

## Multifamily High-rise

### GENERAL DESCRIPTION

The multifamily high-rise prototype is intended to represent a multifamily building w/ 90% market rate apartments and 10% affordable apartments. It is a 26-story building with residential amenity spaces on floors 1 and 2 and 26; and apartments on floors 3 through 25 in a double loaded corridor configuration. The building is slab on grade with no cellar or ground floor commercial spaces.

The building geometry has been defined to be representative for urban sites in the State of Massachusetts. The multifamily high-rise geometry includes **267,000 gross sf** in twenty-six (26) stories above grade. There is an additional 2,500 sf of unenclosed mechanical space at the roof level that is not included in the modeled building gross sf. The building is slab on-grade. There are six (6) variations of this building typology defined as follows:

**Base Case - 10% (Gas-Heat & DHW):** Multifamily high-rise Base Case Scenario is a current 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 per current energy stretch code requirements. Primary heating for the building is a centralized gas boiler plant with water sourced heat pumps (WSHPs) in each apartment. Primary DHW for the building is a central gas boiler plant.

**Base Case - 10% (All Electric):** Multifamily high-rise Base Case Scenario is a current 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 per current energy stretch code requirements. Primary heating for the building is provided via a centralized heat pump water heating plant with electric resistance boilers to provide supplemental heating capacity during peak heating conditions with WSHPs in each apartment. Primary DHW for the building is a central electric boiler plant.

**Base Case - 20% (Gas-Heat & DHW):** Multifamily high-rise Base Case Scenario is an estimated 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 a centralized gas boiler plant with WSHPs in each apartment. Primary DHW for the building is a central gas boiler plant.

**Base Case - 20% (All Electric):** Multifamily high-rise Base Case Scenario is an estimated 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 provided via a centralized heat pump water heating plant with WSHPs in each apartment. Primary DHW for the building is a central heat pump water heater plant.

**Passive House (Elec-Heat & Gas DHW):** This building is expected to exceed current Stretch Energy Code requirements including MA amendments. Primary heating for the building is a centralized gas boiler plant with WSHPs in each apartment. Primary DHW for the building is a central gas boiler plant.

**Passive House (All Electric):** This building is expected to exceed current Stretch Energy Code requirements including MA amendments. Primary heating for the building is provided via a centralized heat pump water heating plant with WSHPs in each apartment. Primary DHW for the building is a central heat pump water heater plant.

## BUILDING ENVELOPE

The exterior envelope consists of cold formed steel framed back up walls with a metal panel rainscreen facade, built-up roof, and slab on grade assemblies.

Envelope System	Gross Area (GSF)	Net Area (SF)
Above Grade Wall	122,549	91,469
Windows		Total = 30,480 (25% WWR) Punched = 27,678 Storefront = 2,802
Opaque Doors		599
Roof		10,941
Floor slab on grade		10,788

A. Exterior Wall: The multifamily high-rise prototype assumes a cold formed steel framed back up wall construction with a metal panel rain screen façade system for all cases. The table below summarizes design differences among the various scenarios.

<p><b>Base Cases - 10% (gas heat / DHW &amp; all electric)</b></p> <p>Façade Attachment: non-thermally broken clip system          Exterior Insulation: 3" of mineral wool          Cavity Insulation: 6" of mineral wool  <i>Effective Assembly R-value = R-15 *with thermal bridging accounted for</i></p>
<p><b>Base Cases – 20% (gas heat / DHW &amp; all electric)</b></p> <p>Façade Attachment: non-thermally broken clip system          Exterior Insulation: 3" of mineral wool          Cavity Insulation: 6" of mineral wool  <i>Effective Assembly R-value = R-15 *with thermal bridging accounted for</i></p>
<p><b>Passive House Cases (gas DHW &amp; all electric)</b></p> <p>Façade Attachment: fiberglass girt system (ie. GreenGirts)          Exterior Insulation: 3.5" of mineral wool          Cavity Insulation: 6" of mineral wool  <i>Effective Assembly R-value = R-20 *with thermal bridging accounted for</i></p>

B. Roof:

- i. **Base Cases 10% and Base Cases 20%**: Built-up roof with roof membrane, R-40 insulation, composite metal decking. Assembly effective R-value = R-35 when thermal bridging is accounted for.
- ii. **Passive House**: 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 effective R-value = R-40 when thermal bridging is accounted for.

