

Boiler Electrification Options

A Hybrid Hot Water Heat Pump Solution

Project Name: Boiler Electrification

Project Number: 124001

Location: Ann Arbor Friends Meeting House, 1420 Hill St, Ann Arbor, MI 48104

Date: September 4, 2026

EXECUTIVE SUMMARY

Inclination Engineering reviewed practical options for reducing natural gas use and carbon emissions at the Ann Arbor Friends Meeting House. The current heating and domestic hot water systems rely primarily on gas-fired equipment, and the existing building construction limits where new piping, ductwork, and equipment can be installed. Because of these constraints, the most practical path is a hybrid electrification approach. This strategy would allow the Meeting House to shift much of its heating and hot water load to efficient electric heat pump equipment while keeping the existing boiler available for backup heat during the coldest weather.

The report presents two upgrade options for consideration. Option 1 focuses on central heating electrification by adding air-to-water heat pumps, making targeted improvements to existing heat emitters, replacing the addition's heating and cooling system, and consolidating domestic hot water into a new heat pump water heater. Option 2 builds on this approach by adding dedicated heating and cooling for the Meeting Hall with a cold-climate mini-split heat pump, which improves comfort and further reduces the amount of time the boiler would need to operate. Both options would require electrical upgrades. A separate ventilation alternative for the Meeting Hall is also included for the Meeting's consideration.

BUDGET CONSTRUCTION COSTS

The rough budget construction costs for the work as described in the report are as shown in table 1.

Option 1: Central Heating	\$150,000
Option 2: Central Heating and Cooling in Meeting Hall	\$160,000
Additional Alternate: Ventilation for Meeting Hall	\$40,000 (in addition to option 1 or 2)

The equipment could be replaced in phases over time, concluding with installing the central hot water heat pumps.

EXISTING EQUIPMENT

The Meeting House has a wall mounted boiler that circulates heating hot water through a continuous pipe loop with finned tube radiators on the upper level. All the radiators are in series meaning the full flow passes through each of them. The first unit in order gets the hottest water and the last radiator gets the coolest water. The lower level has hot water pipes embedded in the concrete slab. A mixing valve in the boiler room mixes the supply and return water to 115 °F before it circulates through the slab.

The original portion of the building has no ceiling space on either level to route new pipes or ducts. The existing hot water piping is below slab or built into the block wall. This creates a challenge to retrofitting a new system.

The 1999 addition to the Meeting House is heated by a small air handling unit in the mechanical room behind the restroom. The air handling unit has a hot water coil that is connected to the boiler. Ducts run from the unit to the lower level restrooms, hallway, and the upper level hall and Committee Room. A small window mounted AC unit provides some cooling to the Committee Room.

A wall mounted, tankless, gas-fired water heater in the boiler room provides hot water to the original 2 restrooms and the kitchen. The pipes to the kitchen are buried under the concrete slab. A small electric water heater in the addition's lower level mechanical room provides hot water to the addition's restroom lavatories.

The kitchen has a 4-burner, gas-fired, residential sized oven-range.

ELECTRIFICATION

The Ann Arbor Friends Meeting can significantly reduce the carbon emissions of the Meeting House by transitioning the existing gas-burning equipment—boiler, water heater, and stove—to efficient electric alternatives. As electric heat pumps and other high-efficiency equipment replace fossil fuel combustion on site, the building's energy use can increasingly be powered by renewable electricity. This renewable energy can be supplied directly from on-site solar photovoltaic panels or indirectly through renewable energy available from the electric grid. Over time, this approach reduces reliance on natural gas, lowers greenhouse gas emissions, and positions the building to benefit as the grid continues to become cleaner.

Lower Hot Water Temperatures

Heat pump water heaters produce lower temperature hot water than the gas-fired boilers they replace. The existing boilers are set to a maximum hot water temperature of 186 °F. The hot water heat pumps will produce 120 °F hot water. At this lower hot water temperature, the existing finned tube radiators will output less heat to the rooms. To increase the heat output, a section of finned tube radiator will be replaced with a cabinet unit heater in the entry, lobby, and meeting hall. See Figure 5 and Figure 6. A cabinet unit heater has multiple rows of finned tube and a fan which gives it a higher heating output at the lower water supply temperature. The unit in the meeting hall will be selected to operate at low fan speed to reduce the noise, however there will be some soft fan noise when the unit is running. People add heat to a space so it is likely that the fan will only run during meetings on the very coldest days.

Since the lower level's heated slab uses 115 °F hot water, no changes are needed on the lower level.

