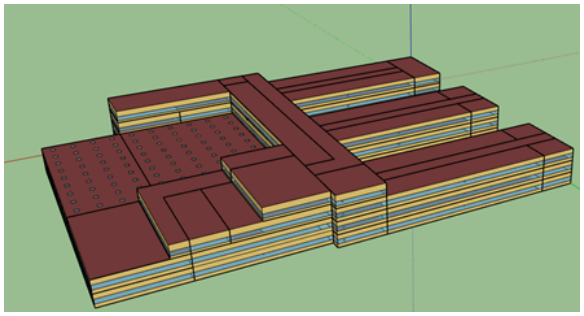
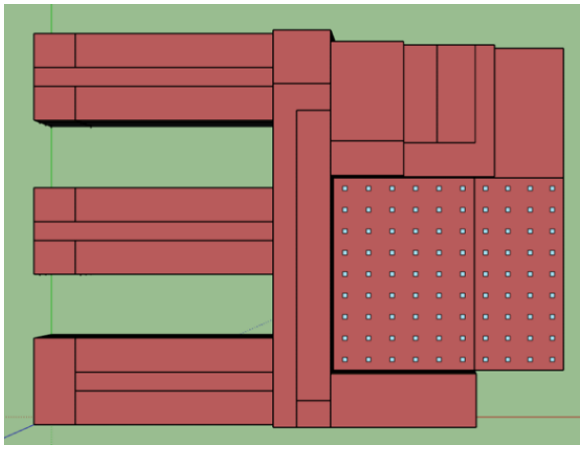
Secondary School Prototype

GENERAL DESCRIPTION





This Secondary School prototype is intended to serve primarily as educational facility with full-service kitchen and dining facilities for the students. The program consists of classroom and instructional spaces located in three wings. The wings attach to common areas such as cafeteria, library, gymnasiums, restrooms, and staff office spaces.

The building geometry has been defined to be representative for public high school anywhere in the State of Massachusetts. There are six (6) variations of this building typology listed below. Two energy code minimum Base Cases use a code minimum performance industry standard system relative to Stretch Energy Code requirements of 10% energy savings above ASHRAE 90.1 2013 Performance Rating Method (Appendix G) and 20% energy savings as represent to potential Stretch Energy Code update. The Passive House and Optimized variations outline both a higher performance, lower capacity Gas-Heating system and an Electric-Heating alternative system along with envelope system improvements. The Secondary School geometry includes **328,000 gross sf** in four (4) stories above grade. The building is slab on grade.

Base Case-10% (Gas-Heat): Secondary School Base Case Scenario is a **code-compliant building**. This building is expected to meet all code requirements of ASHRAE 90.1 2013 and current MA amendments as well as a 10% site energy improvement. Primary heating for the building is gas.

Base Case-20% (Gas-Heat): Secondary School Base Case Scenario is a future **code-compliant building**. This building is expected to meet all code requirements of ASHRAE 90.1 2013 and both current and projected future MA amendments as well as a 20% site energy improvement. Primary heating for the building is gas.

Passive House (Gas-Heat): This building is expected to exceed current Stretch Energy Code requirements including MA amendments. **Primary heating** for the building is **gas** and main heating distribution is a reduced capacity hydronic perimeter heating system.

Passive House (Electric-Heat): This building is expected to exceed current Stretch Energy Code requirements including MA amendments. **Primary heating** for the building is **electric zone-heating systems** with heat pumps.

Optimized (Gas-Heat): is a high-performance **alternate** to Passive house Gas-Heat scenario. Primary change is reflected in envelope system performance.

Optimized (Electric-Heat): is a high-performance **alternate** to Passive house Electric-Heat scenario. Primary change is reflected in envelope system performance.

BUILDING ENVELOPE

Exterior envelope consists of steel framed walls with punched windows, built-up roof, and slab on grade assemblies. Skylights are provided at the gymnasium. Envelope components defined for Passive House and Optimized models apply to both the Gas-Heat and Electric-Heat variations.