B. Slab on Grade:

- i. **All Cases**: Uninsulated slab on grade. R-10 vertical insulation installed at a minimum depth of 24" below grade is provide at the entire slab on grade perimeter as required by code.

C. Windows:

<p><b>Base Cases - 10% (gas heat / DHW &amp; all electric)</b></p> <p>Punched windows – 27,678 SF (45% fixed, 55% operable)</p> <ul style="list-style-type: none"> <li>- Average double-glazed, thermally broken aluminum frame, U-value = 0.50</li> <li>- Center of Glass SHGC = 0.35</li> </ul> <p>Storefront windows – 2,802 SF (all fixed w/ exception of entry door)</p> <ul style="list-style-type: none"> <li>- Good double-glazed, thermally broken aluminum frame, U-value = 0.42</li> <li>- Center of Glass SHGC = 0.35</li> </ul>
<p><b>Base Cases – 20% (gas heat / DHW &amp; all electric)</b></p> <p>Punched windows – 27,678 SF (45% fixed, 55% operable)</p> <ul style="list-style-type: none"> <li>- Good double-glazed, thermally broken aluminum frame, U-value = 0.25</li> <li>- Center of Glass SHGC = 0.35</li> </ul> <p>Storefront windows – 2,802 SF (all fixed w/ exception of entry door)</p> <ul style="list-style-type: none"> <li>- Good double-glazed, thermally broken aluminum frame, U-value = 0.42</li> <li>- Center of Glass SHGC = 0.35</li> </ul>
<p><b>Passive House Cases (gas DHW &amp; all electric)</b></p> <p>Punched windows – 27,678 SF (45% fixed, 55% operable)</p> <ul style="list-style-type: none"> <li>- Good triple-glazed, thermally broken aluminum frame, U-value = 0.17</li> <li>- Center of Glass SHGC = 0.35</li> </ul> <p>Storefront windows – 2,802 SF (all fixed w/ exception of entry door)</p> <ul style="list-style-type: none"> <li>- Good double-glazed, thermally broken aluminum frame, U-value = 0.42</li> <li>- Center of Glass SHGC = 0.35</li> </ul>

D. Infiltration: Whole building air infiltration rates are:

- i. **Base Cases 10%** – 0.40 CFM / SF @ 75 Pa.
  - i. No whole building air-leakage testing.
- ii. **Base Cases 20%** – 0.25 CFM / SF @ 75 Pa.
  - i. In order to achieve this level of air leakage performance, a scope for basic envelope commissioning.
- iii. **Passive House Cases** - 0.17 CFM / SF @ 75 Pa (0.6 ACH50)
  - i. In order to achieve this level of air leakage performance, a scope for enhanced envelope commissioning and whole building air leakage testing should be assumed.

## STRUCTURAL SYSTEM

Steel-framed construction; 187' X 65' rectangular building with 26 floors above grade with the following floor to floor heights:

- Ground floor = 17' 0"
- Floor 2 = 15' 6"
- Typical floors (3 through 24, except floor 13) = 9' 2"
- Floor 13 = 10' 8"
- Floor 25 = 14' 0"
- Upper floor = 12' 0"

All applicable codes and load criteria should be applied.