Geothermal Well Considerations

Geothermal heat pumps can be very efficient and there are still generous federal rebate incentives for installations. After reviewing the building and location, we recommend not pursuing a geothermal heat pump system for the Meeting House. A traditional closed loop geothermal system stores heat in the ground in the summer and extracts it in the winter. Since the meeting hall uses significantly more heat annually than it would use cooling (if it were added), the field would need to be oversized and the performance could suffer over time. An alternative geothermal approach is an open system that extracts heat from ground water and returns the ground water to the aquifer. The Washtenaw County Health Department is skeptical of this system due to the potential to spread the dioxane contamination in the ground water. While the Meeting House is not located inside the county's well-exclusion-zone, it is only five blocks away from the border.

Instead of a geothermal system, the replacement equipment will use air-source heat pumps that exchange heat with the outside air, just like a traditional air conditioner.

Hybrid Approach

The amount of heat that air source heat pumps produce decreases with decreasing outside temperatures. While typical winter temperatures in Ann Arbor are in the range from 20 to 40 °F, minimum temperatures can occasionally be 0°F or even -10 °F. A hybrid approach combining air source heat pumps and the existing boiler for supplemental heat provides significant reductions in natural gas consumption at a lower cost than a system using only heat pumps.

In Option 1 – Central Heating, we selected a system with two 5-ton heat pumps. Based on preliminary heating estimates, we expect this to lead to the heat pumps supplying all the building heat down to 24 °F. As the temperature decreased below 24 °F the boiler would provide increasing amounts of supplemental heating. The cross-over temperature could be reduced to 12 °F with three 5-ton heat pumps, however this was not seen as enough benefit to justify the added cost. See Figure 1.

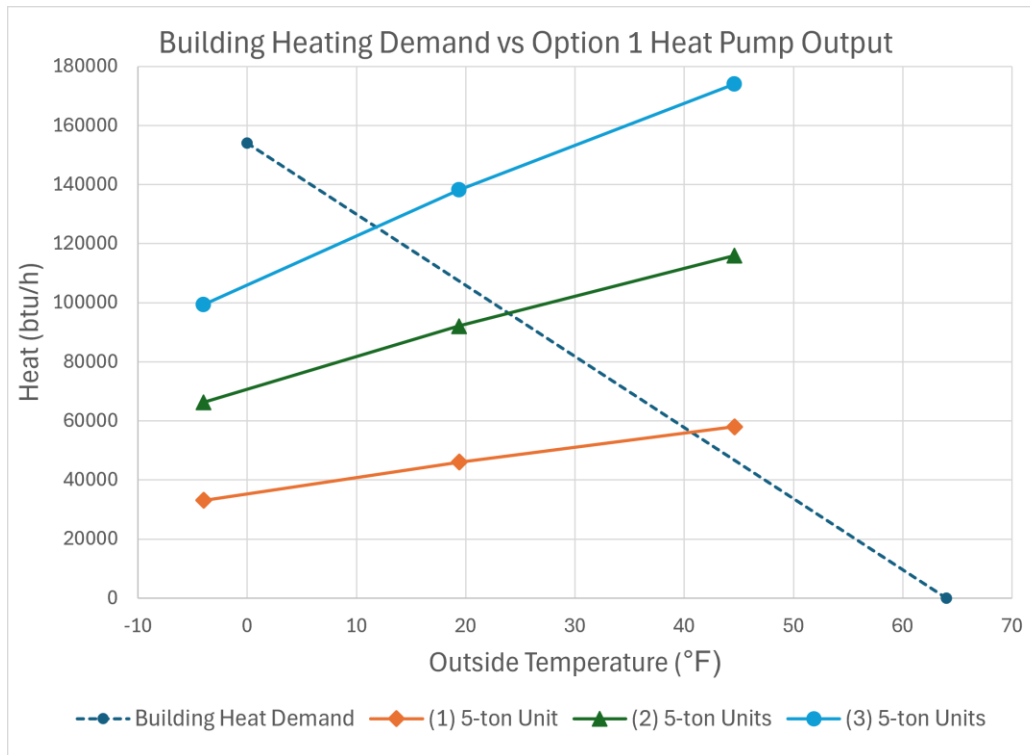


Figure 1: The boiler turn-on temperature decreases as more heat pumps are added.

Cooling in Meeting Hall

In Option 2 - Central Heating and Cooling in Meeting Hall, we added a 3-ton mini-split heat pump. The wall mounted unit will be on the north wall, see Figure 5 (left). Care will be taken to select a quiet unit, however there will be some soft fan noise when the unit is running. Based on our early cooling load estimates this unit should be able to keep the Meeting Hall at a comfortable temperature during summer meetings. The unit will also provide supplemental heating to the hall. This additional heat pump capacity reduces the outdoor temperature the boiler turns on to an estimated 14 °F. See Figure 2.

