

Community Heat Pump Feasibility Study: Pratt Institute, Main Brooklyn Campus

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Community Heat Pump Feasibility Study: Pratt Institute, Main Brooklyn Campus

Final Report

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Abstract

This report evaluated the replacement of the existing central heating plant with a community heat pump network for the main campus of the Pratt Institute in Brooklyn, NY. The study considered the adoption of a ground-source heat pump system covering multiple buildings on the campus that included classroom, dormitory, office, and multi-purpose buildings (i.e. athletics and classroom). The study also considered conventional air-source and water-source heat pump technologies for these buildings. Based on the techno-economic analysis results and discussions with Pratt, ANTARES recommended that heat pumps be further pursued for the campus. Specifically, Option 4A should be studied further in a subsequent PON 4614 Category B application, which would be developing design development drawings for the infrastructure of a community heat pump loop to meet the future needs for ARC, Townhouses, Stabile, Steuben, Pratt Studios, Pantas, and DeKalb.

Keywords

Community heat pumps, ground-source heat pumps, air-source heat pumps, water-source heat pumps, life cycle cost analysis

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Summary

In 2020, Pratt Institute completed their Energy Roadmap (Roadmap) for the campus with co-funding provided by NYSERDA through PON 3438, REV Campus Challenge Technical Assistance for Roadmaps. One of the main objectives of this Roadmap effort was to develop a plan for reducing the energy and carbon footprint at Pratt, which is essential for the campus to meet Local Law 97-2019 mandated carbon levels for 2030. As part of that report, the Roadmap included a recommendation to renovate the central steam boiler plant and steam distribution system to deliver low pressure (<15 psig) steam to the campus, as well as a high-level analysis of upgrading select building mechanical systems with heat pumps and connecting them to ground source heat loops for multiple buildings.

This report evaluated the feasibility of adoption of heat pumps including a community heat pump system (CHP) for 20 buildings on the main campus of the Pratt Institute. The CHP system employs an energy transfer pipe (ETP) for sharing the geothermal loop fields around the campus and the net heat rejection and addition from the heat pumps within each individual building. These buildings included multiple dormitory type buildings, classroom buildings, assembly buildings, multi-purpose athletic/academic buildings, and administrative buildings. Each building has distinct heating and cooling loads that was estimated for the modeling of the community heat pump system using a combination of eQUEST and MS Excel spreadsheet-based models. The diversity of these loads for the multiple building types were accounted in the modeling and provides some economy of scale. The geothermal borefield requirements were estimated by Earth Sensitive Solutions using LoopLink PRO software and the interaction with the multiple loopfields was modeled by GEOptimize using TRNSYS.

The CHP system was limited to the campus of Pratt Institute and did not include surrounding buildings/other building owners into the feasibility discussion. If the CHP system is adopted by Pratt Institute as recommended, it may be replicated by other college campuses in the New York City area and in New York State. Although not evaluated economically in this report, a third-party owner of the geothermal heat exchangers may provide a benefit to Pratt to grow competitive markets for community style heat pumps. As this project was limited to property owned by Pratt,

no regulatory hurdles are expected. However, the lack of data provided by the electric utility, ConEdison, to assess the potential available capacity to serve the campus in the future with heat pumps was disappointing. ANTARES recommends a load letter be submitted to ConEd to press them in providing this information.

ANTARES evaluated eight different heat pump options for Pratt Institute against a baseline case. These options are defined in detail under section 5.7 and are briefly summarized below:

- **Baseline**—For all buildings studied, the HVAC equipment and associated electrical infrastructure are upgraded to comply with current energy and building codes with conventional HVAC equipment.
- **Option 1**—The HVAC equipment and associated electrical infrastructure are upgraded with either air-to-air heat pumps and air-to-water heat pumps (only for Stabile, Steuben, Pratt Studios and Pantas).
- **Option 2**—The HVAC equipment and associated electrical infrastructure are upgraded with water-to-water heat pumps (only for Stabile, Steuben, Pratt Studios and Pantas) or water-to-air heat pumps.
- **Option 3**—CHP alternative for the Townhouses and ARC (water-to-air heat pumps) and the baseline HVAC equipment for the remaining buildings.
- **Option 4**—CHP alternative for the Townhouses, ARC, Stabile, Steuben/Pratt Studios, DeKalb, and Pantas and the baseline HVAC equipment for the remaining buildings.
- **Option 4A**—CHP alternative for the Townhouses, ARC, Stabile, Steuben/Pratt Studios, DeKalb, and Pantas and air-to-air heat pumps for the remaining buildings.
- **Option 5**—CHP alternative for the Townhouses, ARC, Stabile, Steuben/Pratt Studios, DeKalb, Pantas, Thrift, ISC, Library, Engineering, Machinery, and Chemistry and the baseline HVAC equipment for the remaining buildings.
- **Option 6**—CHP alternative for all studied buildings.
- **Option 6A**—CHP alternative for all studied buildings with dry coolers to the energy transfer pipe to reject excess heat during the summer.

