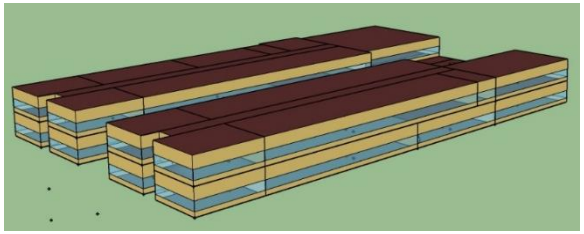
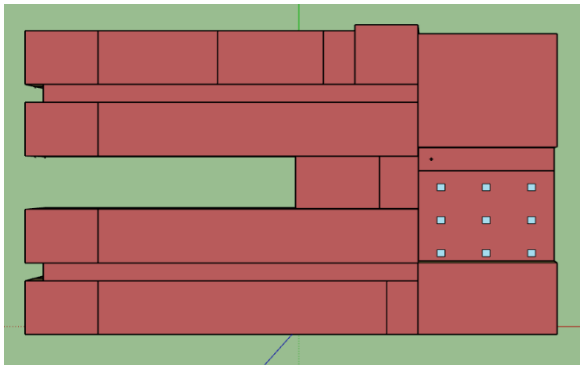
Primary School Prototype





GENERAL DESCRIPTION

This Primary 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 two 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 rural and suburban sites 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 2018 IECC and 2021 IECC with MA Amendments. 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 Primary School geometry includes **73,960 gross sf** in two (2) stories above grade. The building is slab on grade.

Base Case-2018 (Gas-Heat): Primary School Base Case Scenario is a **code-compliant building**. This building is expected to meet all code requirements of Massachusetts energy code (IECC2018) with one anticipated MA amendments (Window U-0.30). Primary heating for the building is gas.

Base Case-2021 (Gas-Heat): Primary School Base Case Scenario is a future **code-compliant building**. This building is expected to meet all IECC2021 code requirements of Massachusetts energy code (IECC2021) which includes MA amendments. Primary heating for the building is gas.

Passive House (Gas-Heat): This building is expected to exceed code requirements of Massachusetts Energy Code. **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 code requirements of Massachusetts Energy Code. **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. The primary design change is window thermal performance and reduced ventilation heat recovery and related HVAC impacts.

Optimized (Electric-Heat): is a high-performance **alternate** to Passive house Electric-Heat scenario. The primary design change is window thermal performance and reduced ventilation heat recovery and related HVAC impacts.

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	47,447	37,029
Windows		10,418
Roof	39,968	39,824
Skylight		144
Slab-on-Grade		36,843

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-IECC2018 & Basecase-IECC2021:
        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-IECC2018:
        i. Fixed Windows (65% of vertical glazing): Assembly window U-factor 0.33, SHGC-0.40
        ii. Operable Windows (35% of vertical glazing): Assembly window U-factor 0.39, SHGC-0.40
        iii. Skylights are provided at gymnasium with assembly performance of U-0.42; SHGC-0.40
    ii. Base Case-IECC2021:
        i. Fixed Windows (65% of vertical glazing): Assembly window U-factor 0.30, SHGC-0.38
        ii. Operable Windows (35% of vertical glazing): Assembly window U-factor 0.30, SHGC-0.38
        iii. Skylights are provided at gymnasium with assembly performance of U-0.42; SHGC-0.40
    iii. 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. Include thermal bridge mitigation strategies for window & skylight installation:
        iv. Structural thermal insulation pads at windowsills
        v. Non-structural thermal insulation pads at jambs and head
    iv. 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 (2018 & 2021): 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-IECC2018 – 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 & Basecase-IECC2021: 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-IECC2018 & Basecase-IECC2021:** HVAC system in the building consists of Air Handling units (VAV), Packaged rooftops (PSZ), perimeter radiator system, gas-fired boilers.
B. **Passive House / Optimized (Gas-Heat)**: HVAC system consists of DOAS Air handler and packaged single-zone (dx/furnace) units.
C. **Passive House / Optimized (Electric-Heat):** HVAC system consists of DOAS Air handler and non-ducted VRF indoor/outdoor 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. Base Cases (2018 & 2021): 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

No Chiller plant

HOT WATER HEATING SYSTEM

A. **Base Case-IECC2018:**(2) 1,300 kBtu/h natural draft 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 2,200 lineal feet of capacity is to be provided with perimeter radiator. Costs to include architectural enclosure for perimeter system. Supply temperature shall be reset to 150 F based on outside temperature (180F at 20F and below, 150 F at 50F and above, ramped linearly in-between).

   The hot water plant shall be arranged as primary variable pumping system with an estimated 165 gpm flow rate total. All pumps will be provided with variable frequency drives.

Hydronic Heat Component	Capacity
Central Plant: Gas-fired Boiler – 88% thermal efficiency	(2) 1,300 kBTU/h each
Fin-Tube Radiators (baseboards) Classroom & Office Zones for perimeter heat	2,200 lineal feet (560 btu/h/feet)
Hot Water Loop Pump	165 gpm

A. **Basecase-IECC2021:**(2) 1,100 natural draft 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 2,200 lineal feet of capacity is to be provided with perimeter radiator. Costs to include architectural enclosure for perimeter system. Supply temperature shall be reset to 150 F based on outside temperature (180F at 20F and below, 150 F at 50F and above, ramped linearly in-between).