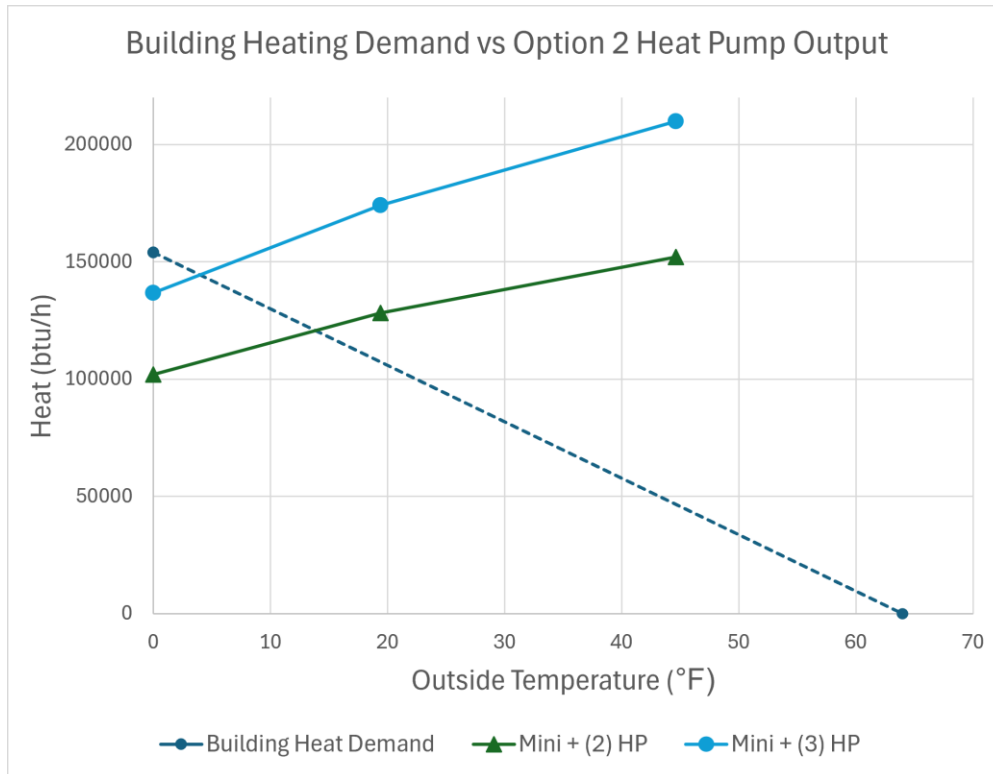


Figure 2: With addition of Meeting Hall mini-split, boiler turn-on temperature decreases.

Committee Room Addition Heating and Cooling

The hot water air handling unit serving the 1999 addition will be replaced with a split-system, air-source heat pump. This removes load from the central hot water loop and will provide cooling to the committee room and addition lower level. Recent advances in this type of equipment mean that the heat pump can provide heat with minimal output loss down to 5 °F. An electric resistance heater will be provided to provide supplemental heat during very cold weather.

Domestic Hot Water

We recommend consolidating the two domestic hot water systems to one heater located in the addition's mechanical room. This solution opens more space in the small boiler room and replaces 65-year-old buried water pipes to the kitchen sink. A packaged electric heat pump water heater will replace the small electric tank water heater in the addition's mechanical room. See Figure 8. The heat pump pulls heat from the lower-level air and will provide some dehumidification.

Meeting Hall Ventilation

The final additional alternative we explored is to add ventilation to the Meeting Hall. An Energy Recovery Ventilator (ERV) would be installed on the east wall and air would be ducted through 2 locations in the clearstory windows. An ERV uses an energy exchanger core with air small channels separated by membrane. In the winter warm air is exhausted from inside and heats cold fresh air coming in as shown in Figure 3. In Summer the exhaust air slightly cools the fresh air. An electric duct heater will boost the incoming winter air temperature to 66 °F. In summer, the added humidity will increase the total amount

of cooling needed in the meeting hall. Running the ERV in summer is not advised under option 1 since the meeting hall would become very humid and warm. If the ERV is added to option 2, two wall mount units would be needed inside. See Additional Alternative – Ventilation for Meeting Hall at the end of the report for more details.

