# Houghton University Community Heat Pump Scoping Study

Final Report | Report Number 24-28 | December 2024

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# Houghton University Community Heat Pump Scoping Study

***Final Report***

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NYSERDA Report 24-28 NYSERDA Contract 181885 December 2024

# Notice



# Preferred Citation

New York State Energy Research and Development Authority (NYSERDA).2024. "Houghton University Community Heat Pump Scoping Study, Final Report." NYSERDA Report Number 24-28. Prepared by EMCOR Service Betlem, Rochester, NY. nyserda.ny.gov/publications.

# Abstract

The Houghton University Community Heat Pump Feasibility Study assesses the feasibility of a community heat pump system at the university located in Houghton, NY, and creates a business model for implementation. The loop would be conditioned by renewable resources and connect a cluster of seven buildings to share resources and reduce energy consumption. If successful, the study will provide a repeatable and scalable proof of concept. This report summarizes the project team's findings on connecting seven buildings on Houghton University's campus to an efficient, all-electric community heat pump system. This report represents the culmination of the team's efforts and findings throughout the feasibility study, including summaries of technologies explored, the buildings modelled, a regulatory review, and the financial and energy impacts. Using the community heat pump loop results in significant energy and greenhouse gas (GHG) emissions savings when compared to the electrification baseline.

The solution the project team analyzed uses a central plant conditioned with an open-source geothermal system. The central plant will be in the Center for the Arts (CFA) and would condition a 2-pipe ambient loop serving seven buildings via distributed pumping. The loop will provide conditioned water to each building for space heating, space cooling, and domestic hot water (DHW) heating. Buildings that require 180ºF heating hot water will use booster heat pumps to provide the necessary lift above the supplied loop water of 105ºF. The implementation costs were estimated for the central plant, distribution pumping, and retrofits in each of the seven buildings.

# Keywords

building electrification, district thermal, heat pump, Houghton, Houghton University

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# Acronyms and Abbreviations

| | |
|---|---|
| AHU | air-handling unit |
| CFA | Center for the Arts |
| Climate Act | Climate Leadership and Community Protection Act |
| COP | coefficient of performance |
| CPI | Consumer Price Index |
| DEC | New York State Department of Environmental Conservation |
| DHW | domestic hot water |
| DX | direct expansion |
| GHG | greenhouse gas |
| HVAC | heating, ventilation, and air conditioning |
| HW | hot water |
| IRA | Inflation Reduction Act |
| IRR | internal rate of return |
| ITC | Inflation Tax Credit |
| MARR | minimum acceptable rate of return |
| MUA | make-up air |
| NEPA | National Environmental Policy Act |
| NPV | net present value |
| NYSERDA | New York State Energy Research and Development Authority |
| P&ID | piping and instrument diagram |
| PPA | purchase power agreement |
| PV | photovoltaic |

| | |
|---|---|
| RG&E | Rochester Gas and Electric Corporation |
| ROI | return on investment |
| SCC | social cost of carbon |
| SPDES | State Pollutant Discharge Elimination System |

## Units of Measurement

| | |
|---|---|
| ºF | degrees Fahrenheit |
| Btuh/ft/ºF | British thermal units per hour per foot per degree Fahrenheit |
| gpd | gallons per day |
| gpm | gallons per minute |
| kV | kilovolt |
| kW | kilowatt |
| kW/ton | kilowatt per ton |
| kWh | kilowatt-hour |
| MBH | thousand British thermal units per hour |
| MMBtu | one million British thermal units |
| MT | metric ton |
| $MTCO_2e$ | metric tons of carbon dioxide equivalent |
| $MTCO_2e$/MWh | metric tons of carbon dioxide equivalent per megawatt-hour |
| MW | megawatt |
| MWh | megawatt-hour |
| sf | square feet |

# Executive Summary

In anticipation of meeting State and federal decarbonization goals, Houghton University partnered with EMCOR Services Betlem (EMCOR), Koester Associates (Koester), and Caster Drilling (Caster) to investigate the potential of installing a community heat pump, also referred to as an ambient temperature or thermal, loop on its main campus that would be used to provide heating and cooling to several buildings. For this feasibility study, seven buildings were selected for analysis to assess the thermal loop's capacity to meet their heating and cooling demands. The final objectives of this project are to determine the feasibility of maintaining the loop temperature using a combination of renewable resources and waste heat within the loop, supplemented by electric heat pumps in each building as necessary.

The following summarizes the Houghton University community heat pump feasibility study approach:

1. Create building thermal models using eQuest and use the hourly data to determine the 8,760-hour aggregate analysis for the thermal loop system.
2. Identify thermal resources, including:
    - Geothermal: Install a test borehole and perform a thermal conductivity test; review drill
      logs to determine borefield feasibility; and evaluate the feasibility of closed-loop versus open-loop geothermal systems as a primary thermal resource, depending on required capacity and drilling location.
    - Sewer heat recovery: Review existing university sewer and water flow and temperature
      data; review water usage data for each of the seven buildings; determine sewer heat extraction locations and quantify available energy using logged sewer data.
3. Develop a conceptual design for the community heat pump system, including:
    - Layout and schematic design of the central plant using an open-source geothermal system. The thermal loop piping layout was determined in this step.
    - Schematic design of participant connection points and systems to provide the necessary
      hot and chilled water to each of the seven buildings using the ambient loop.
4. Create a financial analysis to determine the 25-year impact of the community heat pump system compared to the electric boiler baseline system, including:
    - Development of the preferred business model.
    - Cost estimates for the central plant, distribution system, and building retrofits.
    - Financial analysis assumptions, including project and operating costs for the new system.

- Financial analysis to determine the net present value (NPV) to the university.

5. Assess additional technologies to improve project value, including the development of a conceptual photovoltaic (PV) design.
6. Review possible regulatory and permitting requirements for the development of the community heat pump system.
7. Summarize findings and recommendations.

The project team developed thermal models for each building using eQuest 3.65. Information compiled for these models includes, but is not limited to, architectural and mechanical drawings provided by Houghton University, building occupancy schedules, information on the existing heating, ventilation, and air conditioning (HVAC) system, and building geometry. These models were used to determine each building's heating and cooling needs and to develop an aggregate hourly load for the thermal loop. This information was then used to develop the energy impacts of the base case, which consisted of all electric boilers. The project team hoped to limit the retrofit needs for the seven buildings by using electric boilers.

Following the completion of the building and base-case energy models, the viability of using a closed-loop geothermal system was analyzed. To do this, a test borehole was drilled to obtain design parameters, including thermal conductivity, borehole depth, and water content. While drilling the test borehole, the team discovered that a potential water source would yield sufficient water for a groundwater geothermal system, also referred to as an open-source system, to serve as the primary thermal source or sink. The project team then decided to continue the analysis of the community heat pump project using a groundwater system due to the projected cost of the closed-loop system.

Sewer heat recovery was also considered as a thermal energy resource. Following a review of the flow and temperature at the main sewer plant, the project team determined that the observed flow and temperature were insufficient to justify implementing a whole-system sewer heat recovery. The team then pivoted to a building-specific approach and determined that the Reinhold Campus Center and Gillette Hall had the best potential for a building-specific system, per a review of their domestic water usage.

Sewer flow and temperature meters were installed in the piping leaving both buildings, indicating that Gillette Hall had insufficient flow to support a building-specific sewer heat-recovery system, whereas the Reinhold Campus Center showed potential for such a system. However, a sewer heat-recovery system was excluded from the final analysis due to project costs.

Cost estimates were then developed for each of the seven buildings. This included required retrofits for each building, central plant implementation costs, and distribution costs. Operating and ongoing costs associated with the thermal loop were developed and incorporated into a 25-year life-cycle cost analysis, along with the project costs. Using a range of financial assumptions, the project team determined that the proposed community heat pump system would have an NPV of $324,448 when compared to the base case. Sensitivity analyses across a range of assumptions indicated that maintenance and construction costs, along with heating efficiency (the coefficient of performance, or COP), have the greatest impact on the project's NPV and may be substantial barriers to implementation. If this project proceeds, we recommend further refining these factors.

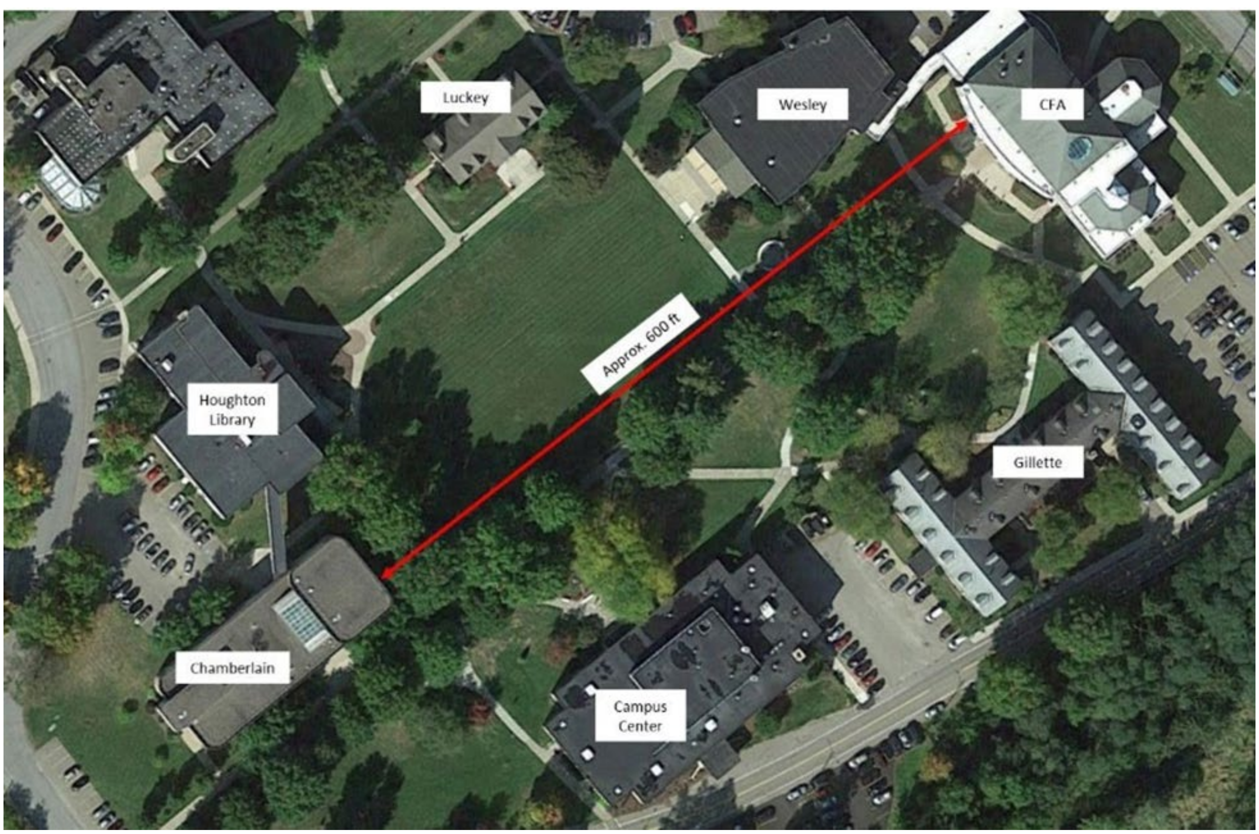
The positive NPV indicates that, if the university pursues an all-electric solution to eliminate fossil-fuel-powered equipment and meet the conditioning needs of the seven buildings used in this analysis, it should adopt a community heat pump instead of the electric boiler base case. This would enable Houghton University to efficiently use available geothermal energy and heat pump technology to meet its campus needs and maximize any available grants, rebates, and incentives. However, compared with the existing operation, which uses fossil-fuel-driven equipment, neither the thermal loop nor the baseline case is financially viable as indicated by negative NPV results calculated from their respective 25-year life-cycle analyses. This indicates that Houghton University will likely avoid pursuing an all-electric option unless required to significantly reduce on campus fossil fuel consumption, or unless significant changes occur in utility costs, potential rebates, or the social cost of carbon (SCC).

# 1 Characterization and Scope of Proposed Community

This Community Heat Pump Feasibility Study provides "proof of concept" for other colleges, particularly rural ones, across New York State. During the initial analysis and scope-of-work development for this study, seven buildings were selected as the focus: Houghton Library, Chamberlain Center (Chamberlian), Reinhold Campus Center, Gillette Hall (Gillette), Center for the Arts (CFA), Wesley Chapel (Wesley), and the Luckey Memorial Building (Luckey). These buildings, which surround the center of campus as shown in Figure 1, were chosen for the following reasons:

- Concentration in a single area of the campus with ample green space for an ambient loop.
- Varying occupancy schedules and use types among the buildings would assist in offsetting loads.
- Existing use of a water-source heat pump system at Chamberlain Center.
- Available green space suitable for a geothermal test borehole.
- Presence of sanitary sewers throughout the green space is suitable for sewer heat recovery.

**Figure 1. Map of Community Heat Pump Loop Buildings**



In addition to their locations and differing use types, these seven buildings use a variety of mechanical systems to meet their heating, cooling, and ventilation needs. To better understand these buildings, the project team conducted several site visits to obtain the information, summarized in Table 1, which was incorporated in the high-level building energy models. Many of these systems, such as the boilers serving Gillette Hall, are well past their expected useful lives and require replacement. When system information was unavailable, the team used assumptions from historical documentation and the *New York Technical Resource Manual* V9 (2022).