   The hot water plant shall be arranged as primary variable pumping system with an estimated 140 gpm flow rate total. All pumps will be provided with variable frequency drives.

Hydronic Heat Component	Capacity
Central Plant: Gas-fired Boiler – 88% thermal efficiency	(2) 1,100 kBTU/h each

Fin-Tube Radiators (baseboards) Classroom & Office Zones for perimeter heat	2,200 lineal feet (560 btu/h/feet)
Hot Water Loop Pump	140 gpm

B. **Passive House (Gas):** (2) 500 MBH natural draft 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 820 lineal feet of capacity is to be provided with perimeter radiator. Supply temperature shall be reset to 150 F based on outside temperature (180F at 20F and below, 150 F at 50F and above, ramped linearly in-between)

The hot water plant shall be arranged as primary variable pumping system with an estimated 65 gpm flow rate total. All pumps will be provided with variable frequency drives.

Hydronic Heat Component	Capacity
Central Plant: Gas-fired Boiler – 88% thermal efficiency	(2) 500 kBTU/h each
Fin-Tube Radiators (baseboards) Classroom & Office Zones for perimeter heat	820 lineal feet
Hot Water Loop Pump	65 gpm

C. **Optimized (Gas):** (2) 700 MBH natural draft 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 1200 lineal feet of capacity is to be provided with perimeter radiator. Supply temperature shall be reset to 150 F based on outside temperature (180F at 20F and below, 150 F at 50F and above, ramped linearly in-between)

The hot water plant shall be arranged as primary variable pumping system with an estimated 90 gpm flow rate total. All pumps will be provided with variable frequency drives.

Hydronic Heat Component	Capacity
Central Plant: Gas-fired Boiler – 88% thermal efficiency	(2) 700 kBTU/h each
Fin-Tube Radiators (baseboards)	1200 lineal feet

Classroom & Office Zones for perimeter heat	
Hot Water Loop Pump	90 gpm

D. **Passive House & Optimized (Electric-Heat)**: no hot-water heating system.

AIR-HANDLING UNITS

A. **Base Case-IECC2018 & 2021:**

- Primary heating provided through baseboard hydronic system. Air handling units provide ventilation air and cooling as described below.
- (VAV-Pod1,2) - units are provided for classrooms in each pod with integrated outside air, dx coils and hot water coils. Supply & Return Fans are equipped with Variable frequency drives for variable flow. Heating coil (gas furnace) is provided to temper outside air to 55F-60F. Each unit is provided with 100% economizer and energy recovery.
- VAV-Common- units are provided for all common areas (Lobby, corridor, library) with integrated outside air, dx coils and hot water coils. Supply & Return Fans are equipped with Variable frequency drives for variable flow. Heating coil is provided to temper outside air to 55F-60F. Each unit is provided with 100% economizer and energy recovery.
- PSZ-Cafeteria, Gym- 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-Cafeteria	1	5,000	4,000	177	17	DX: 11.88 EER; Furnace: 88% eff	Yes	50%
PSZ-Gym	1	4,000	4000	177	13	DX: 12.1 EER; Furnace: 88% eff	Yes	50%
PSZ-Kitchen	1	3,000	2,000	177	10	DX: 12.1 EER; Furnace: 88% eff	Yes	None.
VAV- Pod1	1	18,000	10,000	280	60	DX: 10.78 EER. HW coils	Yes	50%

VAV-Pod2	1	16,000	9,000	252	53	DX: 10.78 EER HW coils	Yes	50%
VAV-Common Areas	1	13,000	6,000	265	43	DX: 10.78 EER HW coils	Yes	50%

B. **Passive House (Gas-Heat):** Same air-handling units' configuration as Basecase, but energy recovery is 80%.

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-Cafeteria	1	5,000	4,000	71	17	DX: 12.2 EER; Furnace: 97% eff	Yes	80%
PSZ-Gym	1	4,000	4000	71	13	DX: 13.5 EER; Furnace: 97% eff	Yes	80%
PSZ-Kitchen	1	3,000	2,000	177	10	DX: 13.5 EER; Furnace: 97% eff	Yes	None.
VAV- Pod1	1	16,000	10,000	112	60	DX: 15.3 EER. (2-speed) HW coils	Yes	80%
VAV-Pod2	1	15,000	9,000	101	53	DX: 15.3 EER. (2-speed) HW coils	Yes	80%
VAV-Common Areas	1	11,000	6,000	67	43	DX: 15.3 EER. (2-speed) HW coils	Yes	80%

C. **Optimized (Gas-Heat)**: Same air-handling units' configuration as Basecase, but energy recovery is 75%.

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-Cafeteria	1	5,000	4,000	88	17	DX: 12.2 EER; Furnace: 97% eff	Yes	75%
PSZ-Gym	1	4,000	4000	88	13	DX: 13.5 EER; Furnace: 97% eff	Yes	75%