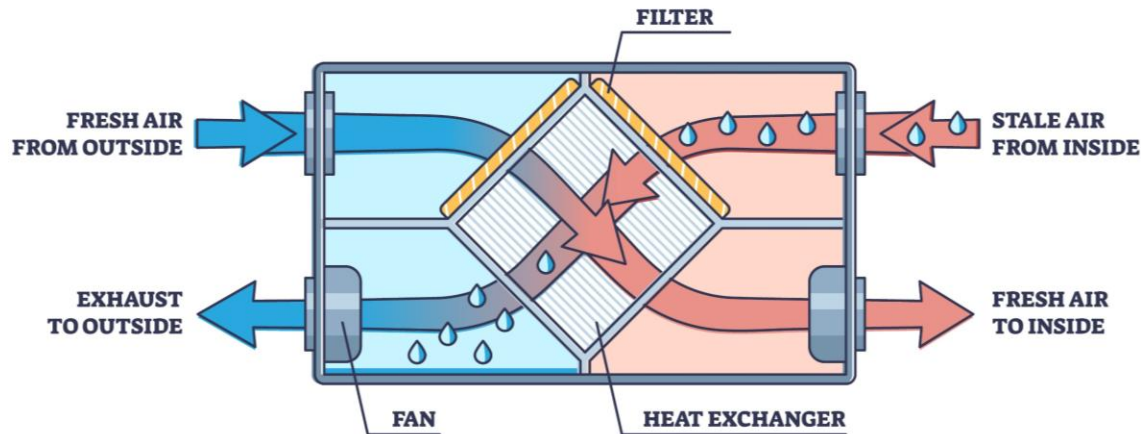


Figure 3: Energy Recovery Ventilator Cross Section

Electrical

The electrical service and panel will need to be upgraded to power the new equipment. This will be further investigated in the detailed design phase. The meeting may wish to consider and incorporate the design of other future electrical needs such as electric vehicle chargers or solar panels at that time.

User Controls Description

There will be three thermostats in option 1; the upper level (meeting hall), the lower level, and the committee room. A fourth thermostat would be added in option 2. The upper-level thermostat would be moved to the lobby and the additional thermostat would be in the meeting hall. The thermostats would be programmed with the typical week's schedule of occupied and unoccupied hours. If an event is added outside the usual hours, the thermostats have a temporary overridden placed on them two hours ahead of the event's start time.

During warm weather, the hot water heat pumps and boiler will automatically shut down. The committee room, and optionally the mini-split for the meeting hall, would have cooling options on their thermostats. The thermostats could be set up to automatically change from heat to cool or it could be done manually. Care will need to be taken to not operate these thermostats in cooling when the hot water system is heating the building.

If the Energy Recovery Ventilator option is added, the unit will also have a week schedule programmed. It will have a carbon dioxide sensor that will automatically adjust the amount of airflow based on the number of people in the space.

A more technical description of the controls is on page 11.

HEATING AND COOLING LOADS

The heating and cooling loads for the building were estimated based on areas taken from the floorplans and an assumed heating load per square foot. In the original Meeting Hall upper level, we assumed 50 btu/h/ft². In the lower level and addition we assumed 40 btu/h/ft² and in the entry way near the door we assumed 60 btu/h/ft². The meeting hall cooling calculation used a rule of thumb for places of worship, an assumed 260 btu/h per seat with 130 seats.

These initial rule-of-thumb estimates are adequate to compare various system options. They should be improved with a computer aided heating load calculation during the detailed design phase.

BUDGET CONSTRUCTION COSTS

The draft electrification report was reviewed by local mechanical contractor Brent Johnson at Robertson Morrison. Brent provided rough budget construction costs for the work as described in the report. These are only rough estimates since the design is in its initial stage.

Option 1: Central Heating	\$150,000
Option 2: Central Heating and Cooling in Meeting Hall	\$160,000
Additional Alternate: Ventilation for Meeting Hall	\$40,000 (in addition to option 1 or 2)

PHASING

The electrification of the Meeting House could be done in phases over time. The final item would be the installation of the hot water heat pumps. The following items could be done independently:

- Addition Split System Heat Pump – would electrify heating and provide cooling to committee room addition.
- Replace fin tube with Hot Water Cabinet Unit Heaters
 - With cabinet unit heaters and a heat pump in the addition, lower hot water temperature can be used by the existing boiler which improves boiler efficiency.
- Electrify the Water Heater
 - There is a small benefit to doing this after the addition heat pump so that boiler hot water piping routing could be used for domestic hot water.
- Installing the Meeting Hall Mini-Split from Option 2 and relocating the existing boiler thermostat
- Electrical upgrades: If any of the above items require an electrical service upgrade, the upgrade should account for all future equipment.

EQUIPMENT REPLACEMENT TECHNICAL SECTION

Option 1 – Central Heating

This option maintains the lower level heated slab and makes some modifications to the upper level radiators to accommodate a heat pump's lower hot water temperature. Two heating-only, air-source heat pumps create hot water to heat the space and the domestic hot water. Cooling, heating, and ventilation are provided to the addition by a stand-alone unit. The gas boiler will remain for supplemental heat during the coldest weather.

Demolition

Remove the wall-hung, gas-fired water heater from the boiler room. Cut and cap the gas pipe back to the main. Remove the water heater flue and air intake and patch exterior wall at penetration. Demolish the hot water air handling unit in the addition mechanical room along with the electrical tank water heater.