**Table 1. Summary of Participant Building Characteristics**

| Name | Use | SF | Year Built | Existing Heating Type Systems | Existing Cooling Type Systems |
|---|---|---|---|---|---|
| Reinhold Campus Center | Mixed use: cafeteria, lounge, offices, gaming, and snack shops | 68,590 | 1972 | • 4 HW heating condensing boilers<br>• 1 steam boiler used for domestic HW and kitchen steam<br>• 5 AHUs w/htg coils<br>• 2 MUAs w/htg coils<br>• 1 gas-fired rooftop unit with DX | • 1 156-ton water-cooled chiller<br>• 1 cooling tower serving the chiller |
| Center for the Arts | Music / Arts Center | 46,000 | 1999 | • 3 HW heating boilers<br>• 9 AHUs with heating coils (hot deck–cold deck system) | • 1 114-ton chiller<br>• 9 AHUs with cooling coils (hot deck–cold deck system) |
| Chamberlain Center | Offices and classrooms | 49,500 | 1989 | • 2 HW heating boilers<br>• 1 MUAs with heating coil | • 43 heat pumps, glycol loops<br>• 1 cooling tower |
| Gillette Hall | Women's dorm | 84,779 | 1950 | • 4 HW heating boilers for heating and DHW<br>• Zone pumps for HW fin radiation<br>• 1 MUAs with heating coil | • None (ventilation makeup air and operable windows) |
| Houghton Library | Library | 50,000 | 1964 | • 3 HW heating boilers<br>• 2 AHUs with heating coils<br>• 2 MUAs with heating coils<br>• HW fin radiation | • 4 split systems |
| Luckey Memorial Building | Administrative offices | 13,765 | 1942 | • 1 steam heating boiler<br>• Steam fin radiation | • None |
| Wesley Chapel | Auditorium and meeting rooms | 31,686 | 1959 | • 2 HW heating condensing boilers<br>• 3 AHUs with heating coils | • None |

A phased approach was not used to develop the proposed schematic design or to estimate implementation costs for the thermal plant and distribution system. Because this is a feasibility study, the project team determined that the seven target buildings would provide a reliable indication of the university's ability to implement a larger system. Therefore, this study evaluates the short-term opportunities, and long-term opportunities were not expressly analyzed. However, the capacity of the proposed system will help Houghton University develop plans for the rest of the campus to meet the New York State goals for electrification and decarbonization.

## 1.1 Participant Modelled Results

EMCOR created thermal models for each building included in this analysis. An existing model was developed using information gathered during site visits, including building construction, occupancy, and space-type breakout. Engineering assumptions were used to address information unavailable during the site visits. Both site-visit data and assumptions reflected the belief that the campus was operating under current and normal conditions. This indicates that facility operations were consistent with those of a nonpandemic year, with each building occupied in its typical space-use type.

The building model results were used to develop an understanding of the buildings' peak design conditions and building operating conditions. This was achieved by creating 8,760-hour thermal load and energy consumption profiles.

Houghton University currently submeters the electricity supply to several buildings, including the seven included in this analysis. Natural gas is not submetered. The electric submeter and natural gas data were weather-normalized and used for tuning the building models. Once each building model was completed, the output data was used to create an aggregate thermal loop profile for the seven buildings. As indicated in Figures 2 and 3, the peak heating load is 11,051.58 MBH, and cooling is 372 tons.

**Figure 2. Aggregated Heating Load**

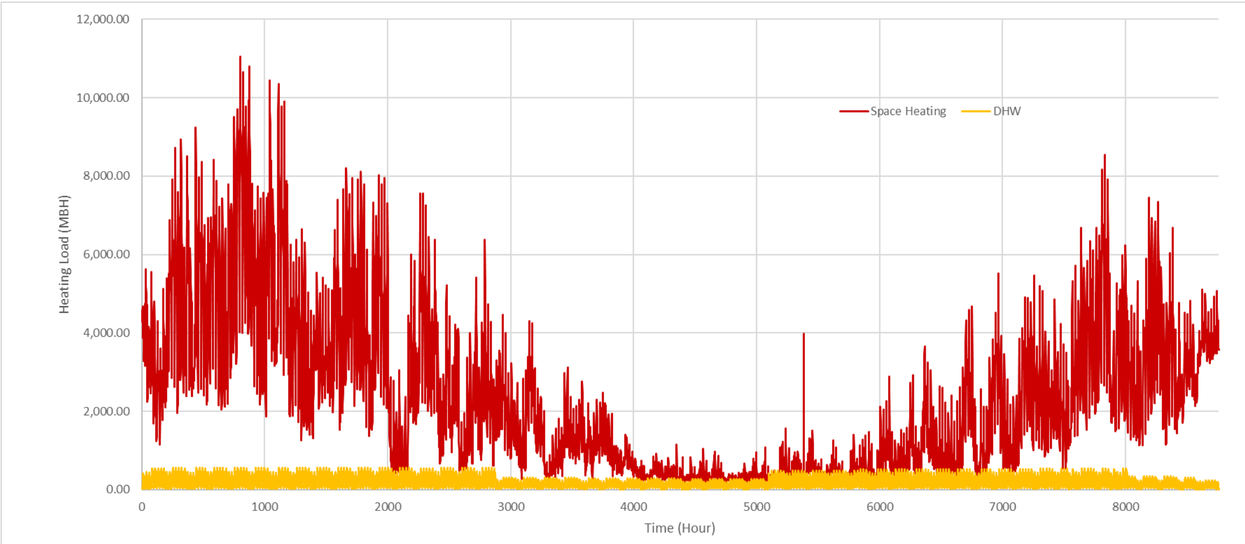
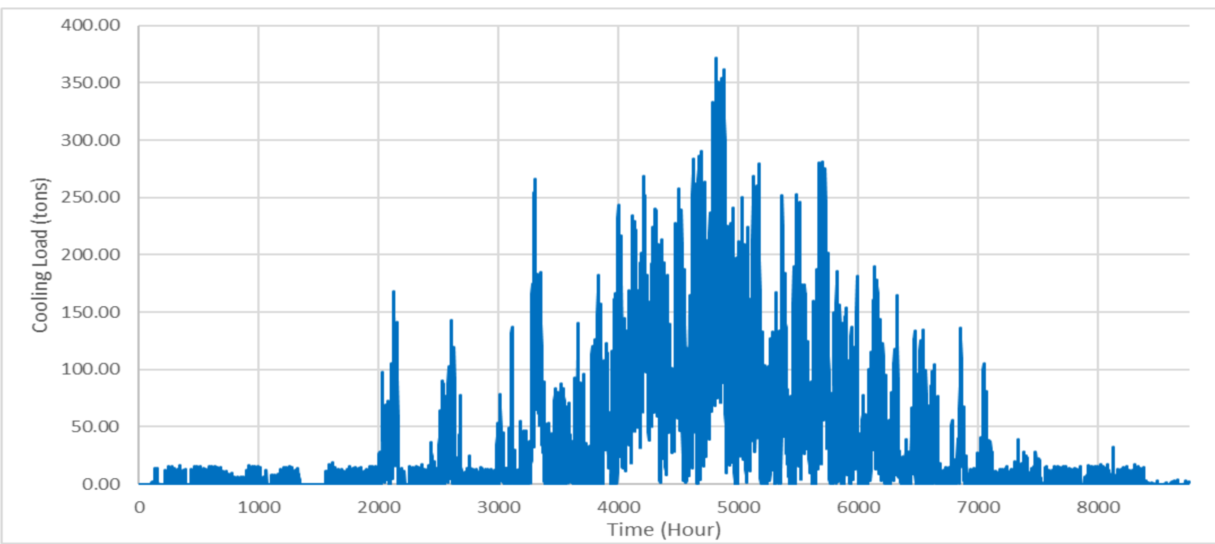



**Figure 3. Aggregated Cooling Load**




## 1.2 Constraints and Hurdles

Throughout each phase of this feasibility study, the team identified various constraints and hurdles that may significantly impact the feasibility of the community heat pump loop at Houghton University. If this project moves forward, these challenges must be addressed before or during the design phase.

1. **Location geology:** A closed-loop geothermal system was first analyzed as part of this feasibility study, with the first step being a test borehole and a thermal conductivity test that resulted in a borehole capacity of 1.5 tons per borehole when drilled to 260 ft. This well capacity is attributable to the area's geology and would require more than 600 boreholes to meet the aggregate heating loads. Most likely, if 600 boreholes are required, the university would have enough land to accommodate 20 ft on center boreholes, even if the depth were increased. The number of boreholes may undermine the project's financial feasibility. However, approximately 100 gpm of water flowed through the test borehole casing during drilling. This flow rate indicates that a groundwater system, also known as an open-source system, would be viable.
2. **Central plant location:** The ambient loop for this project will consist of a central plant located in the Center for the Arts. The team identified the Center for the Arts' basement as the ideal location for the central plant because of the available floor space currently used for storage. Using the existing floor space eliminates the substantial investment required to construct a building to house the central plant. The storage currently located in the basement would need to be relocated to ensure adequate space for the central plant equipment. Any available space in the other buildings was surveyed, but the Center for the Arts' basement has the most floor space available. If this basement is no longer available once the full design of this thermal loop is underway, the basement classroom area of the Library could be repurposed for use as the central plant. This would likely increase the cost of supplying open-source well water to the central plant because the library is much farther away than the current proposed well location near the Center for the Arts.
3. **Existing building HVAC systems:** Each of the seven buildings has its own HVAC system that meets the space conditioning requirements of that building. The basis of design for the Reinhold Campus Center, Center for the Arts, Library, and Wesley Chapel is booster heat pumps that use the thermal loop to provide sufficient lift during the heating season to meet the required supplied water temperature of 180ºF. Booster heat pumps were used to reduce the number of end-use equipment retrofits required in each building. If this setpoint can be lowered, it may reduce the required size of the project's booster heat pump system and improve the financial feasibility. Chamberlain Center will use the existing water-source heat pumps, whereas Gillette Hall and Luckey Memorial Building would require building retrofits to use the thermal loop through fan-coil units.
4. **Electrical upgrades:** Providing the necessary electrical feed to the central plant and participant buildings would likely require costly substation upgrades. This is due to insufficient capacity at the meter serving the seven buildings (the Wesley meter) and at the substation serving the university. These upgrades to the electric supply for the cluster of seven buildings will significantly affect the project's economic feasibility because the university is responsible for funding them at the time of this report. Although preliminary discussions were held between the project team and Rochester Gas and Electric's (RG&E) engineering team, a detailed analysis is recommended to determine the impact of electrical grid limitations on the thermal loop.

# 2 Technologies Assessed

This section summarizes the technologies evaluated in the Houghton University community heat pump feasibility study, with a focus on thermal sources, sinks, and supporting mechanical systems. The assessment considers technical feasibility, site conditions, and cost implications to inform systems.

## 2.1 Thermal Sources and Sinks

The team identified a geothermal system as the primary heat sink or source for the thermal loop at Houghton University. Following completion of a test borehole, the project team concluded that an open-source geothermal system would be the most appropriate solution for this project, given the amount of site work required for a closed-loop borefield. The amount of underground water would enable the system to use extraction and injection wells to provide constant water to and from the central plant located in the Center for the Arts. An open system would eliminate the need for a closed-loop borefield and the associated drilling and materials, particularly steel casings.

Sewer heat recovery was another thermal source included in this study that could provide the thermal loop with additional thermal energy. The project team determined based on the initial investigation that the flow and temperature conditions at the Houghton University wastewater treatment plant would be insufficient to support a large-scale sewer heat recovery system. The team then identified Gillette Hall and the Campus Center as two potential buildings for smaller, building-specific systems. For this study, SHARC's Piranha system served as the basis of design. Sewer effluent flow and temperature data logging for each of these buildings concluded that the limited average flow in Gillette Hall would result in excessive cycling for the smallest Piranha system. The volume and consistency of the Reinhold Campus Center flow would allow for the use of a Piranha system. However, sewer heat recovery was not included in this study's system design due to projected implementation costs.

### 2.1.1 Geothermal

The first step in determining the feasibility of a geothermal system was to drill a test borehole and complete a thermal conductivity test. This test borehole enabled the project team to determine the site geology from the drilling contractor's drill log and to measure the thermal conductivity. Thermal conductivity is incorporated into closed-loop system modelling software during design to determine the required total borehole length. However, the estimated capacity of each well can be calculated using several assumptions. Using the thermal conductivity of 1.12 Btuh/ft/ºF, the test borehole depth of 260 ft, and an assumed temperature difference between the water returning from the end uses and the groundwater of 10ºF, a borehole capacity of approximately 1.5 tons was calculated for Houghton University. This results in a total system requirement of more than 600 boreholes, each drilled to 260 ft.

Even with a drill depth double that of the test borehole, the associated material costs, such as the steel casing, limit the economic feasibility of a closed-loop system. In addition to costs, the amount of space required for this many boreholes would be difficult to procure on campus. If a closed-loop borefield is pursued, the proper amount of space for the required number of boreholes is unlikely to be available.

While drilling the 260 ft borehole, the team determined that a potential water source began at approximately 210 ft. This water source produced a flow rate of approximately 100 gpm through the steel borehole casing installed while the borehole was being drilled. Per Caster, the contracted driller, this flow rate indicates a high likelihood that water wells can be developed for use in a groundwater system. For this analysis, the team assumed that groundwater wells can be developed to consistently deliver the water flow rate required by the community heat pump loop serving the seven buildings. This was used instead of a closed-loop system due to the number of wells required. In discussions with Houghton University and Caster, sufficient land area is assumed to facilitate the implementation of an open-loop system. If this community heat pump system moves to the design phase, a hydrogeologist should confirm the well characteristics, such as water quality, well yield, static water height, and recovery rate for any proposed wells.

### 2.1.2 Sewer Heat Recovery

Sewer heat recovery is a technology that uses raw sewage from an existing sewer stream as a year-round thermal energy source. For this analysis, sewer heat recovery is used as an energy source with cooling provided by the open-loop geothermal system. SHARC's Piranha system was used as the basis for the design of this analysis and has three integral parts to use the sewer as a thermal resource:

1. **Wastewater storage tanks:** This storage tank intakes raw sewage via a gravity feed coming from the buildings and serves as the solids handling tank in which wastewater is held prior to use in the Piranha system. This system does not require prefiltration or macerators prior to use in heat recovery. This tank enables the system to store wastewater when domestic hot water (DHW) demand is low.

2. **Heat pump:** A series of water-source heat pumps uses wastewater energy to provide heat to meet the buildings' DHW demand. Wastewater is drawn from the storage tank into the Piranha system, which extracts thermal energy from the wastewater and uses it to heat incoming DHW. Figure 1 illustrates an overview of the Piranha system.
3. **Preheat storage tanks:** DHW is generated at 140ºF from the heat pump and is stored here. This storage, if properly sized, allows the system to meet DHW during peak conditions.

To assess the viability of a sewer heat-recovery system, sewer effluent flow and temperature were logged at Gillette Hall and the Reinhold Campus Center. Table 2 summarizes this data. Per the analysis completed by SHARC, the limited average flow in the Gillette Hall effluent would result in excessive cycling of its smallest Piranha systems. However, the amount and consistency of flow, along with the average temperature at the Reinhold Campus Center, could provide sufficient thermal energy during peak conditions to meet the building's peak DHW demand. The proper amounts of wastewater and preheated domestic water storage are assumed to be used to meet the needs of the Reinhold Campus Center. Any excess thermal energy generated by the sewer recovery system will be returned to the building loop during heating season. Thermal energy is not rejected from the building loop into the sewer system because the wastewater treatment plant is located downstream.