PSZ-Kitchen	1	3,000	2,000	177	10	DX: 13.5 EER; Furnace: 97% eff	Yes	None.
VAV- Pod1	1	17,000	10,000	140	60	DX: 15.3 EER. (2-speed) HW coils	Yes	75%
VAV-Pod2	1	15,000	9,000	126	53	DX: 15.3 EER. (2-speed) HW coils	Yes	75%
VAV-Common Areas	1	11,000	6,000	84	43	DX: 15.3 EER. (2-speed) HW coils	Yes	75%

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

- PSZ-Cafeteria, Gym- 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.
- PSZ- Kitchen- Single -zone unit with integrated outside air provided for Kitchen space. DX coils(heat pump) provide fully conditioned air to meet zone thermostat requirements. Units are capable of 100% economizer.
- DOAS Pod1,2, Common - units are provided for classrooms in each pod serving outside air. Dedicated OA units have dx coils and heat pump coil. Supply & Return Fans are equipped with Variable frequency drives for variable flow. Heating coil (gas furnace) is provided to temper outside air to 55F-60F. Each unit is provided with 100% economizer and energy recovery.

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-Cafeteria	1	5,000	4,000	71	17	DX: 12.2 EER; Heat pump: 3.2 COP	Yes	80%
PSZ-Gym	1	4,000	4000	71	13	DX: 13.5 EER; Heat pump: 3.2 COP	Yes	80%
PSZ-Kitchen	1	3,000	2,000	177	10	DX: 13.5 EER; Heat pump: 3.2 COP	Yes	None.
DOAS- Pod1	1	10,000	10,000	112	7	DX: 15.3 EER; Heat pump: 3.2 COP	Yes	80%

DOAS-Pod2	1	9,000	9,000	101	7	DX: 15.3 EER; Heat pump: 3.2 COP	Yes	80%
DOAS-Common Areas	1	6,000	6,000	67	4	DX: 15.3 EER; Heat pump: 3.2 COP	Yes	80%

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

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-Cafeteria	1	5,000	4,000	88	17	DX: 12.2 EER; Heat pump: 3.2 COP	Yes	75%
PSZ-Gym	1	4,000	4000	88	13	DX: 13.5 EER; Heat pump: 3.2 COP	Yes	75%
PSZ-Kitchen	1	3,000	2,000	177	10	DX: 13.5 EER; Heat pump: 3.2 COP	Yes	None.
DOAS- Pod1	1	10,000	10,000	140	9	DX: 15.3 EER; Heat pump: 3.2 COP	Yes	75%
DOAS-Pod2	1	9,000	9,000	126	8	DX: 15.3 EER; Heat pump: 3.2 COP	Yes	75%
DOAS-Common Areas	1	6,000	6,000	84	5	DX: 15.3 EER; Heat pump: 3.2 COP	Yes	75%

TERMINAL UNITS / DISTRIBUTION

A. **Base Case-IECC2018 & Base Case-IECC2021:** 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. **Passive House / Optimized (Gas-Heat)**: Same as Base Case.
C. **Passive House / Optimized (Electric-Heat)**: Damper boxes provide ventilation air to each zone through ductwork distribution. Ceiling mounted VRF indoor units provide cooling & heating to each thermal zone as outlined below:

Equipment	# of units	Supply Flow rate	Htng. Coil Capacity (kbtu/h)	Clng. Coil Capacity (tons)
VRF – ceiling mounted.	74 (2/ classroom)		-	-
VRF – ducted	22,000 sf.	Serves corridors, shared offices, library		
VRF –Outdoor unit Cooling EER: 10.06; Heating COP (47F)- 3.2	7			15

ELECTRICAL SYSTEMS

Total Transformer load (All cases) = (2) 300 kVA

A. Lighting and Electrical system controls are required to meet IECC2018 with MA Amendments, which is substantially the same as 2021 IECC requirements.

   Lighting A total of 64,847 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 80,377 watts of plug loads.
C. Elevator: Building shall have a total of 1 hydraulic elevator.
D. HVAC:
   a. Base Case 2018 & 2021: Mechanical panel load (Cooling +Fan peak): 276 kW
   b. Passive House / Optimized (Gas-Heat): Mechanical panel load (Cooling + Fan peak): 280 kW
   c. Passive House / Optimized (Electric-Heat): Mechanical panel load (Cooling + Fan peak): 162 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 200-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- 820 kBtu/h

C. HVAC:

   a. Base Case-IECC2018: Mechanical system load: 3,800 MBH
   b. Base Case-IECC2021: Mechanical system load: 3,300 MBH
   c. Passive House (Gas-Heat): Mechanical system load: 1,400 MBH
   d. Optimized (Gas-Heat): Mechanical system load: 1,850 MBH
   e. Passive House / Optimized (Electric-Heat): Mechanical system load: None.

D. Alternative – estimate gas hook-up and connectivity costs.