Hot Water Heat Pumps

Two, 5-ton, cold climate rated, monobloc, air-to-water heat pumps will be installed on grade outside the Meeting Hall. One unit will be installed on grade right outside the boiler room between the Meeting Hall and Quaker House. The other unit will be installed on the opposite side of the connecting passageway. Ideally, space could be reserved for a third future unit next to the second unit.

Each outdoor unit will have heating hot water (HHW) supply and return pipes that tie back to a 55 gallon buffer tank in the boiler room. Because the water pipes are routed outside, the fluid will be a mix of water and 30% propylene glycol to prevent freezing. A small circulating pump will be installed to each heat pump. The existing boiler will remain to provide supplemental heating when outside temperatures drop below 25 °F. The boiler will be re-piped to feed into the buffer tank. The upper and lower level zone pumps will circulate from the other side of the buffer tank.



Figure 4: (Left) Space between buildings for outdoor unit. (Right) Space for second and future third outdoor units.

The existing makeup water connection to the heating hot water will be disconnected. A glycol feed unit will be installed in the boiler room to provide premixed makeup antifreeze fluid.

Basis of Design: (2) Arctic Heat Pumps 060ZA/BE-R32, 62,000 btu, configured in heating only mode.

Arctic Heat Pumps hybrid composite buffer tank, 55-gallons, 4 port, no electrical heating element.

Hot Water Cabinet Unit Heaters

To increase the heat output at the lower hot water temperature supplied by the heat pumps, a section of finned tube radiator will be replaced with a cabinet unit heater in the entry, lobby, and meeting hall. The cabinet unit heater has multiple rows of finned tube and a fan which gives it a higher heating output at the lower water supply temperature. A small capacity circulator pump or mono-flow tees will be installed to divert some of the water from the main through the cabinet unit heater (CUH) while the remainder flows in a replaced pipe under the CUH and reconnects to the existing piping.

Basis of Design: Modine Model C.

- Entry: Size 002, one row
- Lobby: Size 008, three rows
- Meeting Hall: Size 010, two rows

Provide aquastat and unit mounted return air thermostat accessories.



Figure 5: (Left) North wall of Meeting Hall. Replace finned tube radiator with cabinet unit heater (CUH). (Right) Entry finned tube radiator to be replaced with CUH.



Figure 6: Lobby finned tube radiator under window to be replaced with CUH.

Addition Split System Heat Pump

The air handling unit in the addition mechanical room will be replaced with a 2-ton, air source, split system heat pump. The indoor unit will be a multi-position air handling unit with a similar shape and size as the existing unit. The outdoor heat pump unit will be installed on the east wall of the Committee Room. An alternate location is the roof of the Committee Room. A 3-kW electric duct heater will be installed on top of the air handling unit to provide supplemental heat.

The existing thermostat will be replaced with a 7-day programmable thermostat.

Basis of design: Mitsubishi Electric PUZ-HA24NHA with PVA-AAA7 indoor unit, 2-ton.



Figure 7: (Left) Existing hot water air handler serving addition. (Right) Exterior grade location for heat pump outdoor unit.

Water Heater

A 66-gallon, packaged heat pump water heater will be installed in the addition's mechanical room. New domestic hot water lines will be installed to the addition lavatories, kitchen sink, and original building lavatories. The water heater inlet and outlet air will be ducted into the adjacent hallway.

Basis of Design: AO Smith, Voltex Hybrid Electric Heat Pump, HPTU-66, 4.5 kW element, 66 gallon tank, 240V/1P.



Figure 8: Existing electric water heater in mech room will be replaced with larger heat pump model.

Electrical

The existing electrical panel and possibly the electrical service will most likely need to be upgraded to service the new equipment. Further analysis will be completed in the full design phase.

Controls

The hot water heat pumps will be provided with a controller that will be connected to both heat pumps and the boiler. The controller will be connected to a water temperature sensor in the buffer tank and an outdoor temperature sensor. When the outdoor temperature is above an adjustable threshold (60 °F), the hot water heat pumps, boiler, and all pumps will turn off. This is referred to the warm weather shutdown mode and is preprogrammed in the controller. Below this shutoff temperature, the heating hot water design temperature will be calculated by the controller based on outside air temperature. Colder outside temperatures will have higher heating water design temperatures. The heat pump controller will monitor the temperature of the buffer tank and ramp up one heat pump to maintain the design setpoint in the buffer tank. After a certain amount of time or degree drop, the controller will activate the second heat pump. After another time delay or degree drop, the controller will turn on the backup boiler. Once the buffer tank temperature exceeds the setpoint by 5 °F (adjustable), the heating equipment will go to standby.

Individual circulator pumps will be provided for each heat pump and the boiler. The pump will run when its heating equipment is called to run. See Figure 9.