**Table 2. Summary of Wastewater Data Log**

| Sewer Effluent Flow and Temperature | Reinhold Campus Center | | Gillette Hall | |
|---|---|---|---|---|
| | 2/3/23–2/28/23 | 3/1/23–3/13/23 | 2/3/23–2/28/23 | 3/1/23–3/13/23 |
| Flow Min (gpm) | 0.0 | 0.0 | 0.0 | 0.0 |
| Flow Max (gpm) | 317.9 | 50.8 | 217.3 | 13.5 |
| Flow Avg. (gpm) | 17.9 | 7.5 | 0.6 | 1.5 |
| Temp Min (ºF) | 14.4 | 55.3 | 0.0 | 0.0 |
| Temp Max (ºF) | 93.7 | 83.4 | 84.7 | 82.7 |
| Temp Avg. (ºF) | 73.3 | 70.1 | 63.7 | 61.3 |

### 2.1.3 Large Water-source Heat Pumps

Water-source heat pumps are proposed to be the source of mechanical heating and cooling for the thermal loop. Within the central plant, large water-source heat pumps were sized to use the open-source geothermal water to provide the loop with the necessary heating and cooling. In addition to the central plant heat pumps, water-source heat pumps are located throughout several buildings. The building heat pumps would be used as booster heat pumps to provide the building's system with hot water, while buildings that do not use these heat pumps would have end-use equipment sized to use the water temperature supplied by the loop. The basis of design for the booster heat pumps is to use the loop's ambient water, which is planned at 105ºF, to supply the building's hot-water system with 160ºF–180ºF water. These booster heat pumps will allow the building to provide simultaneous heating and cooling within its water and chilled water systems.

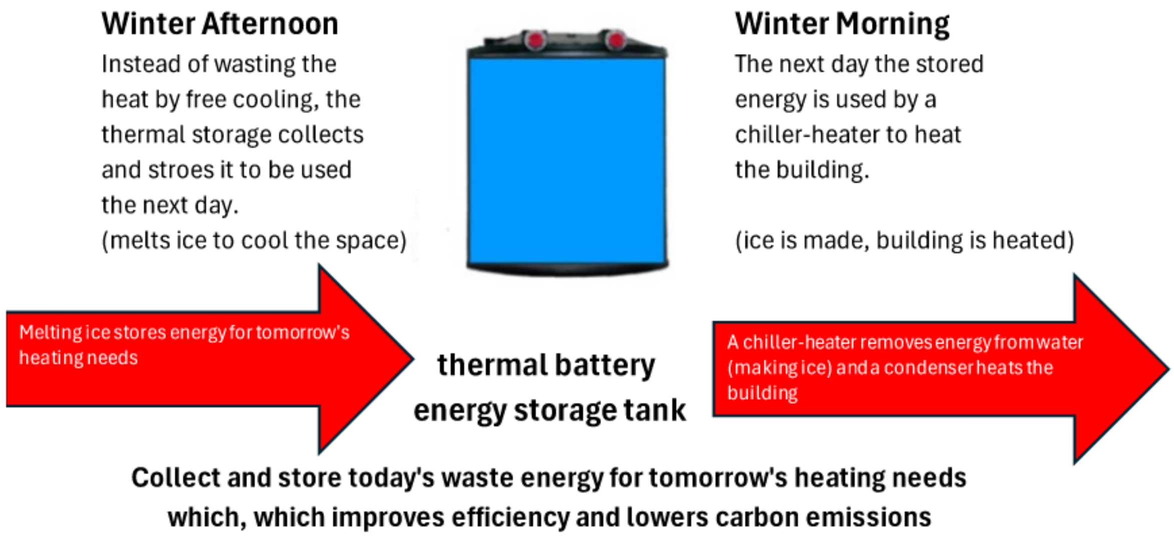
## 2.2 Adjunct Systems

This section evaluates adjunct systems that could enhance the performance, flexibility, and long-term value of the community heat pump system. These technologies were assessed for their ability to support peak-load management, improve energy utilization, and offset increased electrical demand.

### 2.2.1 Thermal Storage

As a part of the scope, the project team evaluated a modular thermal storage system, using a Calmac system, a Trane-owned company, as the basis of discussion. The Calmac system offers water-based thermal storage and phase-change (ice storage) thermal storage options. The possibility of implementing these systems at the central plant and building levels was considered, and a modular thermal storage system may be a more economical solution due to its size and ability to fit within different buildings. Phase-change thermal storage units have a smaller footprint because ice stores more energy per volume than water. This is because the phase-change cycle is more energy-dense due to latent heat than the sensible heat outside of the phase-change process. Thermal storage acts as a storage for today's wasted energy to be used tomorrow. This is called "thermal balancing" and reduces wasted energy because energy must be released or retrieved.

**Figure 4. Thermal Storage Thermal Balancing**




Thermal storage would enable daily peak-load shaving, especially during the peak heating and cooling seasons when available thermal resources, such as the sewer heat recovery and geothermal, are at capacity. During off-peak hours, the available energy from the sewer and geothermal that is not needed for conditioning the ambient loop will be used to "recharge" the thermal storage for the next day. Based on the assumed available energy from the groundwater geothermal system, thermal storage is not required but should be considered if the community heat pump system expands to other buildings on campus and the geothermal system cannot meet the loop's needs.

## 2.2.2 Solar Photovoltaic

Both rooftop and ground-mounted systems were initially considered for this analysis to offset the increased electric usage associated with the all-electric thermal loop. However, given the estimated thermal loop consumption of approximately 4,152,652 kWh, a ground-mounted system was evaluated to maximize generation potential. Building-specific rooftop systems may be viable for offsetting existing building energy use, so Houghton University should evaluate them if it wishes to offset energy use in any of its buildings.

The existing solar field at Houghton University was installed in March 2015 and produces an average annual output of approximately 2,911,068 kWh, equating to approximately 5.86 kWh/SF. Based on this production data, at least 16.3 acres of solar field would be required to offset the thermal loop load. Houghton has the potential for green space or open land to the south of the existing array, but cost constraints would make installing a solar array this size difficult.

During discussions with GreenSpark Solar, the project team learned that the substation serving the arrays, along with the existing arrays, would not be viable due to its capacity. To use arrays at this location, substation upgrades would be required, and per RG&E, these would be similar in scale to the electric infrastructure upgrades required by the thermal loop itself, resulting in two substantial investments the university would need to make.

In lieu of an array located near the existing field, GreenSpark recommended partnering with Houghton University to develop an off-site location. GreenSpark has several project development opportunities that would match or exceed the thermal loop's capacity to offset increased usage. As with the existing array, this project would be completed under a financial power purchase agreement (PPA) that would limit, and potentially eliminate, the university's upfront investment. Although Houghton would not own the array, a PPA would allow them to hedge electricity costs when market rates are high; their electricity costs will likely be high as well, but so would the price of solar energy sold into the wholesale market. The sale of high-priced electricity will help offset their high costs. When market rates are low, electricity costs are low as well, thereby helping to offset any monetary difference owed to the seller. This will allow Houghton to lessen the impact of its utility costs. If a solar array is pursued, a detailed analysis of the proposed PPA and associated costs is recommended to assess its financial impact on the proposed thermal loop.

# 3 Analytical Methods

## 3.1 Building Model Approach

For this feasibility study, the project team used existing building data and information gathered from site walk-throughs and discussions with facility managers to construct energy models of existing building operations in eQuest 3.65software. This information included scheduling for central heating and cooling equipment, occupancy schedules, specific building construction details, and space-use type. Additional assumptions were made using the *New York State Technical Resource Manual*, (New York State Joint Utilities 2022). The existing models were created with the assumption that the buildings were operating under normal conditions. These are conditions during a nonpandemic year when the facility's uses are generally the same as those that were experienced when the spaces are fully occupied.

Once complete, these models were then tuned to applicable weather-normalized utility data. Weather normalization is a process that sets the seasonally variable loads for a given period (12 months of utility bills) to those expected in a "normal" period using 30-year average heating- and cooling-degree-day data. By weather-normalizing the utility data, the baseline model can be tuned on a utility dataset representing a typical weather year, accounting for hotter or colder months observed across the year.

Once tuning was complete for each model, the project team determined that the proposed thermal loop project should be compared against an all-electric baseline. This would enable a direct comparison of electrically driven equipment and demonstrate the benefits of a thermal loop for thermal load distribution and electric usage. The baseline case assumes buildings replace their natural-gas-fired equipment with electrically driven equipment. This was also used as a benchmark in the financial analysis.

## 3.2 Community Heat Pump System Thermal Model

A mass-energy balance, 8,760-hour model was developed based on the building's hourly heating and cooling load data generated by eQuest. EMCOR used hourly data to determine the power consumption required by the new community heat pump configuration. The energy consumption of the central plant, including its associated heat pumps and the open-source geothermal system, to drive the ambient water temperature to the loop setpoint. Each of the seven buildings will use the ambient loop for space conditioning and DHW heating. Booster heat pumps within each building will be used to provide heating hot water during the heating season, and the ambient water will be used to directly cool the chilled water system. This configuration was used to compare the thermal model results with the energy consumption of the existing system and the electric baseline systems.

### 3.2.1 Assumptions

For the analysis, the central plant will supply 105ºF water to the ambient loop during the heating season and 42ºF during the cooling season. This will be achieved by the central plant heat pumps, which will use the groundwater loop as the thermal sink or source. The efficiencies used for the central plant were determined from the groundwater system supplying 56ºF to the central plant heat pumps during the cooling season and 50ºF during the heating season. The central plant system will be the primary heat source or sink for the ambient loop. Booster heat pumps in each of the seven buildings will provide the remaining temperature lift, if required, and the Reinhold Campus Center will also use sewer heat recovery to meet DHW needs.

The peak aggregate load on the central plant is approximately 8,669 MBH during the heating season and 5,113 MBH during the cooling season. The electrical impact of these aggregate loads on the central plant was determined using a heat pump coefficient of performance (COP) of 4.89 and a cooling efficiency of 0.5978 kW/ton. Trane heat pumps were used as the basis for the analysis of central plant operations. Assumed efficiencies for each building-specific piece of equipment were used to determine the impact on electrical consumption for the community heat pump loop, as well as the thermal cost-benefit of using heat pumps. Both the central plant and building analyses were completed via an 8,760-hour analysis. Total pump demand and consumption for the open-source wells, central plant, ambient loop, and building loops were estimated using the previously mentioned assumptions and the existing building equipment data.

### 3.2.2 Energy Consumption Calculations Results and Impact

The heating and cooling needs determined from the eQuest building models served as the basis for this analysis, which was performed using an 8,760-hour simulation. An annual heating demand of 14,086 MMBtu and an annual cooling demand of 2,665 MMBtu were calculated using this methodology. This results in a total annual electrical consumption, including estimated pump consumption, of 4,152,652 kWh required to condition the seven buildings and meet their DHW needs. For comparison, the annual usage associated with the existing systems, including the baseline case and the all-electric boilers, was calculated, and the results are shown in Table 3. Baseline conditions use the existing equipment efficiencies for the existing case and proposed electrical efficiencies for electric boilers.

**Table 3. Summary of Energy Consumption**

| Heat Energy Type | Heat Energy Consumption | Unit of Measurement |
|---|---|---|
| Existing electric | 2,446,281 | kWh |
| Existing natural gas | 27,805 | MMBtu |
| Baseline electric | 9,541,030 | kWh |
| Thermal loop electric | 4,152,652 | kWh |

Table 3 shows the total energy consumed, which can be represented in common units to show the impact of the community heat pump system. As Table 4 shows, electrifying each of the seven buildings will reduce the energy consumption. However, using electric boilers to electrify these buildings is not feasible given the substantial electrical infrastructure upgrades required. Heat pumps can achieve higher efficiency, resulting in an estimated decrease of approximately 14,173 MMBtu or 61%, compared with existing operations.

**Table 4. Summary of Annual Consumption**

Reported in MMBtus.

| Heat Energy Type | Heat Energy Consumption (MMBtu) |
|---|---|
| Existing | 36,154 |
| Baseline | 32,564 |
| Thermal loop | 14,173 |

## 3.3 System Design Approach

The system design approach is to develop a central plant that uses an open-source geothermal system as a thermal energy source or sink for a network of underground water connections that serves the seven participating buildings. The central plant would be in the Center for the Arts' basement, with the extraction/injection wells located beneath the adjacent parking lot. Chiller-heaters will be used in the central plant to exchange thermal energy with the open-source wells via a water-to-water heat exchanger and to supply the thermal loop. For applicable buildings, booster heat pumps will then take the thermal energy and meet the building's heating and cooling needs. Buildings that do not use a booster heat pump will provide thermal energy directly to the building systems. A point of demarcation between the thermal network and the buildings is assumed to be a heat exchanger. This high-level approach for building retrofits was used to determine the cost of retrofitting the current HVAC system. If the community heat pump project moves forward, more detail on the building's proposed systems and layouts is recommended. The extent of building retrofitting will determine the complexity of the final design.

## 3.4 Financial Analysis Approach

The team developed a financial model to determine the financial impact of implementing a thermal loop at Houghton University. The model analyzed construction costs. along with applicable grants, rebates, and incentives through a 25-year life-cycle cost analysis. The proposed system is a central heat pump plant that provides 105ºF and 42ºF during the heating and cooling seasons, respectively. The base-case system used in this analysis is an electric boiler solution that will provide the necessary steam or hot water to the seven buildings included in this analysis. The overall financial impact was quantified, and sensitivity analyses were conducted to identify the most influential financial factors and their effects on net present value (NPV) compared to the base case.

The following assumptions were used in the financial model and the overall life-cycle cost analysis:

- **Day 1:** The start of the financial analysis is January 1, 2026. Estimated costs are inflated to reflect 2026 levels, when the 25-year analysis starts.
- **Inflation rate:** Annual inflation for the life-cycle cost analysis is 2%. This applies to annual capital costs excluding any assumed financed costs.
- **Phasing:** The projects will be phased such that the central plant (proposed base) and necessary electrical infrastructure upgrades will be made in the first year of the analysis. This is assumed to be 50% of the total costs, with the next two years covering the remaining project costs, including building equipment and electrical upgrades.