The key findings of the report and analysis are summarized below:

- To electrify the campus with heat pumps, the peak electrical demand will occur in the winter and will increase from 1718 kW to 3654 kW with geothermal or ground source heat pumps (GSHP) and 4191 kW with air source heat pumps (ASHP).
- Up to 678–500 feet vertical closed loop bores can be installed on the campus based on the available open space on the campus. CHP alternative for all studied buildings requires 558 bores, while the individual GSHP systems (1 per building) would require 725 bores, which is greater than the space available.
- The life-cycle cost analysis (LCCA) indicates that the ASHP approach (option 1) is the most cost effective over the 25-year period by \$16 million over the baseline and by \$15 million over the campus-wide community heat pump option (option 6).

- The LCCA also indicates that the campus-wide community heat pump option (option 6) is more cost-effective than the individual GSHP systems (option 2) by \$3 million over the 25-year period.
- Site energy use is reduced by 75% from the baseline conditions for ASHP approach (option 1) and by 80% for the community heat pump option (option 6). GHG emissions are reduced by 1,824 and 1,966 metric tons of carbon dioxide equivalent (MT CO_{2e}) from the baseline for option 1 and 6, respectively over the baseline.

Table 1 provides the LCC, capital cost, incremental cost over baseline, energy use, and energy costs for all options evaluated. The costs for aggregating electric service (\$7.75 million) and the potential reduced electric rate from high-tension service is not included in the analysis due to lack of data provided by ConEd at the report’s issuance.

TableS-1. Summary Table of Results from CHP Feasibility Study

Option #	25 Yr LLC, \$MM	CapE x \$MM	Annual Energy Use			Energy Cost, \$/yr
			Electric, MWh	Gas, MMBtu	Total, MMBtu	
Base	\$126.5	\$89.5	1,980	42,261	49,019	\$731,284
1	\$110.8	\$95.5	3,053	0	10,418	\$597,603
2	\$128.5	\$114.3	2,936	0	10,016	\$557,746
3	\$122.9	\$95.3	2,202	34,486	42,000	\$708,133
4	\$123.7	\$105.3	2,424	18,858	27,129	\$618,968
4A	\$120.5	\$102.7	2,974	0	10,146	\$564,994
5	\$129.2	109.3	2,666	10,692	19,788	\$515,546
6	\$125.4	\$111.2	2,943	0	10,042	\$559,207
6A	\$124.3	\$110.0	2,974	0	10,146	\$564,994

Based on the techno-economic analysis results and discussions with Pratt, ANTARES recommends that heat pumps be further pursued for the campus. Specifically, option 4A should be studied further in a subsequent PON 4614 Category B application, which would be developing design development drawings for the infrastructure of a community heat pump loop to meet the future needs for ARC, Townhouses, Stabile, Steuben, Pratt Studios, Pantas, and DeKalb. It will further develop capital costing for these buildings for the in-building costs (both mechanical and electrical) and the geothermal system costs (for the loopfields, ETP, and integration of the existing open well system). Option 4A provides flexibility for the campus to expand geothermal to the campus later or install air source heat pumps based mechanical systems to the campus for the future. With any roadmap or long-term planning effort, Pratt should keep flexibility where possible and not be tied to any one technology.