## MECHANICAL SYSTEM

### DESCRIPTION

- Base Case - 10% (Gas-Heat & DHW):** Water sourced heat pumps (WSHPs) for space heating and cooling are provided in each unit. A mild temperature hydronic loop distributes water from the central heating and cooling plants to the WSHPs. The central heating plant is a gas fired boiler plant with a nominal efficiency of 95%. The central cooling plant consists of cooling towers. Domestic water heating is provided via a dedicated 95% efficient gas fired boiler plant for DHW. Ventilation is provided to the residential floors via exhaust from each apartment going through a 55% efficient energy recovery ventilator (ERV) and supply air being provided to corridors from the ERV.
- Base Case - 10% (All Electric):** Water sourced heat pumps (WSHPs) for space heating and cooling are provided in each apartment (one per apt.). A mild temperature hydronic loop distributes water from the central heating and cooling plants to the WSHPs. The central space heating plant is a combination of air sourced heat pump water heaters and electric resistance boilers. Cooling is provided to the mild temperature hydronic loop via the central air sourced heat pump water heaters plus cooling towers. Domestic water heating is provided via a dedicated central electric resistance boiler plant for DHW. Ventilation is provided to the residential floors via exhaust from each apartment going through a 55% efficient energy recovery ventilator (ERV) and equal supply air from the ERV being provided to the building's corridors. All amenity and back of house spaces are ventilated at code minimum rates via a 55% efficient ERV.
- Base Case - 20% (Gas-Heat & DHW):** The system configurations are exactly the same as the 10% Better (Gas Heat & DHW) case with the two exceptions that the central gas boiler plant is an improved condensing boiler plant with a nominal

efficiency of 95% and the dedicated DHW gas boiler plant is an improved condensing boiler plant with a nominal efficiency of 95%. Space heating loads are smaller in this scenario when compared to the 10% Better scenario and system heating capacities have been adjusted accordingly for this scenario.

- D. **Base Case - 20% (All Electric):** The system configurations are exactly the same as the Base Case - 10% (All Electric) case with the one exception that the DHW is being provided via a central heat pump water heating plant. Space heating loads are smaller in this scenario when compared to the 10% Better scenario and system heating capacities have been adjusted accordingly for this scenario.
- E. **Passive House (Elec-Heat & Gas DHW):** Water sourced heat pumps (WSHPs) for space heating and cooling are provided in each apartment (one per apt.). A mild temperature hydronic loop distributes water from the central heating and cooling plants to the WSHPs. The central space heating plant comprises of air sourced heat pump water heaters. Cooling is provided to the mild temperature hydronic loop via the central air sourced heat pump water heating plant. Domestic water heating is provided via a central gas-fired condensing boiler plant with a nominal efficiency of 95%. Ventilation is provided to the residential floors via central exhaust from each apartment going through an 83% efficient energy recovery ventilator (ERV) and equal supply air from the ERV being provided to each apartment. All corridors, amenity, and back of house spaces are ventilated at code minimum rates via a 83% efficient ERV.
- F. **Passive House (All Electric):** Exactly the same as the Passive House (Elec-Heat & Gas DHW) case with the one exception that domestic water heating is provided via a central air sourced heat pump water heating plant that is sized to meet year-round loads, including during peak conditions.

## 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. Apartment Exhaust: central exhaust systems, 25 CFM per kitchen + 20 CFM per bathroom (3 bedroom apts have two bathrooms, 65 CFM exhaust)

- b. Make-up Air
  - i. Base case 10% scenarios: bathroom exhaust connected to ERV system, Make-up air delivered to corridors.
  - ii. Base case 20% scenarios: bathroom exhaust connected to ERV system, Make-up air ducted to apartments, includes fire damper.
  - iii. PH scenarios: bathroom & kitchen exhaust connected to ERV system, cost additional ductwork to connect kitchen exhaust to ERV system, make-up air ducted to apartments, includes fire damper, and air-sealing / testing of ductwork.
- c. Common Areas: ASHRAE minimum by space type
- 4. Filtration: MERV 6 pre-filters and MERV-13 final filters
- 5. Noise: All MEP systems shall be designed to maximum 30dBA permissible background noise.
- 6. Unit Mix
  - a. Studios = 25 (each unit contains 1 bathroom)
  - b. 1 BR = 151 (each unit contains 1 bathroom)
  - c. 2 BR = 151 (each unit contains 1 bathroom)
  - d. 3 BR = 25 (each unit contains 2 bathrooms)
- 7. Common Areas - total area = 29,583 SF
  - a. Corridors / stairwells / transition areas = 15,101 SF
  - b. Lobby = 326 SF
  - c. Restrooms = 283 SF
  - d. Offices = 100 SF
  - e. Lounge / Recreation = 3,770 SF
  - f. Exercise Area = 1,596 SF
  - g. Back of House = 4,188 SF
- 8. Occupancy – 905 total. According to RESNET (# of bedrooms + 1, studios count as one bedroom in occupancy calc.
- 9. Building peak total space heating load
  - a. **Base Cases 10%** = 4,885,000 Btu/hr
  - b. **Base Cases 20%** = 3,692,000 Btu/hr
  - c. **Passive House Cases** = 1,367,000 Btu/hr
- 10. Building peak total space cooling load (sensible + latent)
  - a. **Base Cases 10%** = 3,924,000 Btu/hr
  - b. **Base Cases 20%** = 3,924,000 Btu/hr
  - c. **Passive House Cases** = 3,924,000 Btu/hr
- 11. Domestic hot water consumption – 15 gallons of hot water per person per day. “Hot water” refers to water @ 140 degF.
- 12. Apartment Loads