Envelope System	Gross Area (GSF)	Net Area (SF)
Above Grade Wall	113,170	88,273
Windows		24,897
Roof	130,046	128,606
Skylight		1,441
Slab-on-Grade		40,446

A. Steel-framed wall: Exterior wall is Steel- framed construction with 2x 6 framing at 16” O.C. Exterior finish consists of face brick. Assembly includes the following components:
   - Brick
   - Exterior Sheathing on 6” Steel Stud wall with 1 ½” air gap (stud cavity insulation described below)
   - Membrane applied air-vapor barrier
   - Exterior insulation (exterior insulation values described below)
   - Galvanized steel brick ties
   - Gypsum wall board
   - Shelf Angles at each floor, aligned with window head

   i. Base Case-10% & Base Case-20%:

i. Stud Cavity: R-19 batt insulation
ii. Exterior Insulation: 2” mineral wool insulation (R-8.4) - total assembly U-value of U-0.055

ii. Optimized / Passive House:
i. Stud Cavity: R-19 batt insulation
ii. Exterior Insulation: 5” mineral wool insulation (R-21) - total assembly U-value of U-0.055 derated with thermal bridge accounting
iii. Apply thermal bridging mitigation strategies:
1. employ stand-off or thermally broken brick shelves and thermal isolation pads (structural grade)
2. thermal isolation blocks at base brick courses

B. Glazing assembly are provided at 35% Window to wall ratio and are expected to consist of operable and fixed type window frames.

i. Base Case-10% & Base Case-20%:
i. Fixed Windows (65% of vertical glazing): Assembly window U-factor 0.32, SHGC-0.38
ii. Operable Windows (35% of vertical glazing): Assembly window U-factor 0.38, SHGC-0.38
iii. Skylights are provided at gymnasium with assembly performance of U-0.38; SHGC-0.38

ii. Optimized:
i. Fixed Windows (65% of vertical glazing): Assembly window **U-factor 0.23** SHGC-0.30
ii. Operable Windows (35% of vertical glazing): Assembly window **U-factor 0.28**, SHGC-0.30
iii. Skylights are provided at gymnasium with assembly performance of U-0.20; SHGC-0.30
iv. Include thermal bridge mitigation strategies for window & skylight installation:
v. Structural thermal insulation pads at window sills
vi. Non-structural thermal insulation pads at jambs and head

iii. Passive House:
i. Include thermal bridge mitigation strategies from Optimized
ii. Fixed Windows (65% of vertical glazing): Assembly window U-factor 0.20, SHGC-0.30
iii. Operable Windows (35% of vertical glazing): Assembly window U-factor 0.20, SHGC-0.30
iv. Skylights are provided at gymnasium with assembly performance of U-0.17; SHGC-0.30
v. Passive House Window assumed properties:
1. triple pane w/ Argon gas fill and at least one low-e coating,
2. Non-metal or hybrid glazing spacer,
3. uPVC / fiberglass / or thermally broken metal window frames

C. Roof:

i. Base Case-10% & Base Case-20%: Built-up roof with roof membrane, R-40 insulation, composite metal decking. Assembly U-0.025.
ii. Passive House & Optimized: Built-up roof with roof membrane, R-45 insulation, composite metal decking. Thermal bridge mitigation with thermal isolation pads at mechanical dunnage and parapet structural thermal breaks. Assembly U-0.025 when thermal bridging is accounted for.

D. Below grade assemblies: (All options): Slab on grade is composed of 6" concrete slab with R-10 insulation for 24" vertical. No insulation is assumed underneath the slab.

E. Infiltration reduction: Whole building air infiltration rates are:
   i. Base Case-10% & Base Case-20%: 1.00 CFM / SF @ 75 Pa no whole building air-leakage testing
   ii. Passive House - 0.077 CFM / SF @ 75 Pa (0.6 ACH50)
      i. In order to achieve this level of air leakage performance, a scope for enhanced envelope commissioning should be assumed.
   iii. Optimized: assume air-leakage testing to code minimum: 0.4 CFM/sf @ 75 pa which would require a whole-building air-leakage test at minimum.

STRUCTURAL SYSTEM

Steel-framed construction; 263' X 167' rectangular building with 2 floors above grade 26' height. All applicable codes and load criteria should be applied.