The heated slab and finned tube radiators will work on the same temperature hot water. Thermostats will control zone circulator pumps to push hot water through the zones when heat is called for.

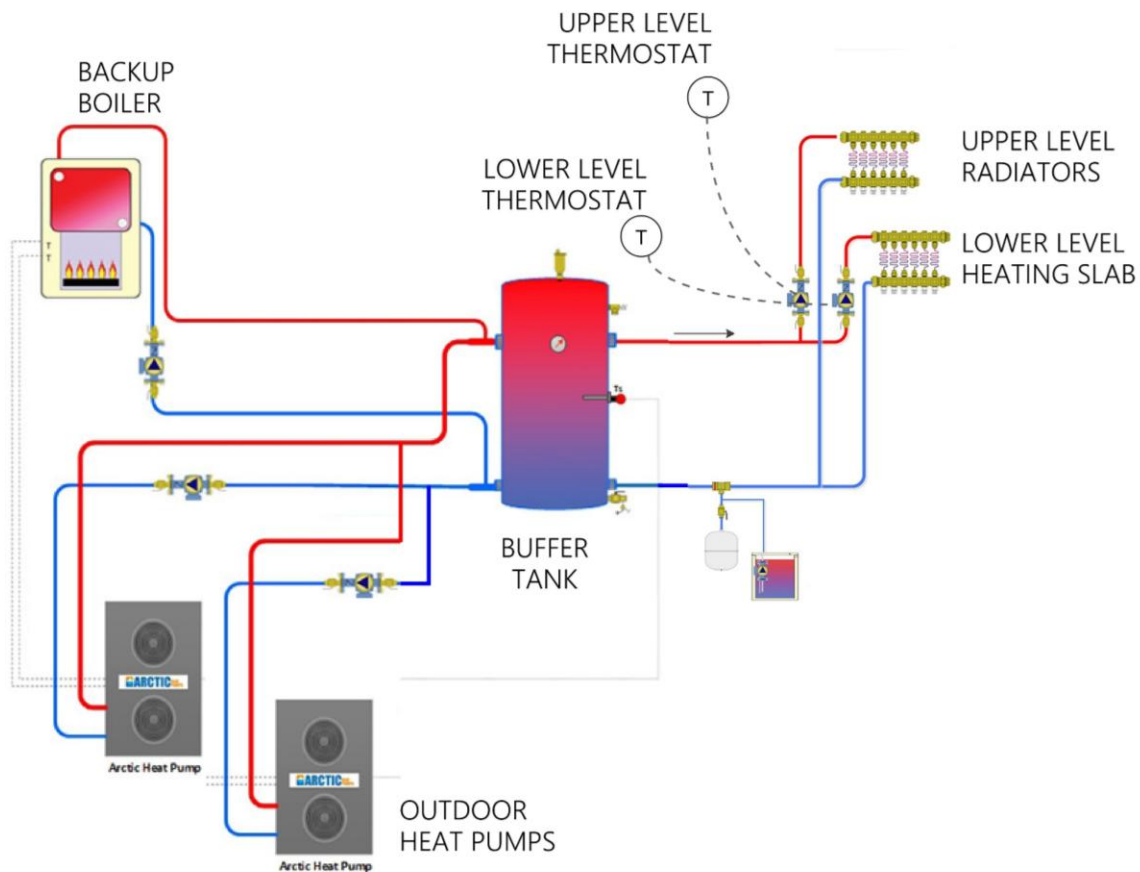


Figure 9: Hot Water Equipment Piping Schematic

Option 2 – Central Heating and Cooling in Meeting Hall

In this option, the finned tube in the meeting hall will not be changed. Instead, a wall mounted mini-split will be installed in the meeting hall to provide cooling and supplemental heating.

Demolition

Same as in option 1.

Hot Water Heat Pumps

Same as in option 1.

Hot Water Cabinet Unit Heaters

To increase the heat output at the lower hot water temperature supplied by the heat pumps, a section of finned tube radiator will be replaced with a cabinet unit heater in the entry and lobby. The cabinet unit heater has additional row of finned tube and a fan which gives it a higher heating output at the lower water supply temperature. A small capacity circulator pump or mono-flow tees will be installed to divert some of the water from the main through the cabinet unit heater (CUH) while the remainder flows in a replaced pipe under the CUH and reconnects to the existing piping.

Basis of Design: Modine Model C.

- Entry: Size 002, one row
- Lobby: Size 008, three rows

Provide aquastat and unit mounted return air thermostat accessories.

Meeting Hall Mini-Split

A wall mounted mini-split unit will be installed on the north wall of the meeting hall. The unit will be paired with a three-ton cold climate rated, air source heat pump outdoor unit installed on grade on the other side of the wall. A thermostat will control the unit and will be scheduled to match the expected occupancy of the meeting hall.