In addition to further developing the community heat pump loop for the seven buildings on east and south campus, ANTARES recommends that Pratt do the following:

- Develop the electrical engineering documentation to distribute medium voltage around the campus to have a single metered service with ConEd. The engineering effort should design a looped or radial feed system, ideally building off of the service for 193 Ryerson. The system should provide flexibility for adding existing buildings onto the service and provide Pratt-owned submetering for future LL84 and LL97 reporting purposes and energy management. The submetering would be an improvement over the data (or lack of data) currently provided by ConEd.
- Upgrade the existing electrical infrastructure within Steuben, DeKalb, Thrift, Machinery, and North Hall should be considered to move forward, which will provide the infrastructure needed on campus to meet the future electrification loads at Pratt. The in-building electrical service and equipment would be sized to meet future heat pump loads for heating these buildings.
- Implement energy conservation measures as prescribed in the Roadmap to reduce the demand for steam heating until the electrified solutions are able to be implemented. Measures include updating HVAC controls to reduce overheating and improve the steam condensate system.
- Start design of a community heat pump system to serve east and south campus and allow the flexibility for adoption by other buildings on the campus in the future. The community heat pump loop should be adopted in the next 8 years (prior to 2030) to meet the GHG limits set by LL97. The buildings that should be considered include Stabile, Townhouses, ARC, Steuben, Pratt Studios, Pantas, and DeKalb. The heat pump adoption for those buildings will allow the central plant to operate at low pressure and provide some additional maintenance and operational cost savings for Pratt.
- Adopt heat pumps for the renovations at other select buildings when possible. Buildings that have mechanical systems that were not part of the initial community heat pump system and should be upgraded over the next 10+ years include ISC, Library, Engineering, Chemistry, Machinery, ELJ and Thrift.

A proposed implementation schedule is provided in Figure 1 through 2030 to implement the heat pump projects and other energy projects at Pratt Institute. The CHP project for the seven suggested buildings will provide about 1,057 MT of greenhouse gas (GHG) reductions, which is an 18.6% reduction from the existing. With the new central steam plant and this CHP project the GHG reductions will be 36% lower than current levels for the 20 buildings studied in the report.

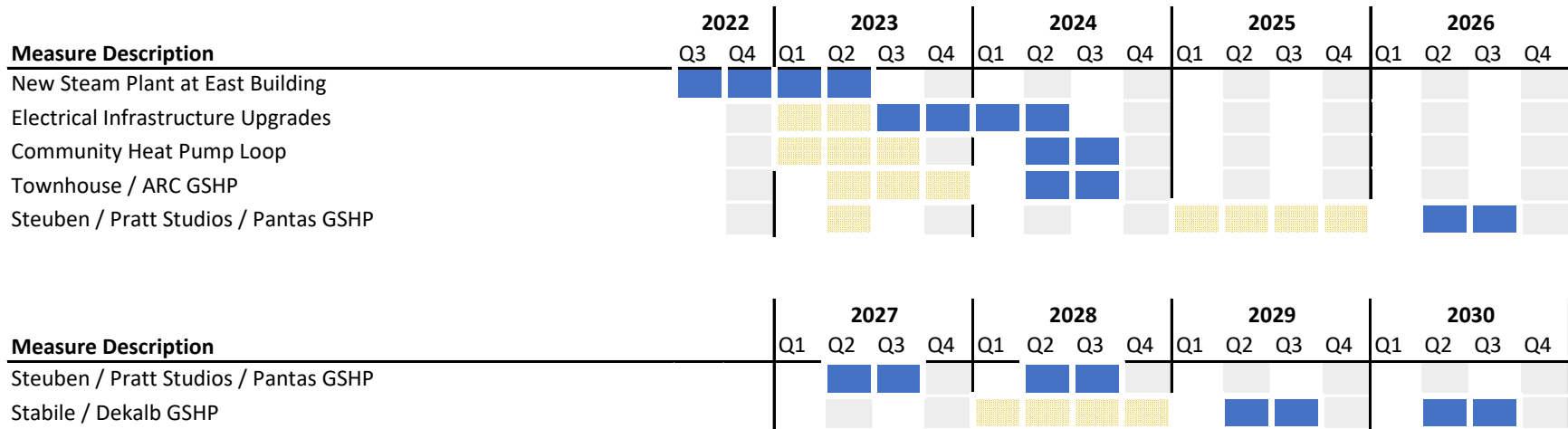
When converting buildings from the existing HVAC systems to the proposed heat pump-based HVAC systems, the following approaches should be taken to minimize system disruptions:

- Perform the retrofit of classroom and dormitory buildings on a floor-by-floor basis. Coordinate efforts to perform upgrades over the summer session.
- Install the ETP early in the project and provide provisions to connect additional buildings and borefields to the ETP. Install automatic air vents to minimize air pocket formation in the ETP as it is expanded through the campus.

