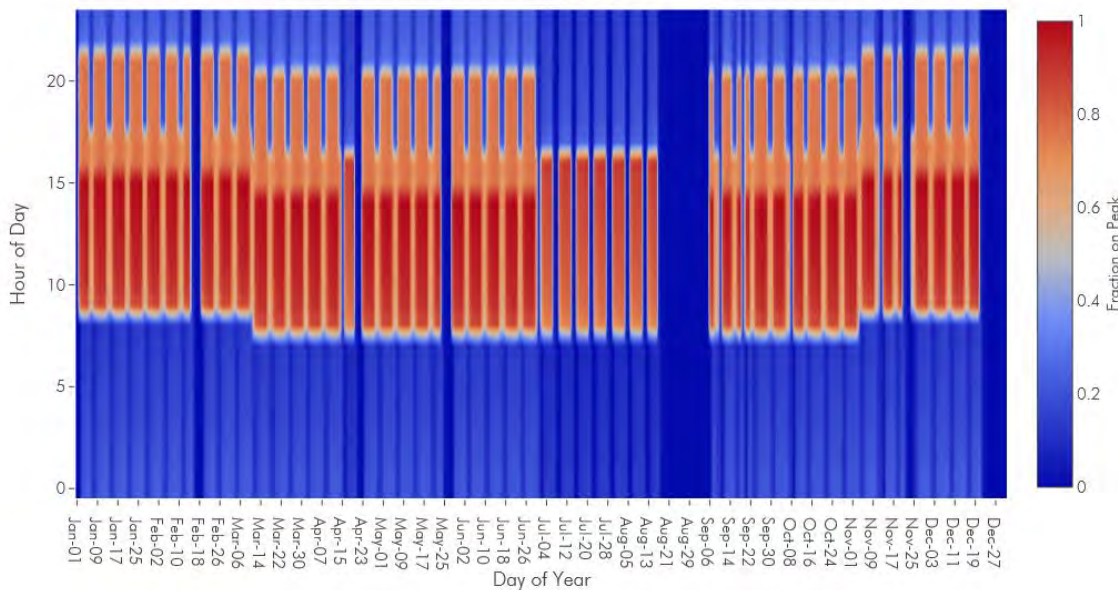
Appendix: Detailed Occupancy Heatmaps

The below heatmaps show the modeled program intensity throughout the year and time-of-day for major program types. Because most energy simulation engines limit schedule assignments to single-hour increments, and because of the ways in which occupancy/load diversity are described within thermal zones, some amount of deviation from the exact program schedules as listed in the report is to be expected. However, the overall seasonal, weekly, and daily trends for each space type are captured as described within the report.

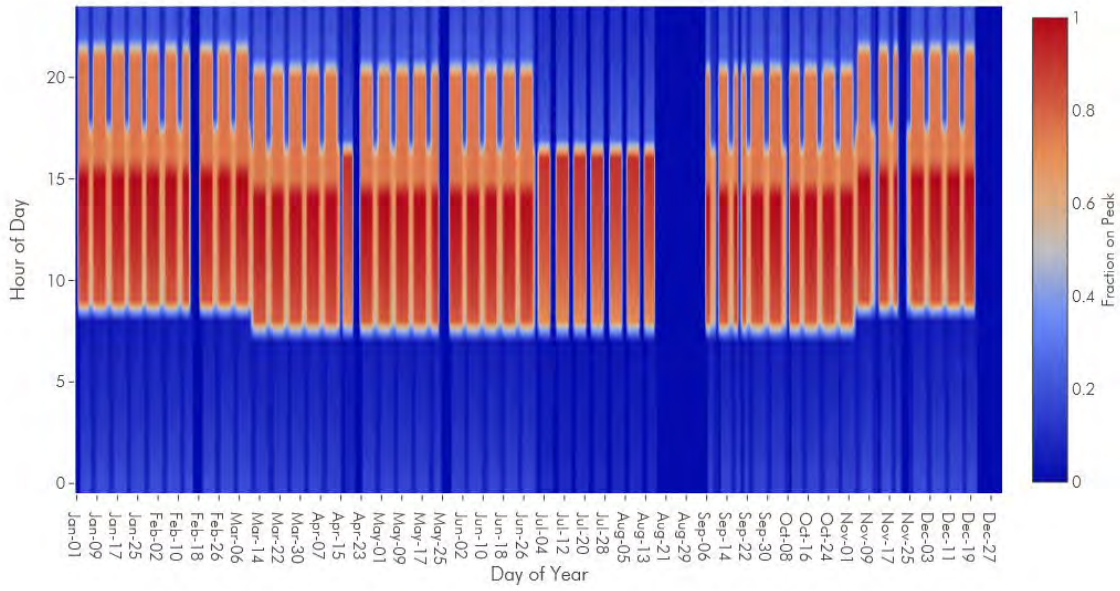
Annual Normal Classroom Program Intensity