- a. Miscellaneous Loads – 0.62 Watts/sf of dwelling area
- b. Refrigerators – 1 per apt. Energy Star
- c. Dishwashers – 1 per apt. Energy Star
- d. In-Unit Clothes Dryer – 1 per apt. Energy Star. Electric ventless condensing dryer.
- e. In Unit Clothes Washer – 1 per apt. Energy Star. Hot water feed from DHW system.
- f. Cooking – Electric conduction range
- g. Lighting – 1.1 Watts/sf of dwelling area

#### 13. Common Loads

- a. Common Clothes Dryers – 23 total. Electric resistance direct exhaust with dedicated make up air to dryer room(s).
- b. Common Clothes Washers – 23 total. Energy Star. Hot water
- c. Lighting & Plugs
  - i. Storage – 4,219 sf, 0.97 Watts/sf
  - ii. Lobby – 326 sf, 1.00 Watts/sf
  - iii. Corridor / Transition – 15,101 sf, 0.66 Watts/sf
  - iv. Restrooms – 283 sf, 0.85 Watts/sf
  - v. Office – 100 sf, 0.93 Watts/sf
  - vi. Electrical / Mechanical – 4,188 sf, 0.43 Watts/sf
  - vii. Lounge Recreation – 3,770 sf, 0.62 Watts/sf
  - viii. Exercise Area – 1,596 sf, 0.50 Watts / sf + gym equipment

#### 14. Duct leakage

- a. **Base Cases 10% and Base Cases 20%:** All ductwork to be sealed according to mechanical code requirements.
- b. **Passive House Cases:** All ductwork to be sealed according to mechanical code requirements. In addition, all ventilation air ductwork to be Aersealed in order to further reduce duct leakage. An Aerseal specification can be found here - <https://aeroseal.com/wp-content/uploads/2018/05/aeroseal-com-specs-180522.pdf>

## HEATING & COOLING TERMINAL SYSTEMS

### Base Cases 10%:

Ducted water sourced heat pumps in each apartment (1 per apt.) provide heating and cooling to the dwelling units. The water sourced heat pumps are sized according to apartment type:

- Studios – heating = 9,000 BTUH / cooling = 8,000 BTUH (incl. latent)
- 1 BR – heating = 13,500 BTUH / cooling = 12,000 BTUH (incl. latent)
- 2 BR – heating = 16,000 BTUH / cooling = 14,000 BTUH (incl. latent)



- 3 BR - heating = 16,000 BTUH / cooling = 14,000 BTUH (incl. latent)

The terminal WSHP units source heating and cooling energy from a mild temperature hydronic loop throughout the building. This loop will total approximately 11,000 linear feet of piping and will be insulated to code minimum levels.

Common spaces will be heated and cooled with ducted WSHPs with a total capacity of heating = 1,270,000 BTUH / cooling = 1,120,000 BTUH.

#### **Base Cases 20%:**

Ducted water sourced heat pumps in each apartment (1 per apt.) provide heating and cooling to the dwelling units. The water sourced heat pumps are sized according to apartment type:

- Studios – heating = 9,000 BTUH / cooling = 8,000 BTUH (incl. latent)
- 1 BR – heating = 11,000 BTUH / cooling = 10,000 BTUH (incl. latent)
- 2 BR – heating = 13,500 BTUH / cooling = 12,000 BTUH (incl. latent)
- 3 BR - heating = 16,000 BTUH / cooling = 14,000 BTUH (incl. latent)

The terminal WSHP units source heating and cooling energy from a mild temperature hydronic loop throughout the building. This loop will total approximately 11,000 linear feet of piping and will be insulated to code minimum levels.