Figure S-1. Potential Implementation Plan Schedule through 2030

Pratt Institute - Implementation Plan Schedule

Engineering and Procurement
 Construction and Implementation



Quarters on calendar year schedule

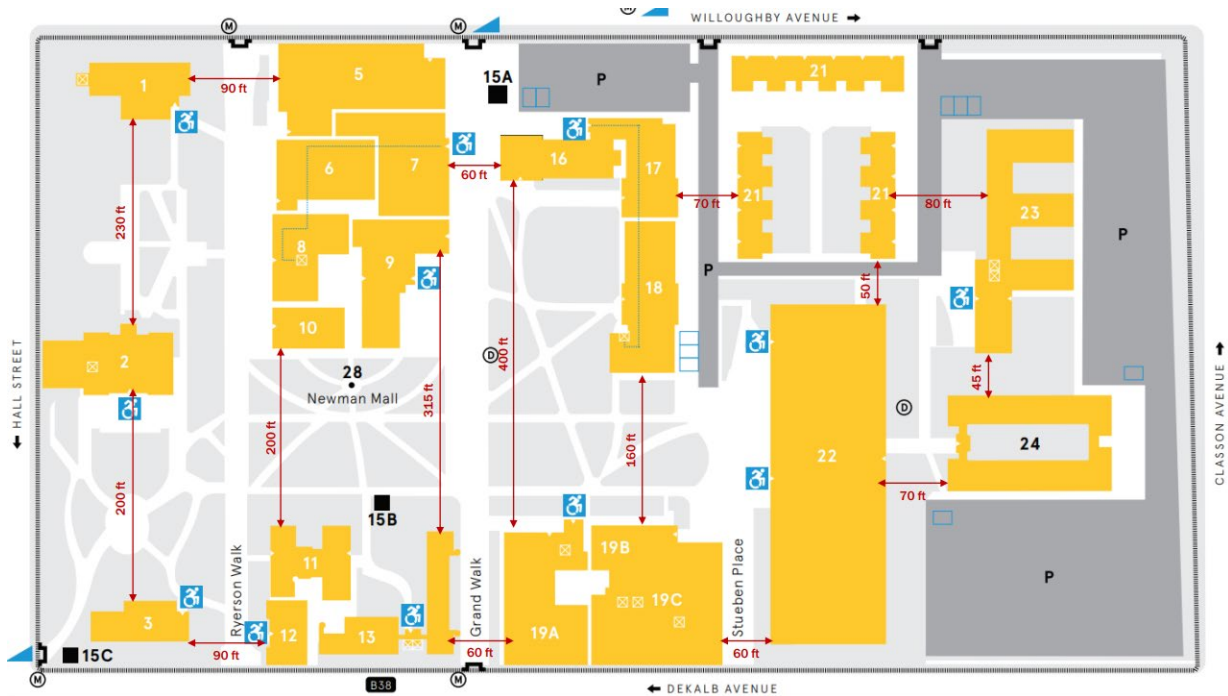
- Q1: January - March
- Q2: April - June
- Q3: July - September
- Q4: October - December

1 Introduction and Background

In 2020, the Pratt Institute Energy Roadmap (Roadmap) was completed for the campus with co-funding provided by NYSERDA through Program Opportunity Notice (PON) 3438: Reforming the Energy Vision (REV) Campus Challenge, Technical Assistance for Roadmaps. One of the main objectives of this Roadmap effort was to develop a plan for reducing the energy and carbon footprint at Pratt, which is essential for the campus to meet Local Law 97-2019 mandated carbon levels for 2030. As part of that report, the Roadmap included a recommendation to renovate the central steam boiler plant and steam distribution system to deliver low-pressure (<15 psig) steam to the campus, as well as a high-level analysis of upgrading select building mechanical systems with heat pumps and connecting them with ground source heat loops for multiple buildings.

The results of the high-level heat pump analysis in the Roadmap report suggested that additional evaluation was warranted to determine feasibility of installing a community heat pump system for several buildings on the main Brooklyn campus (see map on Figure 1). The approximate distances between the buildings is shown in red on the campus map.