MECHANICAL SYSTEM

DESCRIPTION

A. **Base Case-10%:** HVAC system for general spaces consists of Air Handling units (VAV), perimeter radiator system, chillers, boilers, and cooling towers. Auditorium, Gym, Cafeteria and kitchen spaces are served by single zone dx/furnace units.
B. **Passive House / Optimized (Gas-Heat)/ Basecase-20%**: HVAC system for general spaces consists of DOAS & fan coils units, chillers, boilers, and cooling towers. Auditorium, Gym, Cafeteria and kitchen spaces are served by single-zone dx/furnace units.
C. **Passive House / Optimized (Electric-Heat):** HVAC system for general spaces consists of DOAS & fan coils units, chillers, boilers, and cooling towers. Auditorium, Gym, Cafeteria and kitchen spaces are served by single-zone dx/furnace units.

MECHANICAL DESIGN CRITERIA:

The following mechanical design criteria is for reference only.

1. Space temperature and Humidity
    a. Summer: 75F, 55% RH maximum
    b. Winter: 70F
2. Ambient design Conditions
    a. Summer: 87F DB; 71F WB
    b. Winter: 7F
3. Ventilation
    a. Auditorium-0.078 cfm/sf+6.5 cfm/person
    b. Cafetaria-0.234 cfm/sf+9.75 cfm/person
    c. Class-0.156 cfm/sf+13 cfm/person
    d. Corridor-0.078 cfm/sf
    e. Elec/Mech-0.156 cfm/sf
    f. Gym-0.39 cfm/sf
    g. Kitchen-0.91 cfm/sf
    h. Library-0.156 cfm/sf+13 cfm/person
    i. Lobby-0.078 cfm/sf
    j. Office-0.078 cfm/sf+6.5 cfm/person
    k. Restroom-0.078 cfm/sf
4. **Filtration:** MERV 6 pre-filters and MERV-14 final filters
5. **Noise:** All MEP systems shall be designed to maximum 40dBA permissible background noise.
6. Internal load
    a. Equipment- 1.4 Watts/ sf. (General)
    b. Lighting- 0.6 watts/ sf.
    c. Occupancy- 43 sf./ person
7. **Duct leakage**
    a. Baseline: All ductwork to be sealed according to mechanical code requirements.
    b. Passive House (Gas & Electric-Heat): All ductwork to be sealed according to mechanical code requirements. In addition, all ventilation air ductwork to be Aerosealed in order to further reduce duct leakage. An Aersoseal specification can be found here - https://aeroseal.com/wp-content/uploads/2018/05/aeroseal-com-specs-180522.pdf
    c. Optimized (Gas & Electric-Heat): All ductwork to be sealed according to mechanical code requirements.

CHILLED WATER SYSTEM

Base Case-10%/ Basecase-20%/ Passive house/ Optimized: Chilled water requirement for conditioned spaces is provided via chiller/ cooling tower plant. During shoulder months, chilled water supply temperature shall be reset to 54F via BMS controls. Chilled water plants are configured as primary/ secondary pumps. Primary pumps interlock with cooling tower for heat rejection.

2- water cooled chillers with a capacity of 300 tons each provide 44°F water to the Air handling units. The system will operate with a 10°F temperature differential. Variable-speed cooling tower provided a total of 750 tons capacity of heat rejection.

Hydronic Cool Component	Capacity
Central Plant: Chiller-centrifugal—water cooled – 6.6 COP efficiency.	(2) 300 tons each
Central Plant: Cooling tower (Variable-speed).	(1) 750 tons each
CHW primary secondary pumps, Cooling tower pump.	

Passive House/ Optimized Electric heat: Cooling plant capacity to be reduced for Air-Water heat pump capacity.

HOT WATER HEATING SYSTEM

A. **Base Case-10%:** Hotwater boiler provides hot water to baseboard radiators and air handling units. Baseboards are provided at the perimeter to provide primary heating to zones. Control valves are provided to each space to provide temperature control. A total of 6,400 lineal feet of capacity is to be provided with perimeter radiator. Costs to include architectural enclosure for perimeter system.

   The hot water plant shall be arranged as primary variable pumping system. All pumps will be provided with variable frequency drives.