The financial model uses the energy model's inputs to determine energy consumption for space conditioning and DHW heating. These assumptions are based on the modelled and provided energy consumption data from Houghton University.

The building energy models were used to determine the thermal energy requirements associated with:

- Heating loads
- Cooling loads
- DHW loads

Using the utility bills Houghton University provided, utility rates were estimated to determine the annual impact throughout the financial analysis.

- **Natural gas:** The $/therm rate used for the analysis was determined from the weighted average of the York natural gas meter, which serves the Center for the Arts, Chamberlain Center, Gillette Hall, Library, Luckey Memorial Building, and Wesley Chapel, among other buildings, and the Reinhold Campus Center gas meter. The 2022 utility data was used for this analysis.

- **Electricity:** The $/MWh rate used for the analysis was determined from the utility rate taken from utility data taken from 2022 from the Wesley Chapel meter data, which serves all seven buildings, among others.
- **Carbon costs:** Carbon costs are the additional costs associated with a social cost of carbon (SCC) that are assumed to be applied to natural gas users. Natural gas use is accompanied by an additional $52.88 per ton of carbon dioxide ($CO_2$) in greenhouse gas (GHG) emissions. The assumption uses 0.054 tons of $CO_2$ per 1 MMBtu of natural gas.

Fixed operating costs for equipment maintenance and equipment inventory were determined from existing maintenance capital expenses for the seven buildings. Houghton University provided the existing annual budgets allocated for the seven buildings. The equipment inventory was determined from similar maintenance schedules. The assumption is that Houghton University will incur no additional labor, leasing, insurance, legal, tax, or other expenditures associated with the thermal loop. Therefore, the capital costs associated with the thermal loop at Houghton are estimated based on the installation of the central plant and distribution piping.

- **Equipment maintenance:** Existing maintenance for the seven buildings is currently estimated at $237,000 annually. This is assumed not to change for the baseline case, but is expected to increase to $437,000 for the thermal loop due to the inclusion of additional building equipment, the central plant, and the distribution system. The 2% inflation rate applies to both scenarios.
    - These capital cost estimates are in 2023 U.S. dollars (USD), so escalation (2% per year) is added.
    - These costs begin in Year 2 for this analysis.
- **Equipment inventory:** An initial inventory of spare parts and tools will be needed and is assumed to be $5,000 for the proposed (thermal loop) case.
    - These capital cost estimates are in 2023 USD, so escalation (2% per year) is added.
    - These costs begin in Year 2.
- **Thermal loop capital costs:** A total cost of $13,022,195 is currently estimated for the thermal loop with a 3-year phase-in. The phase-in consists of 50% of the total project cost -$7,047,821 in Year 1 and 25% of the total project cost -$3,594,389 in each of Years 2 and 3. This analysis excludes financing and assumes a 25-year cash flow. If this project moves forward, evaluating potential financing along with any Applicable assumptions is recommended.

Potential incentives and tax credits were applied to the financial model. A potential federal tax credit of up to 30% may be available for installing the thermal loop. This federal tax credit is not supported by current law, but is included because proposed bills would provide tax credits for energy-efficient capital projects. In addition, the project is assumed to qualify for NYSERDA's Community Heat

Pump Category C funding. The team applied a blended incentive rate of 30% of total project costs, or $4,029,966, in this analysis, which will follow the same phase-in of construction costs.

Given the extensive list of variables in this financial analysis, the team conducted sensitivity analyses to identify which assumptions have the greatest impact on the investment and may result in a negative NPV. Each sensitivity analysis's impact was determined based on the NPV of the 25-year financial analysis when the variable(s) were changed. These variables include:

- **Maintenance costs:** Maintenance costs are the annual costs associated with operating the district thermal system other than the energy costs. These costs were estimated from current overhead costs for operating each of the seven buildings. Because these costs are constant, they significantly affect the NPV. A range of costs was analyzed within a sensitivity analysis to determine the impact on NPV for the system's operating costs.
- **Cost of electricity:** As New York State advances its plan to reduce reliance on natural gas, the impact on the cost of electricity is uncertain at this point. The electricity cost is assumed to be $93/MWh based on existing Houghton University utility data.
- **SCC (Cap-and-Invest program):** The SCC is incorporated into the financial analysis as a carbon tax associated with the usage of natural gas. Within the financial analysis, this includes the natural gas usage associated with the 3-year phase-in of electric equipment. The SCC is assumed to be applied as a Cap-and-Invest auction assessment under New York State law. Details of the Cap-and-Invest program are to be defined by the State at a later date; therefore, this analysis uses the SOSC outlined by the Climate Act. The financial analysis uses a SCC equal to $52.88/ton of $CO_2$ based on the first carbon surcharge value released by the Climate Act. The change in the SCC was to show the impact of no assessment associated with the SCC up to the value published in the Climate Act's "Establishing a Value of Carbon: Guidelines for Use by State Agencies" (DEC 2021) document. The SCC is published to be $126 with a 2% discount rate (page 34 of the guidelines) in 2020 and is converted to 2023's value using the U.S. Consumer Price Index (CPI). The CPI increased by 18.62% between 2020 and 2023, resulting in a price of $149.46 per ton of CO2 from the published $126.
- **Grants and incentives:** The level to which Houghton University will be able to use local utility, State, and federal grants, tax credits, and incentives will vary depending on the final design of the system. Various rebate rates were analyzed to determine the impact of the total amount of grants and incentives on the NPV.
- **Heating and cooling efficiencies:** The energy usage of the thermal loop is a large driver of the overall cost to operate the system. Therefore, heating and cooling COPs were analyzed as part of the financial analysis to determine their impact.
- **Capital expenses:** Capital costs (i.e., construction and electric infrastructure costs) were included to determine their impact on the NPV. Because these values were determined using high-level assumptions, these costs will likely vary if the project proceeds.

# 4 System Design: Community Heat Pump Infrastructure

The community heat pump distribution system was designed to include a central plant in the Center for the Arts' basement and a piping system connecting the seven participating buildings to the thermal network. This network would use the available green space in the university's quad. The basis of design is to use an open-source geothermal system as a thermal heat source or sink for the central plant's chillers and heaters, providing 42ºF water during the cooling season and 105ºF during the heating season via a 2-pipe system.

## 4.1 Central Plant

The Center for the Arts' basement was identified as the ideal location for the central plant because the space is currently used for storage. The parking lot northeast of Gillette Hall would be sufficient for the extraction and injection wells. Water from these wells would be extracted via submerged pumps, passed through a heat exchanger that serves the central plant heat pumps, and then returned via injection well pumps. Appendix A has a representative piping and instrument diagram.

The central plant equipment consists of the following:

- Water-source heat pumps that serve the ambient loop
- Associated circulation pumps
- Open-source heat exchanger
- Open-source heat exchanger pumps
- Extraction and injection well pumps

The project team discussed the electrical infrastructure upgrades needed for the central plant with the local utility's (RG&E) engineering team to determine project feasibility. The existing Wesley Chapel meter, which serves many campus buildings, including the seven participant buildings, provides only a 4 kV connection to the utility grid. To meet the community heat pump loop's requirements, costly substation upgrades would likely be required to provide the necessary electrical feed to the meter. Rather than connecting to the Wesley Chapel meter, the thermal loop could be fed from the connection point near the Kerr-Pegula Field House. This study assumes that an adequate electrical feed will be provided to the loop, but this assumption will need to be confirmed if this project moves forward.

## 4.2 Distribution System and Building Connections

The ambient loop for this community heat pump project will include:

- Distribution piping network
- Distribution pumps located in the central plant
- Participant connection circulation pumps
- Ambient loop to building loop heat exchangers (the heat exchanger will be the point of demarcation between the community heat pump and member facilities)

Using the available resources for this analysis, Appendix B presents a theoretical distribution piping layout that was developed and used as the basis for the pumping design. Pumping flows were derived from hourly thermal energy demands for the entire loop and for each participating building. This distribution piping network would be a 2-pipe system that supplies and returns the ambient water to and from each of the seven buildings. The pumps serving this loop would be in the Center for the Arts' basement, along with the central plant equipment. The team assumes that sufficient below-grade space for system implementation is available.

Each building can draw from either the supply or the return ambient water, depending on the optimal temperature for each building's heating and cooling applications. The analysis is based on a distributed pumping system design that includes a pump at each building connection and pumps at the main plant. Each building connection includes a three-way valve that allows flow through the building heat exchanger to be reversed as needed to meet facility demands. Because distribution loop temperatures vary between heating and cooling seasons, the three-way valve enables each building to reverse flow between the supply and return water lines to optimize booster heat pump efficiency, depending on each building's requirement. Pump energy for this analysis was determined from the necessary flow required for each connection and an estimated pump head requirement.

## 4.3 Building Retrofits

Each of the seven buildings included in this analysis uses a variety of systems to meet its respective space conditioning requirements. This includes steam, hot water, water-source heat pumps, packaged rooftop units, and air-handling units (AHUs) with some buildings using steam and hot water.

As shown in Appendix C, several technologies were used as the basis for this analysis. In buildings that currently require 180ºF hot water, a booster heat pump uses thermal energy from the ambient loop to meet these temperature requirements.

The deep energy retrofit measures required to lower the heating hot water supply temperature would likely limit the project's economic feasibility, but should be investigated if the project proceeds. Heat rejected during the cooling season will be rejected directly into the building loop, which is served by the ambient loop, without requiring a booster heat pump. This is due to the 42ºF supply water temperature used in this analysis, which meets the design specifications for buildings that use chilled water for cooling. Buildings that use steam or hot-water radiation will have this radiation replaced with fan-coil units that pull thermal energy directly from the building loop without booster heat pumps and reject thermal energy directly to the building loop without utilizing the booster heat pumps. This will add cooling capacity to buildings such as Gillette Hall, the Library (basement through second floors), and Luckey Memorial Building. Wesley Chapel will also install chilled-water coils implemented into existing air-handling units. Buildings that require heating and ventilating units and/or packaged rooftop units will have those units replaced with equipment that can take or reject thermal energy directly from the building loop.

# 5 Business Model

This section outlines the assumed ownership structure and the financial analysis approach used to evaluate the proposed thermal loop project.

- **Ownership and funding assumptions:** The business model assumes that the university will fully fund the thermal loop project because it owns and operates the buildings and properties included in the loop. External financing was not considered at this stage of the project because the project team wanted to determine the financial impacts of implementing the thermal loop through a cash-flow analysis.
- **Financial analysis methodology:** The life-cycle cost analysis combines construction costs with applicable grants, rebates, and incentives to forecast the annual financial impact of electrifying the seven buildings over a 25-year period. The financial ramifications of installing the thermal loop were compared with the base case in which electric boilers replace the existing steam/ hot-water generating equipment in each building. The thermal loop employs central heat pumps, an open-source geothermal system, and building heat pumps to provide the necessary thermal energy. The NPV for the 25-year life-cycle cost analysis was used to determine the financial impact of the thermal loop project. An annual cash flow was determined using the derived assumptions and the annual energy consumption estimates for the district plant and individual buildings.

# 6 Regulatory, Policy, and Legal Considerations

The project team analyzed the permitting, regulatory, legislative, and institutional items (collectively, the "policy" items) that could impact the project's feasibility. Because the seven buildings comprising the thermal loop are owned and operated by Houghton University, Houghton is responsible for the operations and maintenance of the equipment included in the building retrofits, as well as the central plant. Any electrical infrastructure upgrades to buildings will be subject only to university regulations and procedures, including applicable building codes and best engineering practices. Rights-of-way for the construction of the distribution piping will be subject only to university regulations and procedures. Special consideration will be required for the use of groundwater in the open-source geothermal system, which may include determining where Houghton's responsibilities begin and end concerning the system's impact on surrounding groundwater. A detailed legal review of applicable laws, including but not limited to oil, gas, and solution mining law, environmental conservation law, and water resources law, should be completed prior to project implementation.

## 6.1 Environmental Review

This project requires precursor policy items to be completed prior to project implementation and construction.

- **State Environmental Quality Review Act (SEQRA) and National Environmental Policy Act (NEPA) review and approval:** This will require the designation of a Lead Agency and likely the support of a qualified engineering firm familiar with SEQRA/NEPA requirements (if applicable) to support the overall project permitting process. The process must comply with New York State Department of Environmental Conservation (DEC) requirements. No action by any government agency can be taken to undertake, fund, or approve the project unless the project has fully complied with SEQRA and NEPA. The SEQRA process must include an assessment of the proposed action's effects on disadvantaged communities, including whether the action will cause or increase a disproportionate or inequitable burden on a disadvantaged community and whether the action demonstrates compliance with Environmental Justice considerations as required by the Climate Act and DEC regulatory requirements. The DEC may be required to prepare an existing burden report for all projects requiring a DEC permit, following the DEC's adoption of regulations. Although Houghton University is not considered a disadvantaged community, the impact of the community heat pump project, particularly the open-source geothermal system, on neighboring communities that may be disadvantaged will be evaluated as part of SEQRA and NEPA review.
- **Environmental due diligence:** A Phase I environmental site assessment will be required for key components of the project, including the open-source geothermal and the distribution piping systems.

- **Watershed impact analysis:** As part of the environmental review, an analysis should be completed by a competent professional (e.g., a hydrogeologist) to determine the impacts that the open-source geothermal system for Houghton University will have on surrounding watersheds.

## 6.2 Real Property Matters

Because Houghton University owns the campus buildings and property included in this study, no review of real property matters is required.

## 6.3 Potential Legislative Matters

Action by the Town Board (Town of Caneadea) and the County Legislature (Alleghany County) may be required to authorize amendments to local laws governing the proposed community heat pump system.

## 6.4 Central Plant Siting Considerations

The ambient loops' primary thermal sink or source is an open-source geothermal system. The parking lot near Gillette Hall was identified as an ideal location for the proposed injection and extraction wells. Water from these wells would be extracted via submerged pumps, passed through a heat exchanger that serves the central plant heat pumps, and then returned via injection well pumps. The construction of the open-source wells may require Authorities Having Jurisdiction approvals, including but not limited to:

- Geothermal remediation plan, if applicable
- Compliance with NYS Environmental Conservation Law Article 15, Water Resources Law.
- Compliance with NYS Environmental Conservation Law Article 17, Water Pollution Control.
- Compliance with NYS Environmental Conservation Law Article 23, Well Drilling.
- Compliance with 6 NYCRR Part 704/SPEDES Permit, if applicable.
- Compliance with SDWA-EPA Class V injection well, if applicable.
- Compliance with DEC Policy #CP52 Best Technology Available, if applicable.