Figure 1. Pratt Institute Main Campus



The buildings that will be considered for the adaptation of the community heat pump system include the dormitory buildings at Esther L Jones Hall (11), Pantas Hall (13), the Townhouses (21), and Stabile Hall (23). The classroom buildings include Chemistry (16), Machinery (17), Engineering (18), and Pratt Studios/Design Center/Steuben Hall (19A/19B/19C). The Activities and Resource Center (22) has a combination of athletics facilities, classrooms, and offices. Other buildings included in the evaluation include Library (1), ISC (2), DeKalb Hall (3), North Hall (5), Memorial Hall (6), Student Union (7), Main Building (8), East Building (9), South Hall (10), and Thrift Hall (12). The district with the exception of Cannoneer Court (24) is currently served by the central steam plant using a combination of oil-fired and natural gas-fired steam boilers located in the East Building (9). The buildings have varying construction dates between the late 1800s to 2000. This current report addresses the baseline conditions for Task 1, the technical performance evaluation for Task 2, the life-cycle cost analysis for Task 3, and the evaluation of solar PV and EV charging on campus for Task 4 which includes:

- A summary of the baseline conditions for the buildings included in the feasibility study together with existing primary HVAC systems as well as identification of which electrical account serves the building. The electric service to each of the buildings has been obtained and load letters have been issued to ConEd to determine if services/ accounts need to be upgraded to meet the higher electrical demands with the heat pump-based alternatives considered in this study effort.
- A preliminary electrical distribution study was performed to characterize the additional electrical load for the building infrastructure when the additional cooling and ventilation was added, and the heating systems electrified. The study provides an option to aggregate building electrical services to medium voltage/ConEdison high-tension service and improving the reliability of electrical service for the campus.
- A summary of the historical energy requirements for the buildings, which includes electricity, natural gas, and number 2 fuel oil to generate steam. In addition to the energy use, the costs for energy were estimated based on the data provided by Pratt. These historical energy requirements were used to estimate the baseline greenhouse gas (GHG) emissions for the buildings and a comparison to the LL97-2019 emission limits for 2024 and 2030.
- The existing heating and cooling loads for the buildings connected to the central steam plant were estimated using eQUEST. A comparison of the heating energy requirements against the existing central steam plant energy requirements was done along with the peak-heating load comparison. The baseline energy requirements for heating and cooling all of the buildings included the adoption of code compliant systems to meet ventilation and cooling needs for the buildings. Costs to update the buildings to code-compliant levels were provided by Pratt from an independent analysis done by another contractor.

- The potential geothermal capacity on the Brooklyn campus based upon the identified areas found during the site visit in October 2021 was characterized. The capacity was used to connect multiple campus buildings to a closed loop system. Open loop systems, such as the Dutch Aquifer Thermal Energy Storage (ATES) system are included in the evaluation later. However, the open loop systems present maintenance issues due to the high iron content in the existing aquifer and could be used as a supplemental resource to the closed loops. The Task 1 effort used data from a test borehole drilled near Myrtle Hall in 2007 and input from the pressurized ATES from the teleconference on April 1, 2022.
- An evaluation comparing air source, water source, and geothermal source heat-pump systems. The heat pump solutions were compared against the baseline code-compliant systems that would remain reliant on the existing steam system for heating. Four different community heat pump alternatives for the campus were evaluated using a common ground source loop.
- A 25-year life-cycle cost analysis (LCCA) of the evaluated alternative systems was conducted. Pratt Institute evaluates projects on a life-cycle basis for major infrastructure projects such as the community heat pump project. Included in the analysis are the impact of lower greenhouse gas (GHG) emissions and the LL97-2019 savings after 2030, reduced maintenance costs compared to the existing conditions, deferred maintenance capital, and energy cost savings. The LCCA will include construction costs, operations, and maintenance costs (including GHG cost savings), and replacement costs. The LCCA will also include inflation, energy escalation, and discount rates. If the community heat pump project has a lower LCC than the existing conditions, then the project will be considered by Pratt.
- An assessment of on-site renewable energy generation via solar photovoltaics for the shade-free roofs was conducted along with potential electric vehicle charging stations. These technologies can provide potential additional GHG reductions for the campus.

2 Existing Building and Infrastructure Conditions

The following section provides an overview on the campus buildings that are included in the feasibility study effort. The emphasis of the building descriptions is on the existing HVAC systems and electric service to the buildings. The building descriptions are divided into the five steam zones that are served by the main steam plant.

2.1 Building Descriptions—Zone 1 (East Campus)

Zone 1 includes the Townhouses (21), ARC (22), and Stabile (23). The building descriptions for these buildings are provided in the following subsections.

2.1.1 Townhouses

Figure 2. Emerson Place Townhouses



The townhouses include three separate buildings and 27 units. They provide housing for approximately 156 students and cover an estimated 84,144 ft.² The Willoughby Townhouses face Willoughby Avenue on the north side of the campus and include 11 units (44 bedrooms). The Steuben Townhouses face Steuben Avenue on the west and include eight separate units (32 bedrooms). The Emerson Townhouses face Emerson Avenue on the east and include eight separate units (32 bedrooms).