Hydronic Heat Component	Capacity
Central Plant: Gas-fired Boiler – 88% thermal efficiency	(3) 1,500 kBTU/h each
Fin-Tube Radiators (baseboards)	6,400 lineal feet

Classroom & Office Zones for perimeter heat	
Hot Water Loop Pump	

B. **Basecase-20%:** Boiler provides hot water to fan-coils units and air handling units. Control valves are provided to each space to provide temperature control. Supply temperature shall be reset to 120 F based on outside temperature (160F at 20F and below, 140 F at 50F and above, ramped linearly in-between)

   The hot water plant shall be arranged as primary variable pumping system. All pumps will be provided with variable frequency drives.

Hydronic Heat Component	Capacity
Central Plant: Gas-fired Boiler – 95% thermal efficiency	(3) 1,300 kBTU/h each
Fan coil units	2,100 kBtu/h
Hot Water Loop Pump	

C. **Passive House(Gas-Heat)**: Boiler provides hot water to fan-coils units and air handling units. Control valves are provided to each space to provide temperature control. Supply temperature shall be reset to 120 F based on outside temperature (160F at 20F and below, 140 F at 50F and above, ramped linearly in-between)

   The hot water plant shall be arranged as primary variable pumping system. All pumps will be provided with variable frequency drives.

Hydronic Heat Component	Capacity
Central Plant: Gas-fired Boiler – 95% thermal efficiency	(3) 1,100 kBTU/h each
Fan coil units	1,580 kBtu/h
Hot Water Loop Pump	

D. **Optimized (Gas-Heat)**: Boiler provides hot water to fan-coils units and air handling units. Control valves are provided to each space to provide temperature control. Supply temperature shall be reset to 120 F based on outside temperature (160F at 20F and below, 140 F at 50F and above, ramped linearly in-between)

   The hot water plant shall be arranged as primary variable pumping system. All pumps will be provided with variable frequency drives.

Hydronic Heat Component	Capacity

Central Plant: Gas-fired Boiler – 95% thermal efficiency	(3) 1,200 kBTU/h each
Fan coil units	1,900 kBtu/h
Hot Water Loop Pump	

E. **Passive House (Electric-Heat)**: Boiler provides hot water to fan-coils units and air handling units. Control valves are provided to each space to provide temperature control. Supply temperature shall be reset to 120 F based on outside temperature (160F at 20F and below, 140 F at 50F and above, ramped linearly in-between)

The hot water plant shall be arranged as primary variable pumping system. All pumps will be provided with variable frequency drives.

Hydronic Heat Component	Capacity
Central Plant: Air-Water heat pump* Boiler – 3.2 COP efficiency	(3) 1,100 kBTU/h each
Fan coil units	1,580 kBtu/h
Hot Water Loop Pump	

*Air-Water heat pumps to provide cooling capacity along with heating. Cooling plant capacity to be adjusted.

F. **Optimized (Electric-Heat)**: Boiler provides hot water to fan-coils units and air handling units. Control valves are provided to each space to provide temperature control. Supply temperature shall be reset to 120 F based on outside temperature (160F at 20F and below, 140 F at 50F and above, ramped linearly in-between)

The hot water plant shall be arranged as primary variable pumping system. All pumps will be provided with variable frequency drives.

Hydronic Heat Component	Capacity
Central Plant: Air-Water heat pump* Boiler – 3.2 COP efficiency	(3) 1,200 kBTU/h each
Fan coil units	1,900 kBtu/h
Hot Water Loop Pump	

*Air-Water heat pumps to provide cooling capacity along with heating. Cooling plant capacity to be adjusted.

AIR-HANDLING UNITS

A. **Base Case-10%:**

- VAV-Typical : units are provided for classrooms and general areas in each floor with integrated outside air, CHW cooling and hot water coils. Supply & Return Fans are equipped with Variable frequency drives for variable flow. Heating coil (HW) is provided to temper outside air to 55°F-60°F. Each unit is provided with 100% economizer and energy recovery.

- PSZ-Cafeteria, Gym, Auditorium, AuxGym: Single -zone units with integrated outside air provided for Cafeteria and Gym spaces. DX coils, furnace provide fully conditioned air to meet zone thermostat requirements. Units are capable of 100% economizer and energy recovery.

- PSZ- Kitchen: Single -zone unit with integrated outside air provided for Kitchen space. DX coils, furnace provide fully conditioned air to meet zone thermostat requirements. Units are capable of 100% economizer.