Common spaces will be heated and cooled with ducted WSHPs with a total capacity of heating = 1,080,000 BTUH / cooling = 970,000 BTUH.

#### **Passive House Cases:**

Ducted water sourced heat pumps in each apartment (1 per apt.) provide heating and cooling to the dwelling units. The water sourced heat pumps are sized according to apartment type:

- Studios – heating = 9,000 BTUH / cooling = 8,000 BTUH (incl. latent)
- 1 BR – heating = 11,000 BTUH / cooling = 10,000 BTUH (incl. latent)
- 2 BR – heating = 13,500 BTUH / cooling = 12,000 BTUH (incl. latent)
- 3 BR - heating = 13,500 BTUH / cooling = 12,000 BTUH (incl. latent)

The terminal WSHP units source heating and cooling energy from a mild temperature hydronic loop throughout the building. This loop will total approximately 11,000 linear feet of piping and will be insulated to code minimum levels.

Common spaces will be heated and cooled with ducted WSHPs with a total capacity of heating = 1,065,000 BTUH / cooling = 955,000 BTUH.

## CENTRAL PLANT HEATING AND COOLING SYSTEMS

### **Base Case 10% (Gas Heat and DHW):**

Heating – x3 gas fired **condensing** boilers with a nominal efficiency of **95%** provide a total capacity of 5,500 kBtu/hr of heating to the mild temperature hydronic loop, helping keep this loop between 60-100 degF year-round.

Cooling - x2 variable speed cooling towers providing a total of 400 tons capacity of heat rejection help keep the mild temperature hydronic loop between 60-100 degF year-round.

The hot and cold water plants shall be arranged as primary/secondary pumping system. All pumps will be provided with variable frequency drives.

### **Base Case 10% (All Electric):**

Heating – x2 air sourced heat pump water heaters with a total capacity of 2,500 kBtu/hr plus an additional electric resistance boiler plant with a total capacity of 3,000 kBtu/hr provides a total heating capacity of 5,500 kBtu/hr to the mild temperature hydronic loop, helping keep this loop between 60-100 degF year-round.

Cooling - x2 variable speed cooling towers providing a total of 170 tons capacity of heat rejection plus the building's x2 air to sourced heat pump water heaters providing an additional total cooling capacity of 230 tons help keep the mild temperature hydronic loop between 60-100 degF year-round.

The hot and cold water plants shall be arranged as primary/secondary pumping system. All pumps will be provided with variable frequency drives.

### **Base Case 20% (Gas Heat and DHW):**

Heating – x3 gas fired condensing boilers with a nominal efficiency of 95% provide a total capacity of 4,000 kBtu/hr of heating to the mild temperature hydronic loop helping keep this loop between 60-100 degF year-round.

Cooling - x2 variable speed cooling towers providing a total of 400 tons capacity of heat rejection help keep the mild temperature hydronic loop between 60-100 degF year-round.

The hot and cold water plants shall be arranged as primary/secondary pumping system. All pumps will be provided with variable frequency drives.

**Base Case 20% (All Electric):**

Heating – x2 air sourced heat pump water heaters with a total capacity of 2,500 kBtu/hr plus an additional electric resistance boiler plant with a total capacity of 1,500 kBtu/hr provides a total heating capacity of 4,000 kBtu/hr to the mild temperature hydronic loop, helping keep this loop between 60-100 degF year-round.

Cooling - x2 variable speed cooling towers providing a total of 170 tons capacity of heat rejection plus the building's x2 air to sourced heat pump water heaters providing an additional total cooling capacity of 230 tons help keep the mild temperature hydronic loop between 60-100 degF year-round.

The hot and cold water plants shall be arranged as primary/secondary pumping system. All pumps will be provided with variable frequency drives.

**Passive House (Elec-Heat & Gas DHW):**

Heating – x3 air sourced heat pump water heaters provides a total heating capacity of 4,300 kBtu/hr to the mild temperature hydronic loop, helping keep this loop between 60-100 degF year-round.