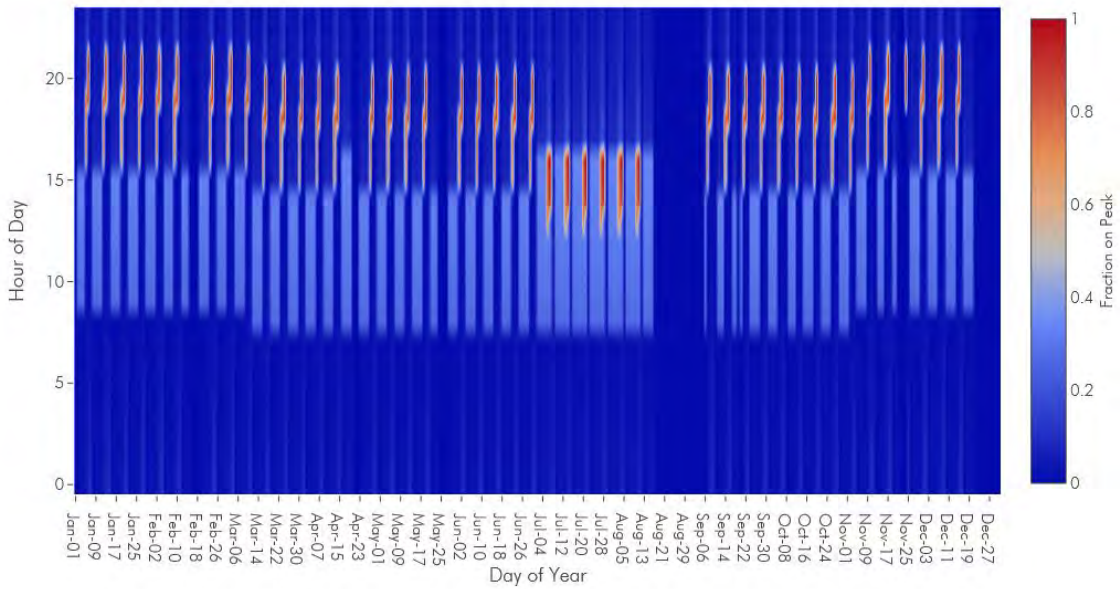
Annual Extended Classroom Program Intensity



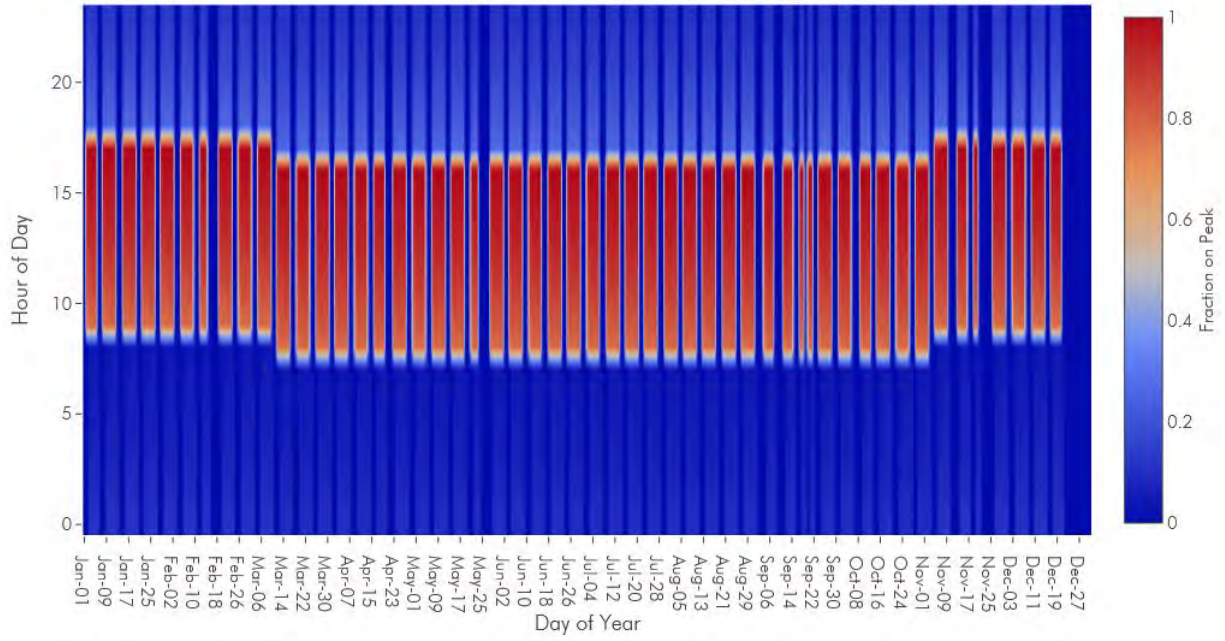
Annual Extended Gym Program Intensity



Annual Auditorium Program Intensity



Annual District Office Program Intensity



Annual Community School Office Program Intensity