Air Loop	# of units	Supply Flow rate (cfm)	Outdoor Air flow rate (cfm)	Htg. Coil Capacity (kbtu/h)	Clg. Coil Capacity (tons)	Unit type/ Efficiency	Economizer	Energy recovery
PSZ- Audi	1	12,000	6,000	381	22	DX: 11.88 EER; Furnace: 88% eff	Yes	50%
PSZ-Aux Gym	1	11,000	6000	328	18	DX: 11.0 EER; Furnace: 88% eff	Yes	50%
PSZ-Cafetaria	1	9,000	6000	369	17	DX: 11.0 EER; Furnace: 88% eff	Yes	50%
PSZ-Gym	1	14,000	9000	477	24	DX: 11.0 EER; Furnace: 88% eff	Yes	50%
PSZ-Kitchen	1	3,000	3,000	319	12	DX: 12.1 EER; Furnace: 88% eff	Yes	None.
VAV-Typical	4	37,500	19,500	622	116	CHW/ HW coils	Yes	50%

B. **Basecase-20% (Gas-Heat):**

DOAS-Typical: units are provided for classrooms and general areas in each floor with integrated outside air, CHW cooling and hot water coils. Supply & Return Fans are equipped with Variable frequency drives for variable flow. Heating coil (HW) is

provided to temper outside air to 55°F-60°F. Each unit is provided with 100% economizer, energy recovery and CO2 based demand control ventilation. Fan motor to have static pressure reset control.

PSZ-Cafeteria, Gym, Auditorium, AuxGym: Single -zone units with integrated outside air provided for Cafeteria and Gym spaces. DX coils, furnace provide fully conditioned air to meet zone thermostat requirements. Units are capable of 100% economizer and energy recovery. Supply fans to be equipped with variable frequency drive.

PSZ- Kitchen: Single -zone unit with integrated outside air provided for Kitchen space. DX coils, furnace provide fully conditioned air to meet zone thermostat requirements. Units are capable of 100% economizer. Supply fans to be equipped with variable frequency drive.

Air Loop	# of units	Supply Flow rate (cfm)	Outdoor Air flow rate (cfm)	Htg. Coil Capacity (kbtu/h)	Clg. Coil Capacity (tons)	Unit type/ Efficiency	Economizer	Energy recovery
PSZ- Audi	1	12,000	6,000	381	22	DX: 16 EER; Furnace: 97% eff	Yes	70%
PSZ-Aux Gym	1	11,000	6000	328	18	DX: 15.0 EER; Furnace: 97% eff	Yes	70%
PSZ-Cafetaria	1	9,000	6000	369	17	DX: 15.0 EER; Furnace: 97% eff	Yes	70%
PSZ-Gym	1	14,000	9000	477	24	DX: 15.0 EER; Furnace: 97% eff	Yes	70%
PSZ-Kitchen	1	3,000	3,000	319	12	DX: 15.0 EER; Furnace: 97% eff	Yes	None.
DOAS-Typical	4	19,500	19,500	335	22	CHW/ HW coils	Yes	70%

C. **Passive House (Gas-Heat):**
Same air-handling units defined under the Base Case -20 % (Gas Heat) except for Energy recovery efficiency of 80%

D. **Optimized (Gas-Heat)**: Same air-handling units defined under the Base Case, but energy recovery is 75%.

E. **Passive House (Electric-Heat):**

DOAS-Typical: units are provided for classrooms and general areas in each floor with integrated outside air, CHW cooling and hot water coils. Supply & Return Fans are equipped with Variable frequency drives for variable flow. Heating coil (HW) is provided to temper outside air to 55°F-60°F. Each unit is provided with 100% economizer, energy recovery and CO2 based demand control ventilation. Fan motor to have static pressure reset control.

PSZ-Cafeteria, Gym, Auditorium, AuxGym: Single -zone units with integrated outside air provided for Cafeteria and Gym spaces. DX, heat pump coils provide fully conditioned air to meet zone thermostat requirements. Units are capable of 100% economizer and energy recovery. Supply fans to be equipped with variable frequency drive.

PSZ- Kitchen: Single -zone unit with integrated outside air provided for Kitchen space. DX, heat pump coils provide fully conditioned air to meet zone thermostat requirements. Units are capable of 100% economizer. Supply fans to be equipped with variable frequency drive.