Basis of Design: Mitsubishi Electric PUZ-HA36NHA2 with indoor PKA-A36FA-2, 3-ton.

Relocate Upper Level Heating Hot Water Thermostat

The existing thermostat that controls the upper-level HHW zone pump will be relocated to the other side of the wall from its current location. The mini-split thermostat will primarily serve the meeting hall and the HHW zone thermostat will sense the temperature in the lobby.

Addition Split System Heat Pump, Water Heater, and Electrical

Same as in option 1.

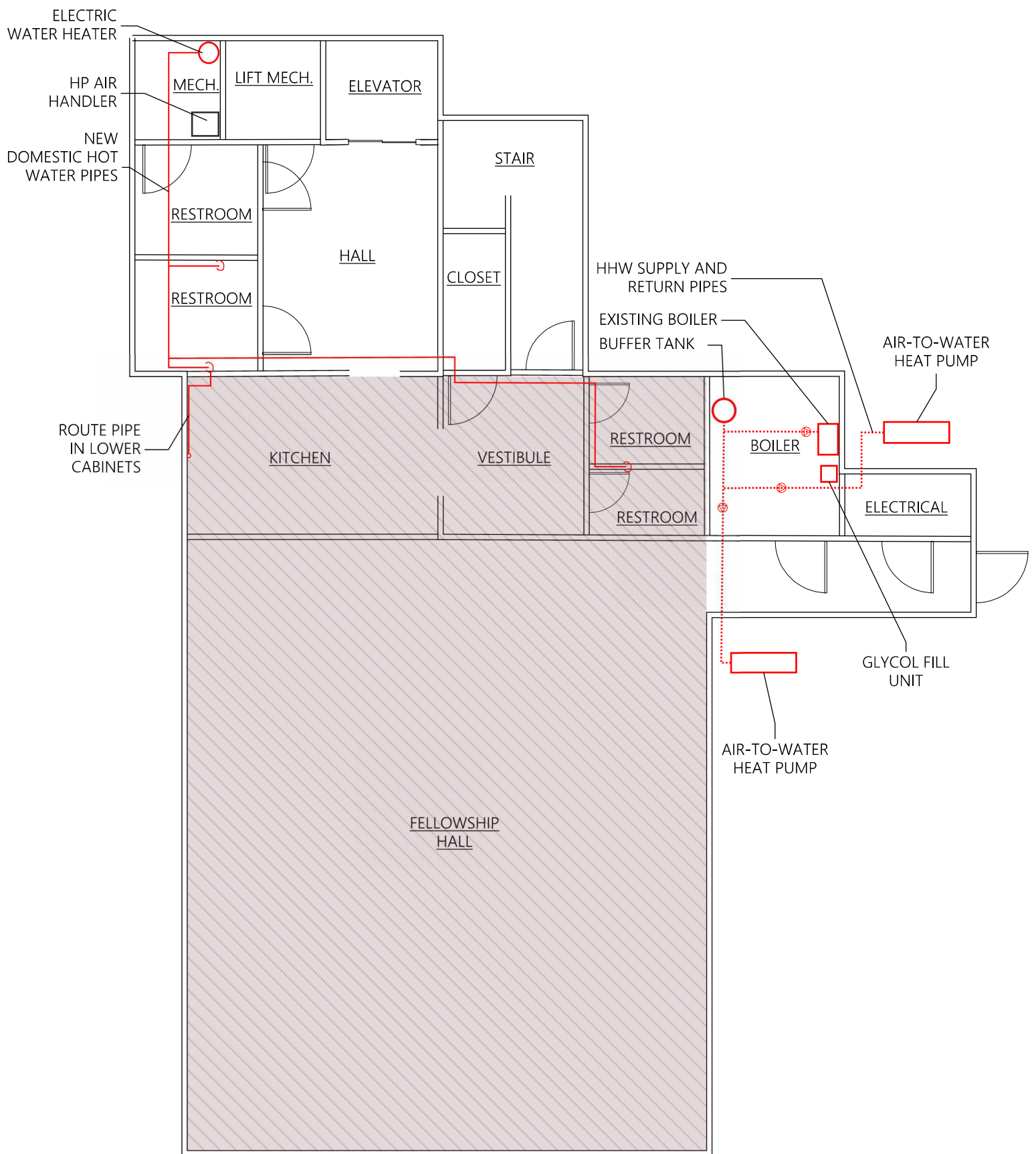
Additional Alternative – Ventilation for Meeting Hall