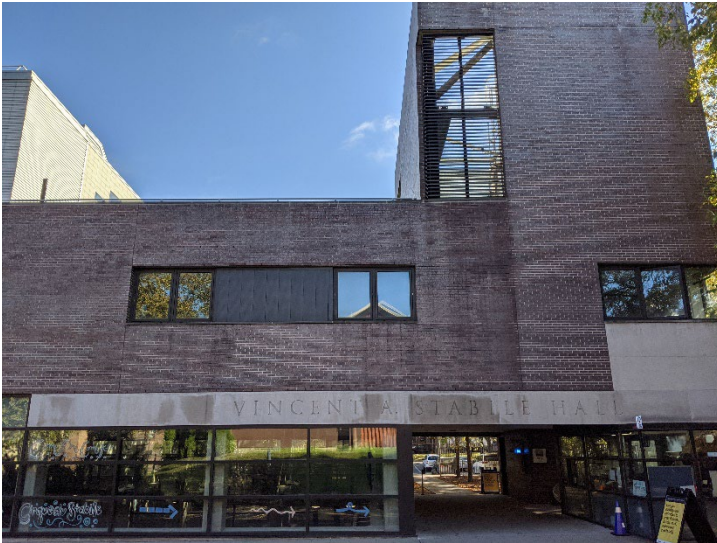
The Townhouses were built in 1900 with major renovations from 2010 to 2015 to the building envelopes. The walls are brick masonry with fiberglass-batt insulation. The roofs are sloped wood-framed with asphalt shingles and fiberglass-batt insulation in the ceiling. The operable windows are aluminum framed with double paned glass.

Each of the 27 units is heated using steam radiators with steam delivered from the central plant. None of the units are equipped with air conditioning and instead use windows for natural ventilation. Each unit in Steuben and Willoughby has 90A 208V electric service from ConEdison. Two meters are in place for the Willoughby Townhouses at 224 Willoughby and 234 Willoughby based on the Roadmap.¹ One meter at 171 Steuben Street is in place for the Steuben Townhouses based on the Roadmap. The Emerson Townhouses have their electric service aggregated from ConEdison with the service entering 172 Emerson with an 800A 208V electric service. The electrical service for the 11 units at Willoughby and eight units at Steuben are each assumed to have 90A 208V electric service based on the observations at 220 Willoughby Avenue. Steam is not sub metered by Pratt to serve these units. Steam heating is controlled within each unit and not included in the building management system (BMS). Based on the findings from the Roadmap, these townhouses do not control the heat well on moderate heating days with indoor temperatures reaching 82°F on a 43°F day.

Each of the townhouses has a National Grid natural gas meter for the domestic hot water (DHW) heating and the clothes dryer in the basement. The condensing DHW heater witnessed in 172 Emerson, which was assumed to be typical of the other townhouses, was a 50-gallon AO Smith ProLine XE Vertex (model GDHE-50) unit. The clothes dryer witnessed in 172 Emerson, which was assumed to be typical of the other townhouses, was a Maytag commercial single-load gas dryer.

2.1.2 Stabile Hall

Figure 3. Entrance to Stabile Hall



Stabile Hall is a residence hall with 119 rooms housing 236 students on five floors and a basement with a total estimated floor area of 79,756 ft.² The building was constructed in 2000 with pre-stressed concrete. The operable windows are double-paned, and the roof has rigid foamboard insulation under the membrane surface. The walls, roof and basement are all assumed to have with code-compliant insulation from 2000.

The building is heated and cooled with distributed two-pipe fan coils in the dormitory rooms and two central constant volume air handling units (AHUs) for the corridors and lobby respectively. Heating is distributed within the building via heating hot water generated by a heat exchanger supplied with steam from the central steam plant. Cooling is achieved using chilled water generated by 4 to 60-ton reciprocating water cooled chillers located in the basement of the building and served by a cooling tower. The chiller, hot water converting station, and AHUs are controlled by the central BMS; however, the fan coils are not included in the BMS. The building has two condensing gas-fired DHW boilers for DHW generation at the building.

The steam used for Stabile Hall from the central plant is not sub metered. Electricity is delivered by ConEdison on a separate account than other buildings with a 2500A main service at 208V. Natural gas is delivered by National Grid for use in domestic hot water heating only.