Cooling - The building's x3 air to sourced heat pump water heaters provide a total cooling capacity of 400 tons to help keep the mild temperature hydronic loop between 60-100 degF year-round.

The hot and cold water plants shall be arranged as primary/secondary pumping system. All pumps will be provided with variable frequency drives.

**Passive House (All Electric):**

Heating and Cooling – same as Passive House (Elec-Heat & Gas DHW) case.

**AIR-HANDLING UNITS****Base Cases 10%:**

Each apartment is continuously exhausted at a rate of 45 CFM per bathroom and should comply with code minimum requirements. The apartment exhaust goes through the building's energy recovery units (ERVs). An equal volume of

outdoor is supplied to the residential corridors from the ERVs, however due to fire code requirements restricting airflow from corridors to the apartments, it is assumed that approximately half of the supply air to the corridors is not ever reaching the apartments. As a result, the additional makeup air is pulled through air leaks in the exterior envelope.

The supply and exhaust fans in the ERV are to be equipped with variable frequency drives to maintain a constant flow of air to the building. A DX heating and cooling coil is provided in each ERV to temper supply air to room neutral temperatures before it is delivered to the building. The ERV is provided with a 100% economizer to directly bring in outdoor air when free cooling potential exists.

Common areas are to receive constant balanced ventilation through an ERV according to code minimum rates.

All ductwork is to be sealed to industry standard minimum levels and limit duct leakage to 10%. All ductwork is assumed to have fire dampers at all locations where required by code.

Air Handler	# of units	Supply Flow rate (cfm)	Outdoor Air flow rate (cfm)	Htg. Coil Capacity (kbtu/h)	Clg. Coil Capacity (tons)	Unit type/ Efficiency	Economizer	Sensible Energy Recovery Eff.	Total Fan Eff. (Watts/CFM)
ERV	<b>2</b>	<b>13,200</b>	<b>13,200</b>			<b>HW coil, CW coil</b>	<b>Yes</b>	<b>55%</b>	<b>1.00</b>

**Base Cases 20%:**

The ventilation design is assumed to be exactly the same as the 10% cases with the one exception to the ERV total fan efficiency indicated in the table below.

Air Handler	# of units	Supply Flow rate (cfm)	Outdoor Air flow rate (cfm)	Htg. Coil Capacity (kbtu/h)	Clg. Coil Capacity (tons)	Unit type/ Efficiency	Economizer	Sensible Energy Recovery Eff.	Total Fan Eff. (Watts/CFM)
ERV	<b>2</b>	<b>13,200</b>	<b>13,200</b>			<b>HW coil, CW coil</b>	<b>Yes</b>	<b>55%</b>	<b>1.50</b>

### Passive House Cases:

Each apartment is continuously exhausted at a rate of 25 CFM per kitchen plus 20 CFM per bathroom and comply with code minimum requirements. The apartment exhaust goes through the building's ERVs. An equal volume of outdoor air is supplied to each apartment. At each apartment supply and exhaust register, constant air flow regulators (CAR dampers) are provided to ensure proper airflows are maintained year-round.

The supply and exhaust fans in the ERV are to be equipped with variable frequency drives to maintain a constant flow of air to the building. A DX heating and cooling coil is provided in each ERV to temper supply air to room neutral temperatures before it is delivered to the building. The ERV is provided with a 100% economizer to directly bring in outdoor air when free cooling potential exists.

Common areas are to receive constant balanced ventilation through an ERV according to code minimum rates.

All ductwork is to be sealed to industry standard minimum levels plus receive additional air sealing via the AeroSeal process to limit duct leakage to 3% maximum. All ductwork is assumed to have fire dampers at all locations where required by code.