## 6.5 Tax Considerations

The business model used for this analysis does not assume any financing, so the ability to finance the community heat pump loop is expected to have limited impacts on the project's feasibility. If financing is pursued, a detailed analysis of its impact on the project timeline is recommended.

This project may have substantial tax implications for Houghton University. Construction of the central plant building, electrical upgrades, and ambient loop is assumed to be sales-tax-exempt through the NYS Capital Improvement exemptions due to the capital and permanent nature of the projects. The applicability of the Investment Tax Credit (ITC), as recently amended and expanded under the

Inflation Reduction Act (IRA), with respect to the geothermal systems and other components of the project. The U.S. Treasury is promulgating draft regulations, and preliminary indications are that the ITC will not extend to the ambient loop portion of the project. Refundability of the ITC, assuming it applies in part to the project, should also be evaluated prior to project implementation to lower overall project costs, given the assumed tax-exempt status of Houghton University.

## 6.6 Climate Act Compliance

The Climate Act requires New York State to reduce economy-wide GHG emissions by 40% by 2030 and by at least 85% by 2050 from 1990 levels. Section 7.3 of the Climate Act requires that, in issuing permits, State agencies (including DEC) must not disproportionately burden disadvantaged communities and must prioritize reductions of GHG emissions and co-pollutants in disadvantaged communities. In addition, recent legislation (Chapter 840 of the Laws of 2022) prohibits DEC from approving or renewing permits (including air permits) if such permits may cause or contribute, directly or indirectly, a disproportionate or inequitable pollution burden on a disadvantaged community. This project will serve as a cornerstone in Houghton University's Climate Act compliance strategy.

## 6.7 Constitutional Amendment Considerations

New York State recently adopted a constitutional amendment to the Article I Bill of Rights, which provides that "each person shall have a right to clean air and water, and a healthful environment." (Pa. Const. art. I, § 27). This provides a broader context for the planned transition from natural gas to community thermal as Houghton works to reduce environmental impacts consistent with its ongoing commitment to meet the thermal needs of its campus in a cost-effective and environmentally responsible manner.

## 6.8 DEC Environmental Permitting

DEC water withdrawal permitting is required for any groundwater withdrawal system with the capacity to withdraw 100,000 gpd or more of groundwater. If the final design of this community heat pump project indicates the capacity will equal or surpass this, DEC recommends scheduling a preapplication conference to clarify project objectives and obtain DEC's recommendations. The project team recommends this occur once the central plant design nears completion, prior to development of construction plans. Once a Water Withdrawal Permit is submitted, the permitting process will follow DEC's guidelines.

As outlined on the DEC's website, several steps in the permitting process may significantly affect the plausibility and timeline of the system's implementation. Because the community heat pump project will likely be classified as a "major project," a public hearing will likely be held after the DEC's review of the application (currently scheduled 15 days from receipt). This requires the Notice of Complete Application to be published in the DEC's Environment Notice Bulletin as well as a local newspaper, followed by a public comment period established by the DEC. A specific timeline is not listed on the DEC's website. but publishing of the Notice of Complete Application may increase the length of time required to obtain the permit.

Based on community feedback and the DEC's review, a public hearing may be held to solicit comments on the application. As outlined on the DEC's website, this hearing must commence within 90 days of the completeness determination and can range from a single-day to a multiday hearing with various levels of review, examination, and approval (DEC n.d.). Following the hearing, the DEC must issue a final decision on the application within 60 days of receiving the final hearing records.

The utilization of a double-walled, brazed plate heat exchanger should prevent any pollutants returning to the ground via the injection well. This, along with the absence of a sewer heat-recovery system used in this project, reduces the likelihood that a SPDES permit will be required. Confirmation of whether a SPDES permit is required should be completed before implementing the community heat pump system.

At any point in the permitting process, obstacles or delays may arise that delay project implementation. When combined with potential challenges in material or equipment procurement or financing, these issues may result in significant delays in implementing the community heat pump.

# 7 Community Heat Pump System Impact

Implementation of a community heat pump system at Houghton University will provide a green energy solution to meet the heating and cooling needs of the seven participating buildings. These buildings employ various system types and load profiles that enable them to use the network's shared thermal energy. For this feasibility study, the project team analyzed an open-loop geothermal system as the thermal sink or source of the loop.

## 7.1 Baseline and Proposed Solutions Comparison

The financial implications of installing a thermal loop were compared with the base case of installing electric boilers in place of the steam/hot-water generating equipment over a 25-year period. Table 5 summarizes the cash-flow analyses for the implementation period (over 3 years), a year after implementation, and at the end of the financial analysis through 2050. The first 3 years of the financial analysis show an overall negative cash flow, indicating that Houghton would pay more per year to implement the thermal loop. This is due to the loop's construction costs. The next year, cash flow turns positive, largely due to the dramatic increase in electrical costs associated with the base case. If construction costs or project phasing changes occur, if this project moves forward, these may delay the year this cash flow turns positive. The overall NPV of the new district thermal system during the 25-year cash flow analysis is $324,448.

**Table 5. Summary of Cash-Flow Analysis**

| Cost Category | 2026 | 2027 | 2028 | 2029 | 2050 |
|---|---|---|---|---|---|
| **Electric Boiler** | | | | | |
| Equipment maintenance | $0 | $261,667 | $266,900 | $272,239 | $412,623 |
| Parts inventory | $0 | $3,000 | $3,060 | $3,121 | $4,731 |
| Natural gas costs | $156,694 | $106,552 | $54,342 | $0 | $0 |
| Electricity costs | $23,772 | $8,083 | $16,489 | $694,082 | $1,051,997 |
| SCC costs | $88,343 | $59,845 | $30,405 | $0 | $0 |
| Water costs | $0 | $0 | $0 | $0 | $0 |
| Chemical costs | $0 | $0 | $0 | $0 | $0 |
| Wastewater costs | $0 | $0 | $0 | $0 | $0 |
| Capital costs spent | $3,788,513 | $1,932,141 | $1,970,784 | $0 | $0 |
| Capital costs expensed | $3,788,513 | $1,932,141 | $1,970,784 | $0 | $0 |
| **Total** | **$4,057,322** | **$2,371,289** | **$2,341,980** | **$969,442** | **$1,469,350** |

**Table 5. (continued)**

| Cost Category | 2026 | 2027 | 2028 | 2029 | 2050 |
|---|---|---|---|---|---|
| **Thermal Loop** | | | | | |
| Thermal loop charges | $0 | $487,483 | $497,233 | $507,178 | $768,712 |
| Natural gas costs | $156,694 | $106,552 | $54,342 | $0 | $0 |
| Electricity costs | $22,849 | $13,194 | $26,916 | $290,938 | $440,964 |
| SCC COSTS | $88,343 | $59,845 | $30,405 | $0 | $0 |
| Conversion costs spent | $5,741,989 | $2,928,414 | $2,986,983 | $0 | $0 |
| Conversion Costs expensed | $5,741,989 | $2,928,414 | $2,986,983 | $0 | $0 |
| Rebates and incentives | -$1,722,597 | -$878,524 | $896,095 | $0 | $0 |
| **Total** | **$4,287,279** | **$2,716,965** | **$2,699,784** | **$798,115** | **$1,209,676** |
| **Total difference in cash flow** | **-$229,956** | **-$345,676** | **-$357,804** | **$171,326** | **$259,673** |

In addition to NPV, the project team calculated several financial metrics to further evaluate the project's viability. This includes the internal rate of return (IRR) and return on investment (ROI) for the thermal loop compared to the base case. Using the 25-year cash-flow analysis, the IRR was determined to be 4.19% and will be compared to Houghton University's minimum acceptable rate of return (MARR) when the thermal loop is considered for implementation. The ROI was evaluated based on energy savings (kWh) and, as summarized in Table 6, was calculated at 66%. The IRR and ROI indicate that the thermal loop project would benefit Houghton relative to an all-electric boiler baseline.

**Table 6. Summary of Financial Metrics**

| Metric | Amount |
|---|---|
| Est. savings (kWh) | 5,388,378.0 |
| Project cost | $6,022,195 |
| Est. 2023 utility rate ($/kWh) | $0.09 |
| Est. annual savings | $511,141.54 |
| Term | 25 |
| Inflation rate (assumed) | 2% |
| Present worth of annual savings | $9,979,249.55 |
| ROI | 66% |

## 7.2 Sensitivity Analyses

Each sensitivity analysis of the district thermal system shows the financial impact of each variable. The impact of each variable on the NPV is shown in the following sensitivity analyses.

The SCC has the least impact on the NPV of the financial analysis, as shown in Table 7. Because this analysis assumes identical project phasing for both the base case and the thermal loop and that their natural gas phase-downs will be similar, the change in SCC does not impact the NPV. In this analysis, the SCC is shown as a Cap-and-Invest auction assessment or cost for using natural gas for space heating need. The SCC is important to consider moving forward when understanding the requirements from the Climate Act and analyzing the financial impact of continuing to use natural gas. If this assumption changes with the implementation of this project, the impact of SCC should be reevaluated.

**Table 7. Change per Percent Change of Assumption**

| Cost Type | Annual Cost |
|---|---:|
| Maintenance cost-baseline | $33,163.79 |
| Maintenance cost-thermal loop | $61,150.11 |
| Electricity cost | $41,997.44 |
| SCC | $0.00 |
| Rebate rate | $19,414.14 |
| COP, heating | $40,978.40 |
| COP, cooling | $5,131.52 |
| DHW COP | $1,382.95 |
| Construction cost-baseline | $34,786.50 |
| Construction cost-thermal loop | $45,299.65 |

As shown in Table 7, annual maintenance costs and construction costs have a substantial impact on NPV. For maintenance and construction costs, analyses were conducted for both the base case and the thermal loop estimates, as these factors were based on high-level estimates. If this project moves forward, these values should be confirmed. As shown in Table 8, a 25% increase in either maintenance or construction costs could drastically impact the NPV. If construction costs associated with the thermal loop increase by 25%, the NPV drops to ($808,043) because only an increase of approximately 7% results in a negative NPV, as shown in Table 9. The NPV will turn negative with an increase of greater than 5% for maintenance costs, as shown in Table 10. Because electric infrastructure costs are included in overall construction costs, a separate sensitivity analysis was conducted for them. This analysis determined that the electric infrastructure costs also have a significant impact on the NPV, as an increase of greater than 23% would result in a negative NPV, as shown in Table 11.

**Table 8. Twenty-five Percent Increase Impact on Net Present Value**

| Category | Thermal Loop | Base Case |
|---|---|---|
| Maintenance costs | -471% | 256% |
| Construction costs | -349% | 268% |
| Electric infrastructure | -107% | 191% |

**Table 9. Thermal Loop to Baseline Construction Cost Analysis**

| Category | NPV | -25% | -12.5% | Current | 25% | 50% | 75% | 100% |
|---|---|---|---|---|---|---|---|---|
| Thermal Loop | $324,448 | $5,250,000 | $6,125,000 | $7,000,000 | $8,750,000 | $10,500,000 | $12,250,000 | $14,000,000 |
| -25% | $9,766,646 | $587,277 | $1,022,108 | $1,456,940 | $2,326,602 | $3,196,265 | $4,065,927 | $4,935,589 |
| -12.5% | $11,394,421 | $21,032 | $455,863 | $890,694 | $1,760,356 | $2,630,019 | $3,499,681 | $4,369,344 |
| Current | $13,022,195 | -$545,214 | -$110,383 | $324,448 | $1,194,111 | $2,063,773 | $2,933,436 | $3,803,098 |
| 25% | $16,277,744 | -$1,677,705 | -$1,242,874 | -$808,043 | $61,619 | $931,282 | $1,800,944 | $2,670,607 |
| 50% | $19,533,292 | -$2,810,197 | -$2,375,366 | -$1,940,534 | -$1,070,872 | -$201,210 | $668,453 | $1,538,115 |
| 75% | $22,788,841 | -$3,942,688 | -$3,507,857 | -$3,073,026 | -$2,203,363 | -$1,333,701 | -$464,038 | $405,624 |
| 100% | $26,044,390 | -$5,075,179 | -$4,640,348 | -$4,205,517 | -$3,335,855 | -$2,466,192 | -$1,596,530 | -$726,867 |

**Table 10. Thermal Loop to Baseline Maintenance Cost Analysis**

| Category | NPV | -50% | -25.0% | Current | 25% | 50% | 75% | 100% |
|---|---|---|---|---|---|---|---|---|
| Thermal Loop | $324,448.34 | $118,500.00 | $177,750.00 | $237,000.00 | $296,250.00 | $355,500.00 | $414,750.00 | $474,000.00 |
| -50% | $218,500.00 | $1,723,764 | $2,552,859 | $3,381,954 | $4,211,048 | $5,040,143 | $5,869,238 | $6,698,333 |
| -25.0% | $327,750.00 | $195,012 | $1,024,106 | $1,853,201 | $2,682,296 | $3,511,390 | $4,340,485 | $5,169,580 |
| Current | $437,000.00 | -$1,333,741 | -$504,646 | $324,448 | $1,153,543 | $1,982,638 | $2,811,732 | $3,640,827 |
| 25% | $546,250.00 | -$2,862,494 | -$2,033,399 | -$1,204,304 | -$375,210 | $453,885 | $1,282,980 | $2,112,074 |
| 50% | $655,500.00 | -$4,391,246 | -$3,562,152 | -$2,733,057 | -$1,903,962 | -$1,074,868 | $245,773 | $583,322 |
| 75% | $764,750.00 | -$5,919,999 | -$5,090,904 | -$4,261,810 | -$3,432,715 | -$2,603,620 | -$1,774,526 | -$945,431 |
| 100% | $874,000.00 | -$7,448,752 | -$6,619,657 | -$5,790,562 | -$4,961,468 | -$4,132,373 | -$3,303,278 | -$2,474,184 |

**Table 11. Thermal Loop to Baseline Electric Infrastructure Cost Analysis**

| Category | NPV | -25% | -12.5% | Current | 25% | 50% | 75% | 100% |
|---|---|---|---|---|---|---|---|---|
| Thermal Loop | $324,448 | $3,750,000 | $4,375,000 | $5,000,000 | $6,250,000 | $7,500,000 | $8,750,000 | $10,000,000 |
| -25% | $3,000,000 | $51,126 | $361,720 | $672,313 | $1,293,501 | $1,914,688 | $2,535,876 | $3,157,063 |
| -13% | $3,500,000 | -$122,807 | $187,787 | $498,381 | $1,119,568 | $1,740,756 | $2,361,943 | $2,983,131 |
| Current | $4,000,000 | -$296,739 | $13,855 | $324,448 | $945,636 | $1,566,823 | $2,188,011 | $2,809,198 |
| 25% | $5,000,000 | -$644,604 | -$334,010 | -$23,417 | $597,771 | $1,218,958 | $1,840,146 | $2,461,333 |
| 50% | $6,000,000 | -$992,469 | -$681,875 | -$371,282 | $249,906 | $871,093 | $1,492,281 | $2,113,468 |
| 75% | $7,000,000 | -$1,340,334 | -$1,029,740 | -$719,147 | -$97,959 | $523,228 | $1,144,416 | $1,765,603 |
| 100% | $8,000,000 | -$1,688,199 | -$1,377,605 | -$1,067,012 | -$445,824 | $175,363 | $796,551 | $1,417,738 |

The costs of both electric and heating efficiency also have substantial impacts on the NPV. However, for electricity costs to reduce the NPV, they would need to decrease, which is unlikely. The analysis showed that heating efficiency has a significant impact on the project's NPV if it is lower than the values included in the analysis. A decrease of about 25.2% results in a COP of approximately 2.86, and a value below that would result in a negative NPV. Moving forward, deep energy retrofits (i.e., changing coils to use lower heating hot water temperatures) may be a better long-term solution for hot water and chilled water systems, allowing for a higher COP to be achieved.