Air Loop	# of units	Supply Flow rate (cfm)	Outdoor Air flow rate (cfm)	Htg. Coil Capacity (kbtu/h)	Clg. Coil Capacity (tons)	Unit type/ Efficiency	Economizer	Energy recovery
PSZ- Audi	1	12,000	6,000	381	22	DX: 16 EER. Heat Pump: 3.2 COP	Yes	80%
PSZ-Aux Gym	1	11,000	6000	328	18	DX: 15.0 EER; Heat Pump: 3.2 COP	Yes	80%
PSZ-Cafetaria	1	9,000	6000	369	17	DX: 15.0 EER; Heat Pump: 3.2 COP	Yes	80%
PSZ-Gym	1	14,000	9000	477	24	DX: 15.0 EER; Heat Pump: 3.2 COP	Yes	80%
PSZ-Kitchen	1	3,000	3,000	319	12	DX: 15.0 EER; Heat Pump: 3.2 COP	Yes	None.
DOAS-Typical	4	19,500	19,500	335	22	CHW/ HW coils	Yes	80%

F. **Optimized (Electric-Heat):** Same air-handling units defined under the Passive House (Electric-Heat) scenario, but energy recovery is 75%.

TERMINAL UNITS / DISTRIBUTION

A. **Base Case-10%:** Variable Air Volume Terminal units are to be installed to provide zone control to space. Each terminal box is controlled from a wall mounted thermostat within the respective zone. When the space temperature rises above the set temperature the VAV box will modulate open, if the space temperature continues to raise the box will continue to open until it is at its maximum position or until the space temperature is satisfied. The box will modulate to a closed position if the temperature in the space begins to drop.

B. **Basecase-20%/Passive House / Optimized (Gas-Heat)**: Damper boxes provide ventilation air to each zone through ductwork distribution. Four-pipe fan coils provide cooling & heating loads for the building. Each unit is controlled via zone thermostat.

Hydronic Heat Component	Capacity
Fan coil units	149 units (1/classroom) + 124,000 sf. - ducted units. Unit distribution to be estimated based on unit/ sf.

Passive House / Optimized (Electric-Heat): Same as Passive house/Optimized (Gas-heat).

ELECTRICAL SYSTEMS

Total Transformer load (All cases) = (2) 1000 kVA

A. Lighting and Electrical system controls are required to meet IECC2018 with MA Amendments.

   Lighting A total of 117,600 watts of interior lighting is to be provided in the building. Exterior lighting of 3,381 watts is to be provided. Based on 20-watt CF fixture, 170 fixtures are estimated. Standard code compliant lighting controls- Occupancy, vacancy sensors and daylighting controls are to be provided.

B. Electrical: Electrical systems are designed for a total of 114,700 watts of plug loads.
C. Elevator: Building shall have a total of 2 hydraulic elevator. (32.4 kW)
D. HVAC: Mechanical panel load (Cooling +Fan peak): 562 kW
E. Kitchen loads

   Kitchen and dining associated equipment loads are as specified below

   - Reach-in-Freezer: 0.915 kW
   - Reach in Refrigerator: 0.57 kW
   - Other Refrigeration (walk-in freezer, refrigerator): 4.6 kW
   - Electric (Servery, electric cooking) - 31.9 kW

PLUMBING SYSTEMS

A. Domestic Water System
   Building shall have restrooms located at each floor. Hot water is to be provided to restroom and kitchen spaces. Domestic hot water will be generated from 600-gallon storage water heaters(gas) located in central location. Water heater provides 140F hot water. Standard plumbing fixtures, routing, pipe insulation, distribution pumping systems are applicable. A booster heater (6 gal) is to be installed in the kitchen to serve dishwasher needs.
B. Cooking Gas-Demand in Commercial Kitchen: Kitchen loads Gas peak load- 1237 kBtu/h
C. Heating peak demand
   Basecase-10% : 7,200 kBtu/h
   Basecase-20% : 6,000 kBtu/h

   Passive House(Gas-Heat): 5,400 kBtu/h

   Optimized (Gas-Heat): 5,800 kBtu/h

   Passive House / Optimized (Electric/Heat): None.