Outdoor Energy Recovery Ventilator

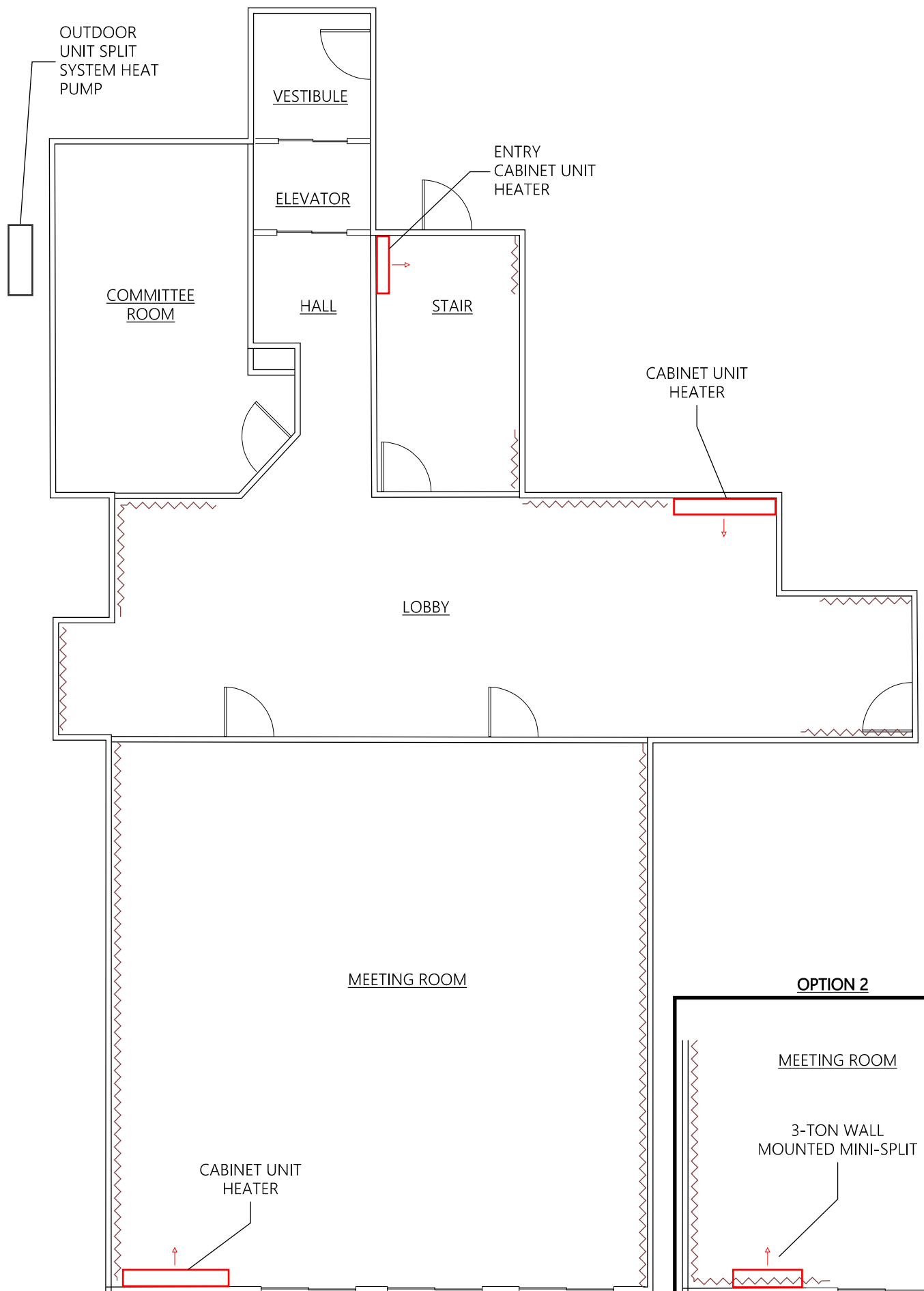
An outdoor rated Energy Recovery Ventilator (ERV) would be installed on the exterior of the east wall of the meeting hall to provide a maximum of 705 CFM of ventilation. 12" round Supply and return ducts would extend to opposite ends of the wall. Panes from the existing clearstory windows would be removed and replaced with an air grille and shorter pane. A 4 kW, outdoor rated, electric duct heater would be installed after the ERV to maintain a minimum leaving air temperature of 66 °F. The heater could be turned off over the summer. The ERV will be provided with manufacturer control accessories: a programmable scheduler and CO₂ sensor for demand control ventilation.

To compensate for the summer fresh air cooling load, the meeting hall mini-split in option 2 would instead be a 4-ton outdoor unit connected to two, 2-ton indoor units.

Basis of Design: Renewaire HE10-JRTH, 705 CFM, energy core heat exchanger, with CO₂ detector, and time clock accessories. Greenheck IDHE-O outdoor electric duct heater, rectangular 12"x12", 4 kW, 240V/1P.



ANN ARBOR FRIENDS MEETING HALL - LOWER LEVEL



ANN ARBOR FRIENDS MEETING HALL - UPPER LEVEL