## 7.3 Energy Consumption

The energy consumption of the community heat pump system is estimated to be 4,152,652 kWh, which includes the usage associated with the building booster heat pumps along with pump consumption. This results in an estimated GHG emission of approximately 440.8 $MTCO_2e$ using Upstate New York eGrid 2021 total equivalent $CO_2$ emissions ($CO_2e$).106 $MTCO_2e$/MWh. This is an estimated 1,295.7 $MTCO_2e$ improvement over the existing natural gas system and a 571.9 $MTCO_2e$ improvement over the all-electric baseline. The total estimated emissions saved during the 25-year life cycle is approximately 1,4297.5 $MTCO_2e$ when comparing the thermal loop to the all-electric baseline.

# 8 Conclusion

The proposed community heat pump system is a potential solution that would enable Houghton University to transition from fossil-fuel-based conditioning to electrically driven systems. The system would enable campus buildings to retrofit their existing systems and connect to a clean, more efficient heating solution than individual heating options. However, when compared to existing operations that use natural-gas-fired equipment, neither the base case consisting of all electric boilers, nor the proposed community heat pump loop, make financial sense. This is indicated by a negative NPV calculated from their respective 25-year life-cycle analyses. Houghton is unlikely to pursue an all-electric option unless required to significantly reduce campus fossil fuel consumption, unless significant changes occur in utility costs, available rebates, and/or SCC rates.

Through sensitivity analyses, maintenance and construction costs, along with heating efficiency (COP), were identified as the most influential factors affecting the project's NPV and may represent significant barriers to implementation. The project team determined that retrofitting existing building systems involves a wide range of potential costs. These retrofits result in high capital expenditures for several buildings due to required modifications to end-use equipment that currently relies on steam or 180ºF design hot-water supply temperatures. Buildings requiring 180ºF hot water would need booster heat pumps to achieve the required temperature lift from the thermal loop supply temperature of 105ºF. Meeting the 180ºF supply temperature drastically reduces system efficiency due to the additional lift required. If this project moves forward, pursuing deep energy retrofits across all seven buildings may be financially advantageous because eliminating the need for booster heat pumps would improve system efficiency and reduce both capital and maintenance costs.

Low-interest financing and substantial upfront funding from grants, incentives, and potential investors would significantly improve the financial viability of the proposed thermal loop. Favorable interest rates on any financed portions of the project would further enhance the system's overall financial outlook. Building retrofits represent major capital improvements and would likely require a combination of low-interest financing and grant or incentive support. The total cost to Houghton University will remain uncertain until available incentives, grants, and tax credits are more clearly defined. As the requirements of the Climate Act continue to evolve, the project team will periodically reevaluate the system's feasibility, including the potential use of programs such as Cap-and-Invest to incentivize emissions reductions. In addition to State-level funding and emissions-reduction benefits, federal funding opportunities, such as those available through the IRA, will need to be explored as program details become available. Tax credits will also require further clarification during the design phase and as the project advances toward implementation.

The project team believes that an open-source geothermal system presents an opportunity to provide clean heating and cooling for buildings at Houghton University and could be scalable and replicable across other rural areas and campuses throughout the State and country. New York State has established GHG emissions reduction goals that will affect all sectors statewide. The proposed community heat pump system is a potential solution that would allow for the removal of natural-gas-fired equipment. Houghton would be able to retrofit the buildings evaluated in this analysis and implement a clean heating solution. With the State's goals and the need to provide a clean heat solution to buildings in New York State, a community heat pump system that uses open-source geothermal energy can be a part of the area's efforts to meet these goals.

# 9 References

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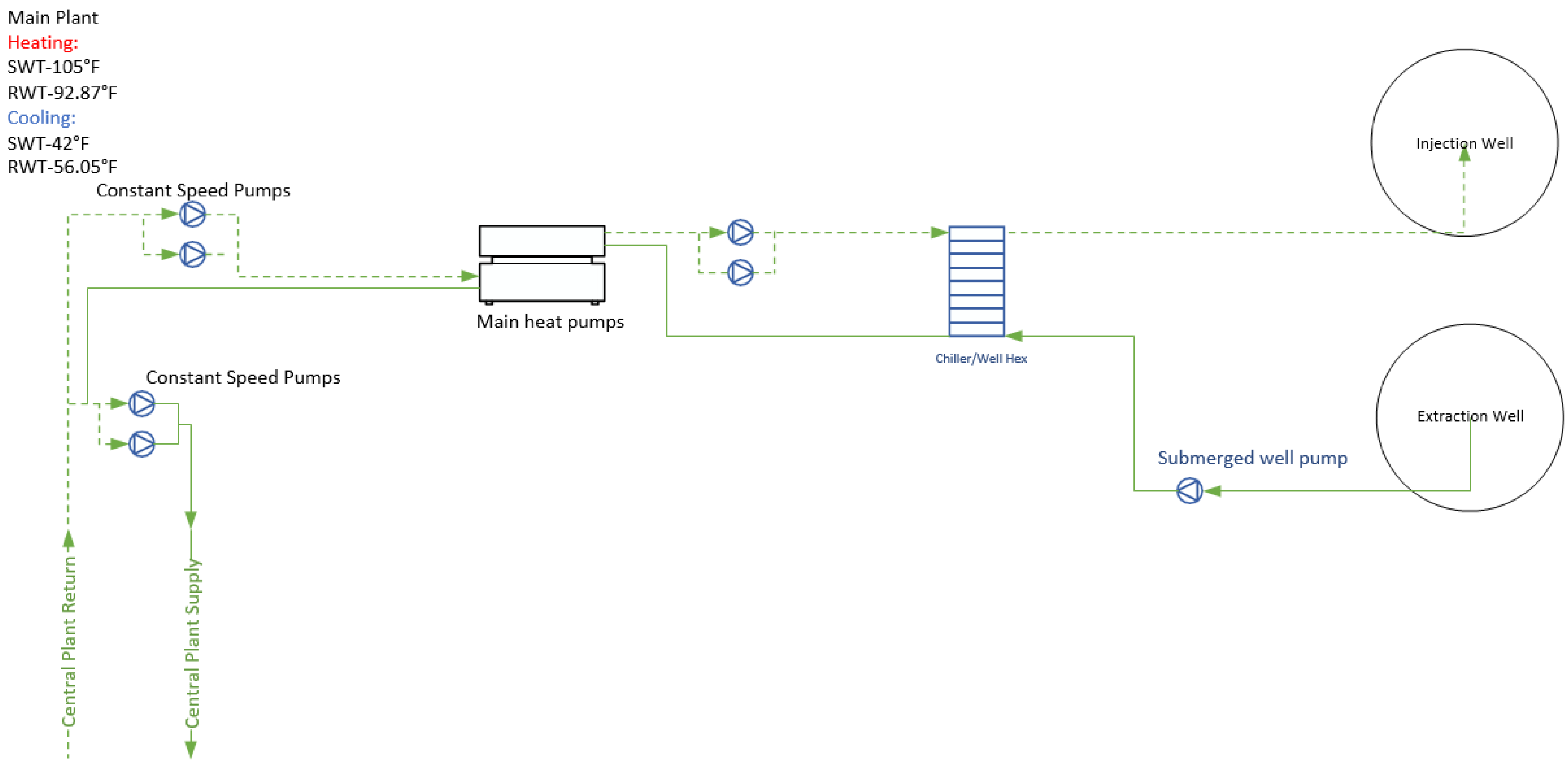
New York State Department of Public Service (DPS). 2021, October 27 (issue date of Version 9). New York Technical Resource Manual. Ver. 9, October 27. https://dps.ny.gov/system/files/documents/2022/11/technical-resource-manual-version-9-filed-october-27-2021-effective-january-1-2022.pdf.

Pa. Const. art. I, § 27. https://www.legis.state.pa.us/.

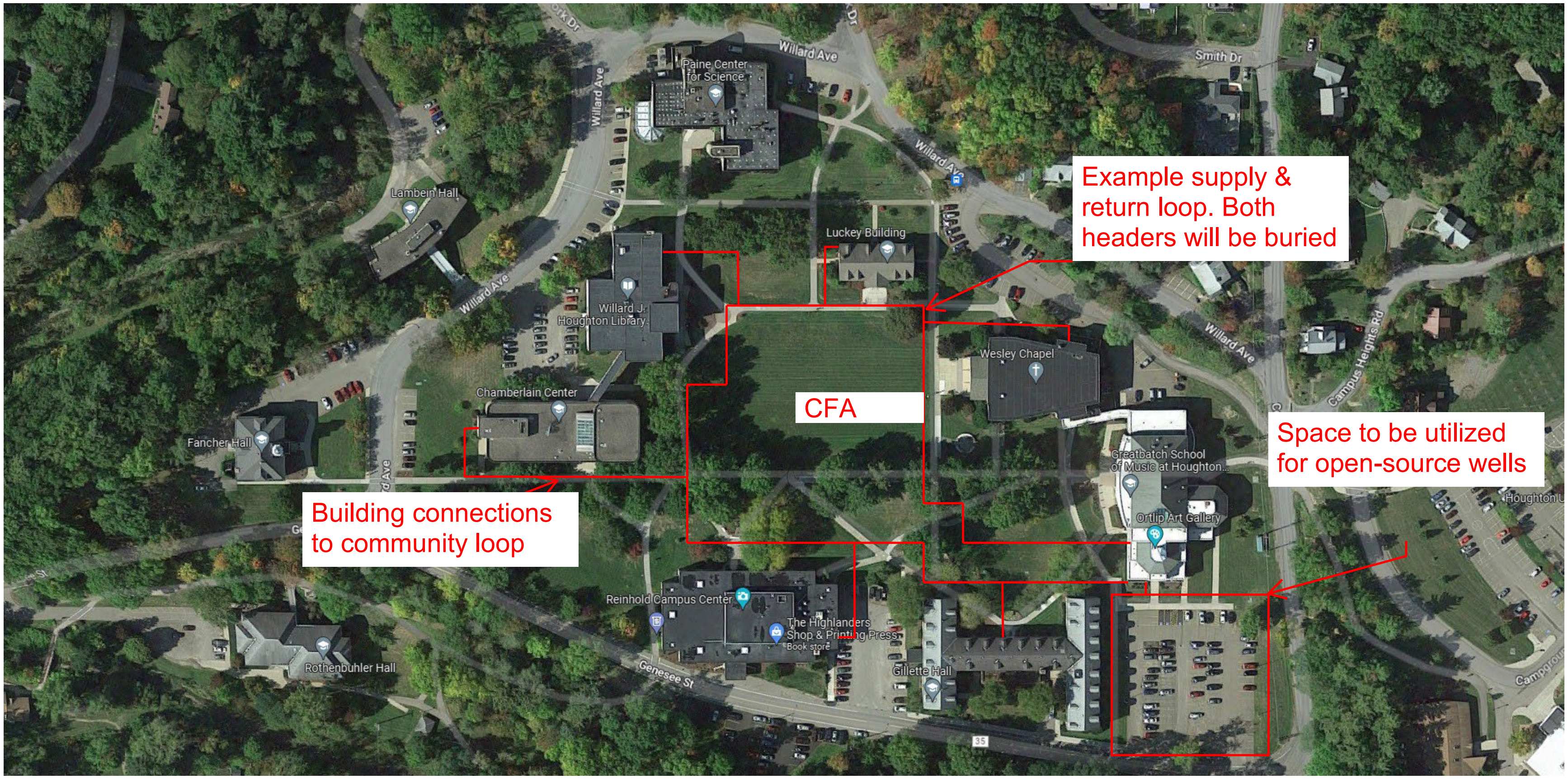
# Appendix A. Central Plant Piping and Instrument Diagram