2.1.3 Activity and Resource Center

Figure 4. Activity and Resource Center Building Field House—Upper Floor



The Activity and Resource Center (ARC) building is a multi-functional building that includes the main athletic facility on campus on the floor above grade that includes the gymnasium, fitness center and dance studio, and athletic offices and locker rooms. The floor below grade includes classrooms, computer labs, and offices for computer graphics, math and science, and media arts. The building was constructed in 1975 with a total estimated floor area of 114,452 ft.² The building has pre-stressed concrete walls with heavy laminated wood beam framing for the roof. The very few windows are double-paned, and the roof has rigid foamboard insulation under the white membrane surface, which was installed in 1991.

The building is heated and cooled with four central variable volume air handling units (AHUs) for the lower level located on the north and south end of the building. Six heating and ventilating (H&V) units are installed on the upper level to heat and ventilate the gymnasium, locker rooms, weight room and dance studio with other spaces having hot water radiators. No centralized mechanical cooling is provided to the upper floor. Three DX AHUs serve the lower level of the building. AH-3 is a constant volume unit. The fourth AHU is served by a 100 Ton DX chiller which also serves about 30% of Steuben Hall. Heating is distributed within the building via heating hot water supplied that is generated using a HX supplied with HP steam generated by the central steam plant. The two north side lower-level AHUs are served by low pressure steam. The building has two gas-fired atmospheric DHW boilers for generating DHW at the building.

The Campus BMS controls three of the lower-level AHUs and the chiller. Older defunct pneumatic controls are still in place for the upper-level equipment and terminal units on the upper and lower levels.

The ARC Building was originally constructed to use geothermal cooling and heating with two open wells and one discharge well using water from the aquifer that is approximately 100 feet below the surface. The water in the aquifer has a high iron content and caused fouling on the heat exchanger surfaces, requiring frequent cleaning to make the system operable. The wells have been abandoned in place due to the high-maintenance requirements.

The steam use for ARC from the central plant is not sub metered. Electricity is delivered by ConEdison on a separate account than other buildings with a 4000 amp (A) main service at 208 volts (V). Some electricity is stepped up to 480V for the building with a 500 kilovolt-amp (kVA) transformer located within the main electrical room on the east side of the building on the lower level.

2.2 Building Description—Zone 2 (Central Campus)

Zone 2 includes the Engineering, Machinery, and Chemistry buildings along with the Main, South, and East Buildings. The building descriptions for these buildings are provided in the following subsections.

2.2.1 Chemistry/Machinery/Engineering

Located near the main north entrance to the campus, the Chemistry Building (27,024 ft²) is connected to the Machinery Building (36,439 ft²), which is connected to the Engineering Building (58,716 ft²). The Chemistry Building was constructed in 1905, with the Machinery/Engineering Buildings constructed in 1929. All three buildings have brick and masonry walls with no insulation. The roofs are a combination of sloped and flat roofs with insulation installed during the latest re-roofing. The Chemistry Building has relatively new double paned operable windows, while the Engineering and Machinery Buildings have the original single pane operable windows.

These three buildings all have perimeter steam radiators to heat the spaces using low-pressure steam from the central steam plant. Cooling is done using mostly window air conditioners with a 30-ton rooftop unit (RTU) that is used for the small auditorium in the Engineering Building and several Mitsubishi split systems scattered throughout. These buildings are not controlled by the BMS and frequently are overheated due to the lack of precise control on the steam radiators. Windows are opened or used frequently to alleviate the overheating and to ventilate the buildings.

These buildings are provided electric service from ConEdison via the account at 193 Ryerson. A separate service and submeter from ConEdison is present in the main electrical room within the basement of the Machinery Building for all three buildings. The main electrical room serving the three buildings has a 1200A, 208V main breaker. Steam use from the central steam plant is not sub metered by Pratt for these buildings.

2.2.2 Main Building, East Building, and South Building

Figure 5. Entrance to the Main Building from Ryerson Street



The Main Building is a multi-functional building that includes classrooms, offices, and studios. The seven-story building was constructed in 1887 with a total estimated floor area of 52,880 ft.² The building has brick and masonry walls with no insulation. The windows are a combination of older double-pane and single pane operable windows. The flat roof has rigid foamboard insulation under the membrane surface.

The East Building is a multi-functional building that includes classrooms, offices, studios, and the central steam plant. The six-story building was constructed in 1887 with a total estimated floor area of 53,865 ft.² The building has brick and masonry walls with no insulation. The windows are a combination of double-pane and single-pane windows. The roof has rigid foamboard insulation under the membrane surface.