Air Handler	# of units	Supply Flow rate (cfm)	Outdoor Air flow rate (cfm)	Htg. Coil Capacity (kbtu/h)	Clg. Coil Capacity (tons)	Unit type/ Efficiency	Economizer	Sensible Energy Recovery Eff.	Total Fan Eff. (Watts/CFM)
ERV	2	12,000	12,000			HW coil, CW coil	Yes	83%	0.80

## ELECTRICAL SYSTEMS

### Total Transformer loads

- **Base Case - 10% (Gas-Heat & DHW):** 1,772 kVA
- **Base Case - 10% (All Electric):** 2,803 kVA
- **Base Case - 20% (Gas-Heat & DHW):** 1,739 kVA
- **Base Case - 20% (All Electric):** 2,314 kVA
- **Passive House (Elec-Heat & Gas DHW):** 1,955 kVA

- **Passive House (All Electric):** 2,181 kVA

A. Lighting and Electrical system controls are required to meet IECC2018 with MA Amendments. Standard code compliant lighting controls. Occupancy, vacancy sensors and daylighting controls are to be provided in common areas

## DOMESTIC WATER / PLUMBING SYSTEMS

All plumbing fixtures are to be low flow fixtures. All cases are assumed to have a central domestic water heating (DHW) system, with continuous hot water recirculation year-round. Thermostatic balancing valves are to be provided on every hot water riser to ensure a properly balanced system. DHW circulation piping is to be laid out in a “box-format” to improve the system’s distribution efficiency. Total DHW recirculation piping is estimated to be 10,950 linear feet and is insulated to code minimum levels. All branch piping / crotons to the apartments are to be insulated to code minimum levels.

The recirculation pumping system will have a total pumping power of 3.0 BHP.

Domestic pressure booster pumps will be provided with a total pumping power of 20.0 BHP and will be equipped with a variable frequency drive.

### **Base Case 10% (Gas Heat and DHW):**

Domestic water heating will be provided via x3 95% efficient gas fired condensing boilers that provides a total DHW heating capacity of 3,000 kBtu. This DHW gas boiler plant will be a separate boiler plant from the space heating boiler plant. 1,500 gallons of domestic hot water storage will be provided and will store water at a minimum temperature of 140 degF.

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

### **Base Case 10% (All Electric):**

Domestic water heating will be provided via a central electric resistance boiler plant with a total DHW heating capacity of 3,000 kBtu/hr. This DHW electric boiler plant will be a separate boiler plant form the space heating boiler plant. 1,500 gallons of domestic hot water storage will be provided and will store water at a minimum temperature of 140 degF.

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

**Base Case 20% (Gas Heat and DHW):**

Domestic water heating will be provided via x3 95% efficient gas fired boilers that provides a total DHW heating capacity of 3,000 kBtu. This DHW gas boiler plant will be a separate boiler plant from the space heating boiler plant. 1,500 gallons of domestic hot water storage will be provided and will store water at a minimum temperature of 140 degF.

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

**Base Case 20% (All Electric):**

Domestic water heating will be provided a central air sourced heat pump water heating plant with a total DHW heating capacity of 3,000 kBtu/hr. This DHW heat pump water heating plant will be a separate heat pump water heating plant from the space heating heat pump plant. 3,000 gallons of domestic hot water storage will be provided and will store water at a minimum temperature of 140 degF. An electric resistance heating element within the storage tanks will be provided to help keep the tank temperature above the minimum temperature threshold.

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

**Passive House (Elec-Heat & Gas DHW):**

Domestic water heating will be provided via a 95% efficient gas fired boiler plant with a total DHW capacity of 3,000 kBtu/hr. 1,500 gallons of domestic hot water storage will be provided.

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

**Passive House (All Electric):**

Domestic water heating will be provided a central air sourced heat pump water heating plant with a total DHW heating capacity of 3,000 kBtu/hr. This DHW heat pump water heating plant will be a separate heat pump water heating plant from the space heating heat pump plant. 3,000 gallons of domestic hot water storage will be provided and will store water at a minimum temperature of 140 degF. An electric resistance heating element within the storage tanks will be provided to help keep the tank temperature above the minimum temperature threshold.

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

## RENEWABLE ENERGY

No renewable energy systems are assumed in the following scenarios: Base Case 10% (Gas Heat and DHW), both Base Cases 20%, and both Passive House Cases.

**Base Case 10% (All Electric):** A 70 kW photovoltaic located on site to meet the requirements of IECC 2018 C406.5. Given the limited available roof space due to the building's compact floor plate, and the need for rooftop space for mechanical equipment, a canopy PV array should be assumed.