### Figure A-1. Central Plant Piping and Instrument Diagram



# Appendix B. Community Heat Pump Loop Example

**Figure B-1. Houghton University Community Heat Pump Loop Example**



# Appendix C. Building Piping and Instrument Diagrams

### Figure C-1. Reinhold Campus Center Piping and Instrument Diagram

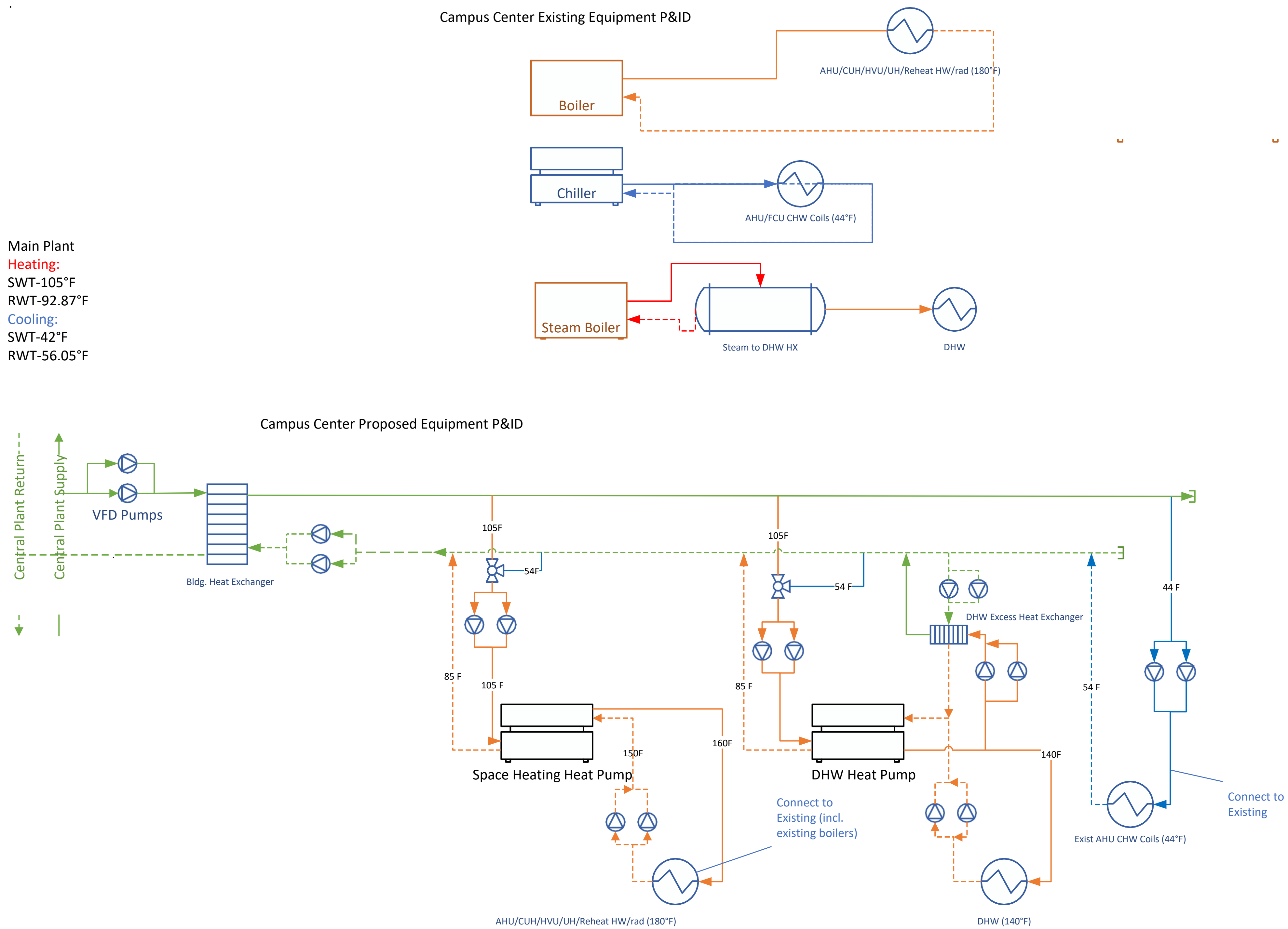


**Figure C-2. Center for the Arts Piping and Instrument Diagram**

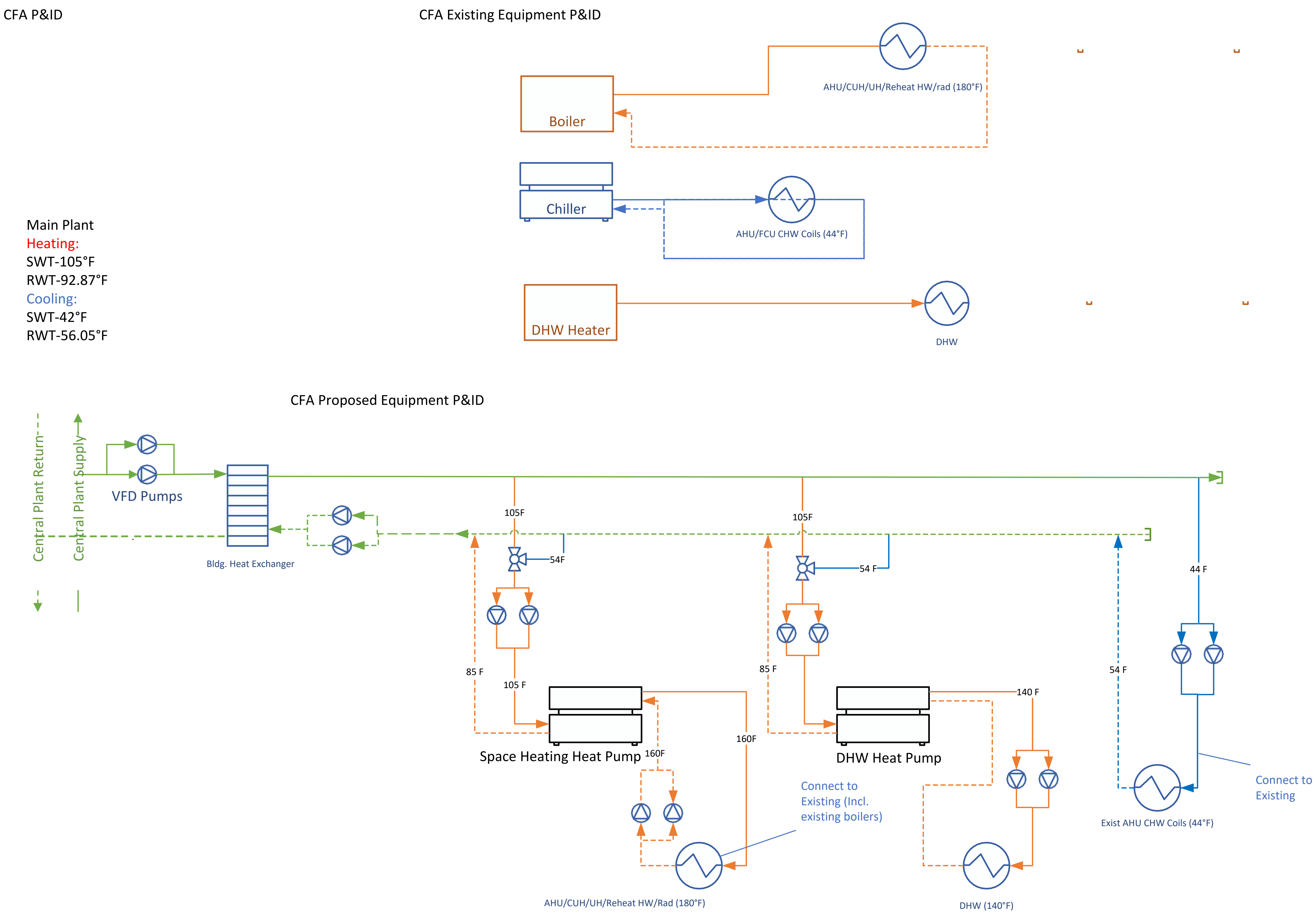


**Figure C-3. Chamberlain Center Piping and Instrument Diagram**

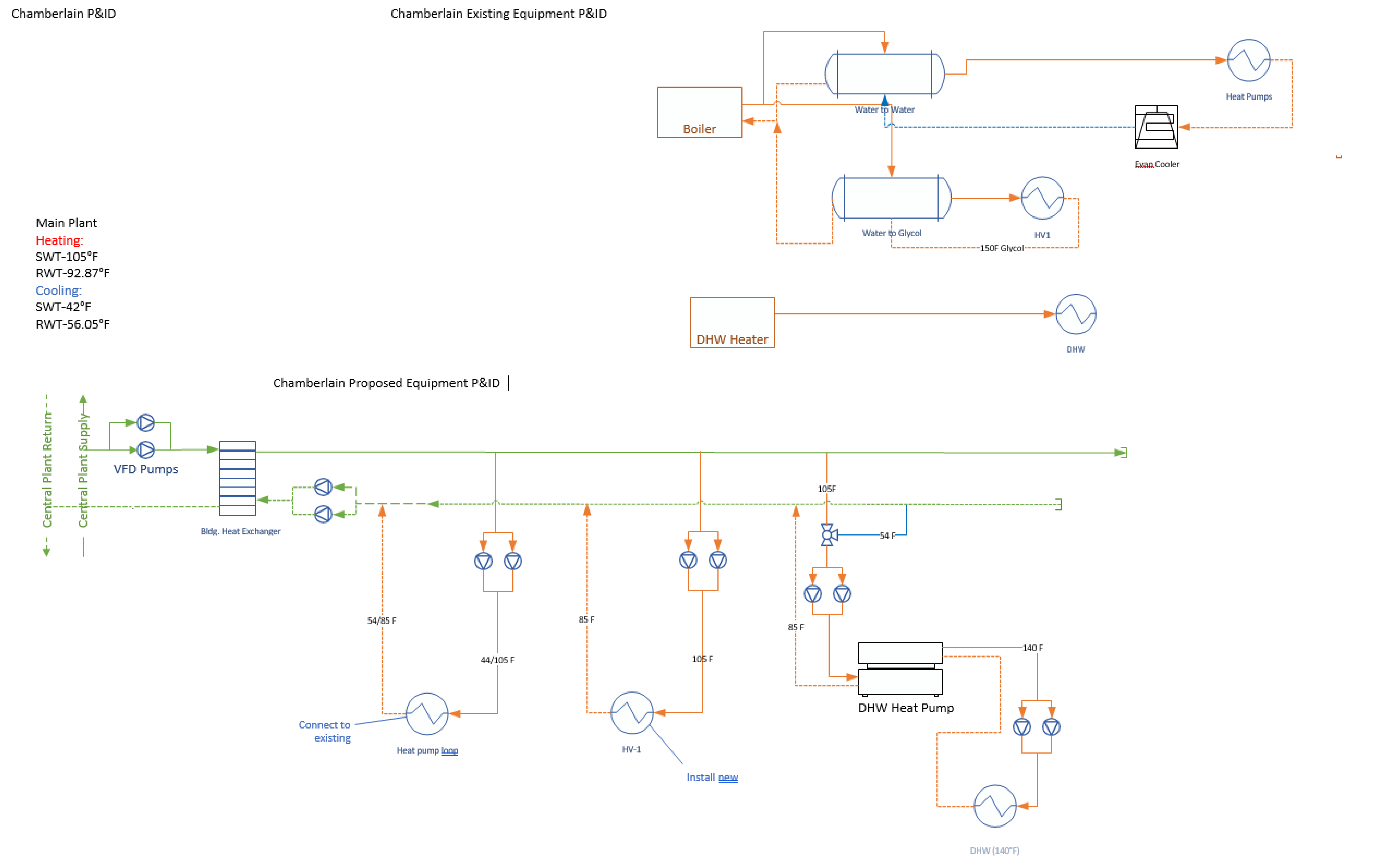
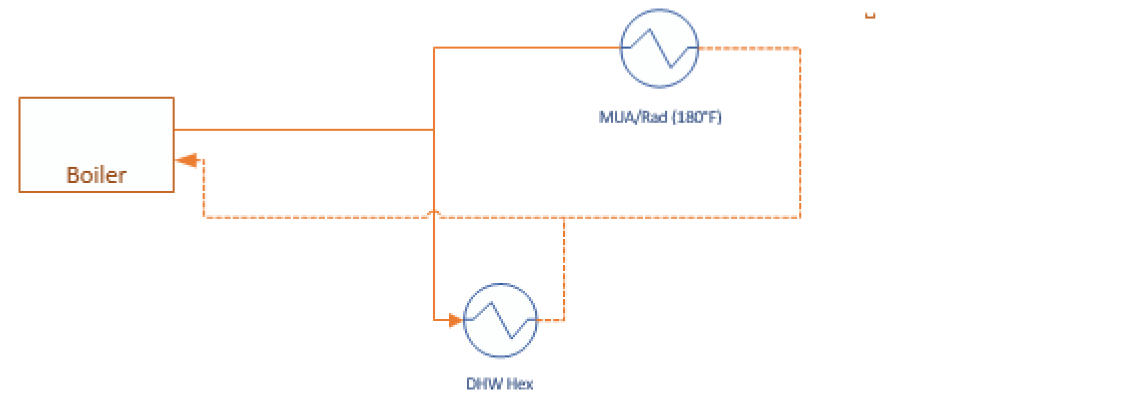


**Figure C-4. Gillette Hall Piping and Instrument Diagram**

Gillette Hall P&ID

Gillette Hall Existing Equipment P&ID




Main Plant
Heating:
SWT-105°F
RWT-92.87°F
Cooling:
SWT-42°F
RWT-56.05°F

Gillette Hall Proposed Equipment P&ID

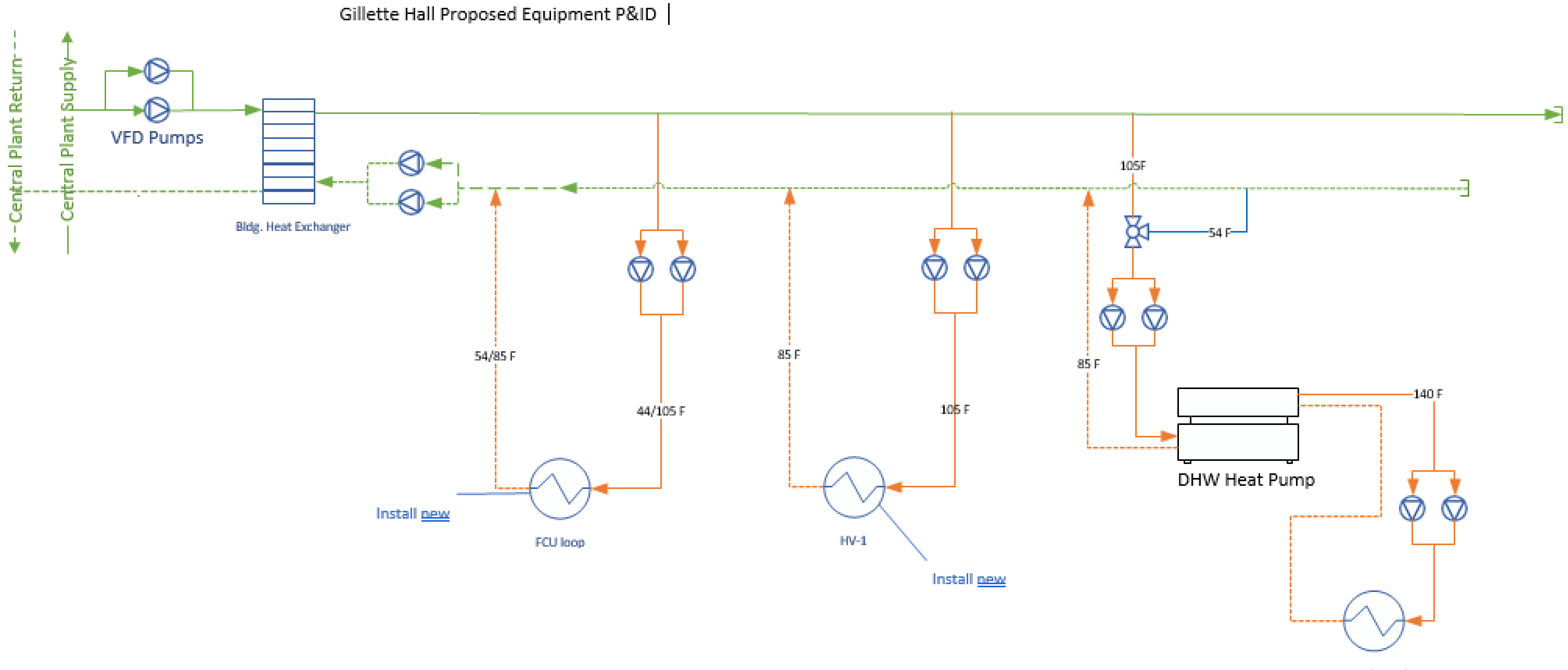


**Figure C-5. Houghton Library Piping and Instrument Diagram**

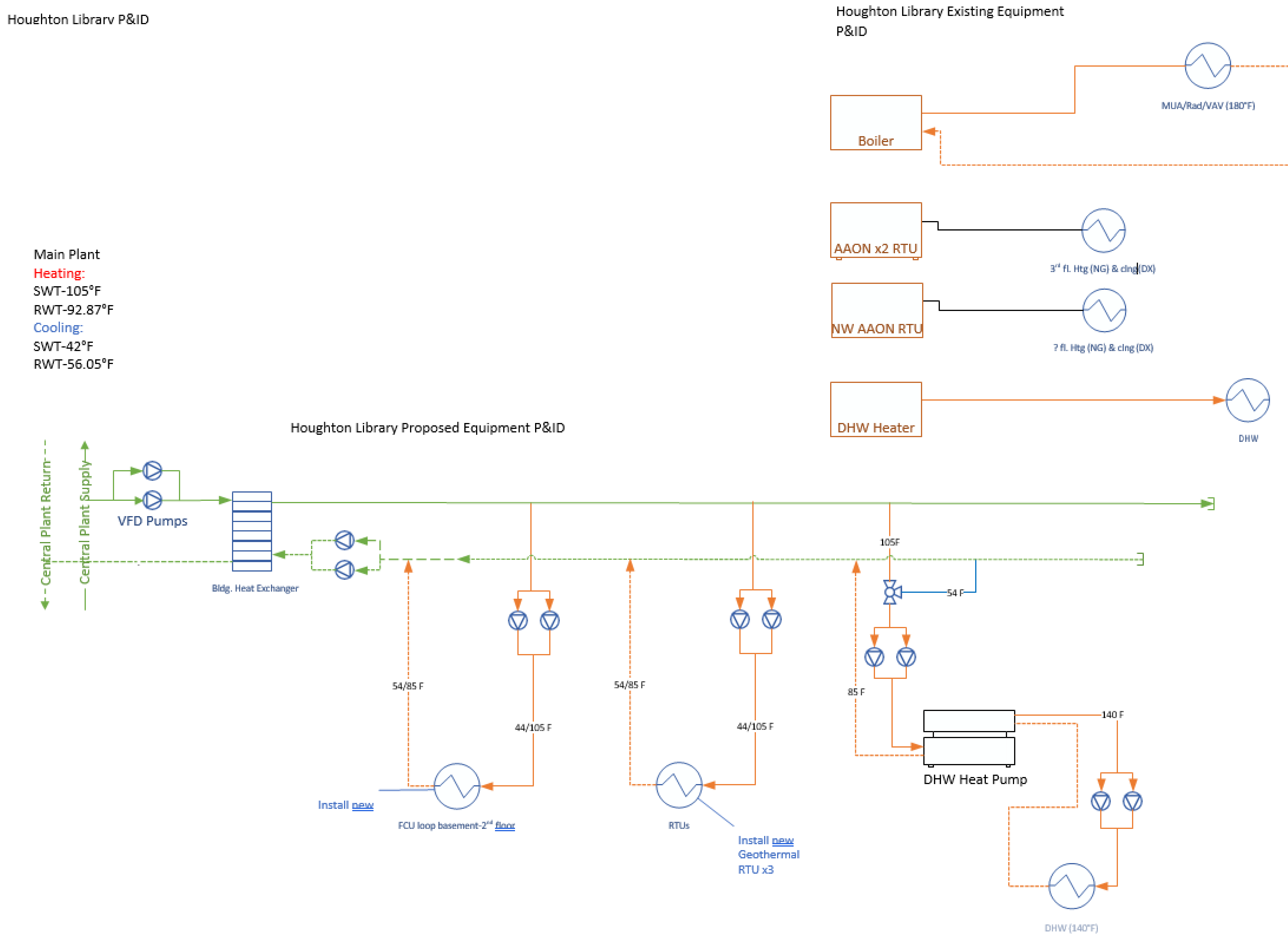


**Figure C-6. Luckey Memorial Building Piping and Instrument Diagram**

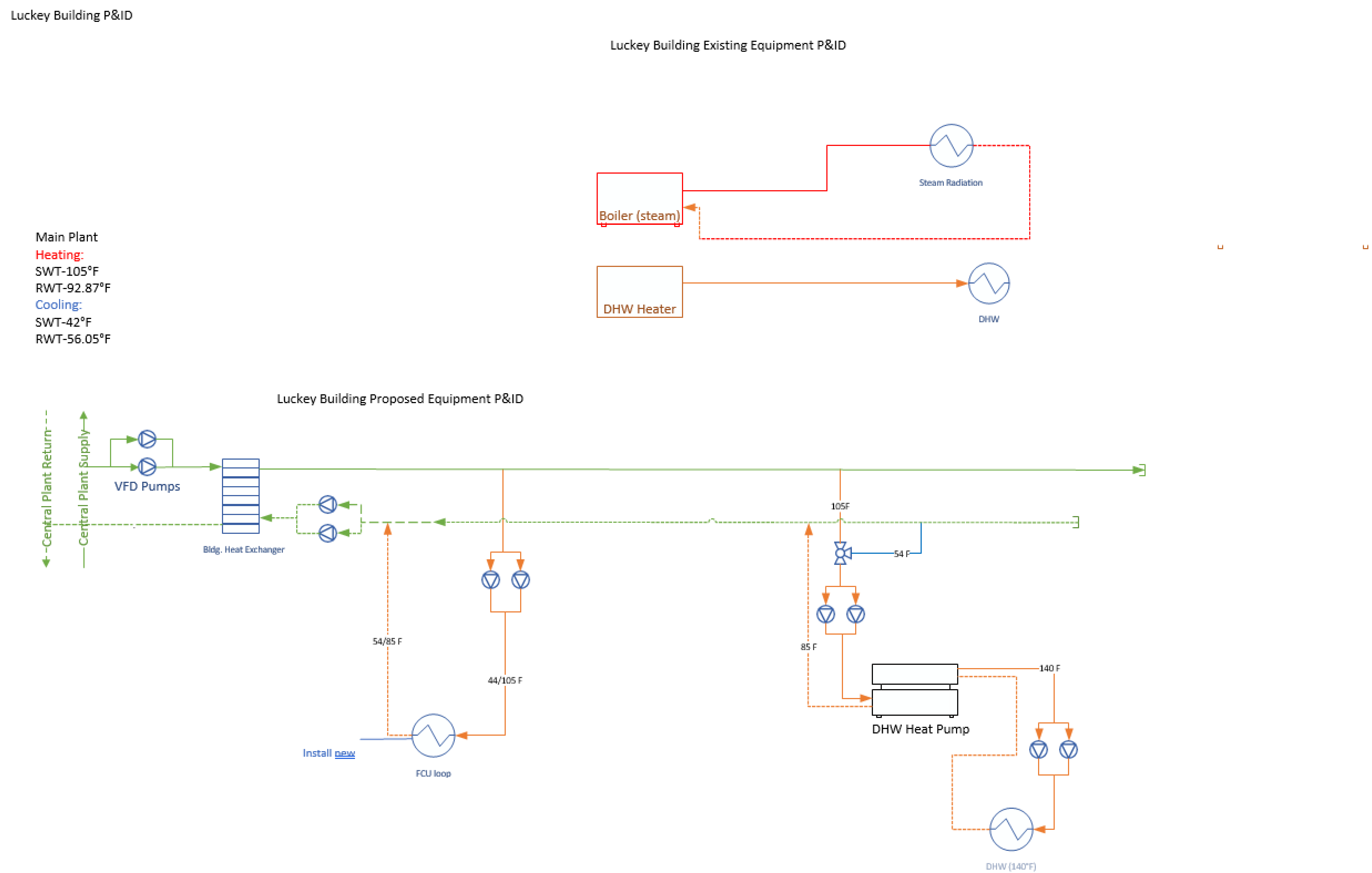
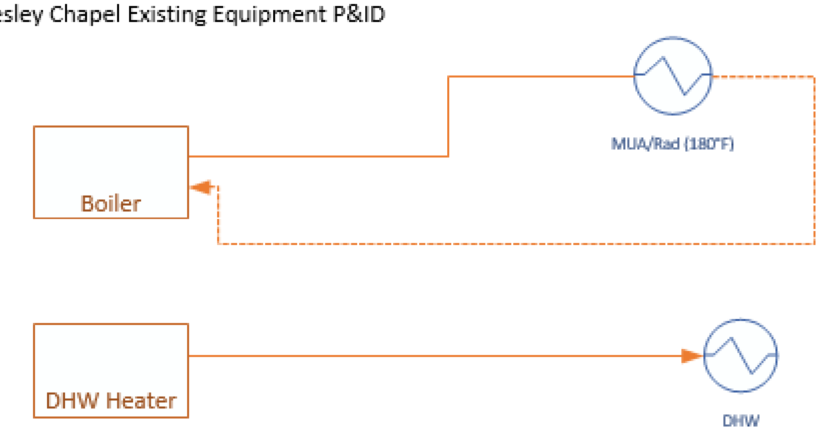


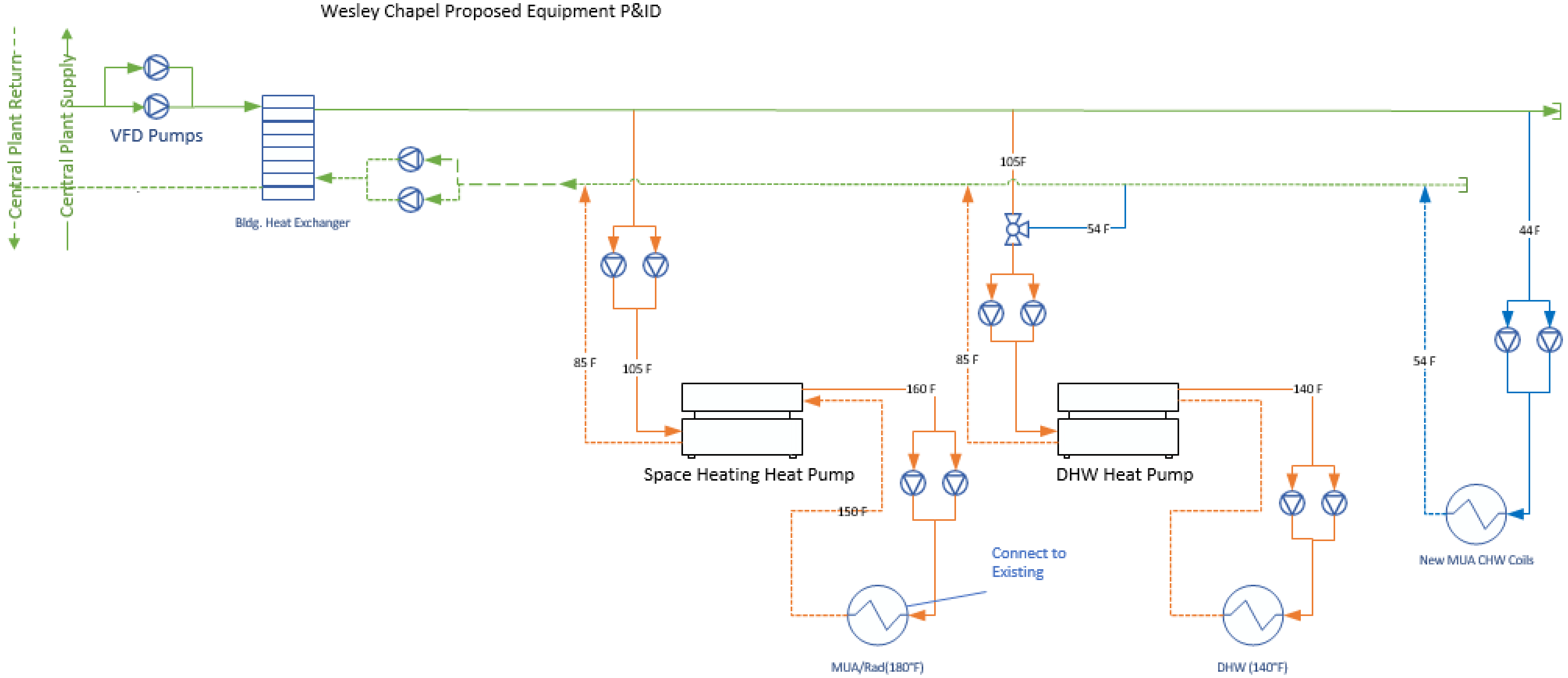
**Figure C-7. Wesley Chapel Piping and Instrument Diagram**

Wesley Chapel Existing Equipment P&ID




Main Plant
Heating:
SWT-105°F
RWT-92.87°F
Cooling:
SWT-42°F
RWT-56.05°F

Wesley Chapel Proposed Equipment P&ID



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