South Hall is a multi-functional building that includes classrooms, offices, and studios. The four-story building was constructed in 1889 with a total estimated floor area of 16,021 ft.² The building has brick and masonry walls with no insulation. The windows are a combination of double-pane and single pane windows. The flat roof has rigid foamboard insulation under the membrane surface.

These three buildings have perimeter steam radiators to heat the spaces using low-pressure steam from the central steam plant. Cooling is done mainly with window air conditioners, with a HP/VRF system for Main 1 Administrative area and a split system DX for main base student services. These buildings are not controlled by the BMS and frequently are overheated due to the lack of precise control on the steam radiators. Windows are opened/used frequently to alleviate the overheating and to ventilate the buildings.

These three buildings are provided electric service from ConEdison via the account at 193 Ryerson via service at North Hall. The North Hall service is delivered at 208V with a 4000A main breaker on the switchboard at the electric room in North Hall. The North Hall electric room has three 167 kVA single phase transformers that step up and supply 480V three-phase power to East, Main, and South where power is then stepped back down to 208V with one 250 kVA transformer at Main Building and one transformer at East Building.² South Hall service comes off the Main Building at 208V. Steam use from the central steam plant is not sub metered by Pratt for the Main, East, and South Buildings, and the valves to isolate each building from Central Plant are old and hard to access.

2.3 Building Descriptions—Zone 3 (West Campus)

Zone 3 includes the Library and ISC Buildings. The building descriptions for these buildings are provided in the following subsections.

2.3.1 ISC Building

Figure 6. ISC Building



The ISC building is comprised of offices, lab spaces for the Center for Continuing and Professional Studies, and the Spatial Analysis and Visualization Initiative. The four-story building was constructed in 1955 with a total estimated floor area of 26,314 ft.² The building has brick walls with steel framing. The windows are single-paned, and the roof has rigid foamboard insulation under the membrane surface.

Steam from the central plant is converted to heating hot water via a steam to hydronic HX within the ISC Building. Centralized mechanical cooling is provided to the four pipe fan coils from the 80-ton, air-cooled chiller. Supplemental HP/VRF units serve the basement, while the second floor has a Mitsubishi split. The South side addition and Copy Center hand classroom have a RTU DX with AC only. Heating is distributed within the building via heating hot water to the fan coil units and hot water radiators.

The BMS controls the HX but the old pneumatic controls throughout the building do not work.

The steam use for ISC from the central plant is not sub metered. Electricity is delivered by ConEdison via the account at 193 Ryerson on a sub metered account at the ISC with a 1200A 208V main breaker and switchboard located in the basement of the ISC Building.

2.3.2 Library

Figure 7. Library Building



The Library Building is comprised of the library, offices, conference room, and computer study spaces. The three-story building was constructed in 1896 with a total estimated floor area of 56,389 ft.² The building has brick and masonry walls with fiberglass insulation. The windows are double-paned, and the roof has fiberglass insulation under the membrane surface.

Low-pressure steam from the central plant is used to heat the building via three air handling units (AHUs). The AHUs also provide cooling to the building. Centralized mechanical cooling is provided by three air-cooled chillers (one per AHU). The AHUs are controlled by the central BMS; however, the chillers are locally controlled. The building has a 30-gallon electric domestic hot water (DHW) heater to provide DHW for the building.

The steam use for the library from the central plant is not sub metered. Electricity is delivered by ConEdison via the account at 193 Ryerson on a sub metered account at the library with an assumed 2000A 208V main breaker and switchboard located in the basement.³

2.4 Building Descriptions—Zone 4 (South Campus)

Zone 4 includes the Design Center (Steuben/Pratt Studios), Pantas Hall, Esther Jones Hall, DeKalb Hall, and Thrift Hall. The building descriptions for these buildings are provided in the following subsections.

2.4.1 Design Center—Steuben Hall/Pratt Studios

Steuben is comprised of classrooms, studios, academic offices, and offices for the facilities maintenance. The four-story building with a basement was originally constructed in 1900 with additions in 1920 and 1960 with a total estimated floor area of 114,000 ft.² The original building has brick and masonry walls without insulation. The operable windows are double-paned, and the roof has rigid foamboard insulation under the membrane surface.

Pratt Studios is an academic building with classrooms, studios, shop spaces, and offices. The five-story building with a basement was constructed around 1900 with a 74,532 ft² of floor area and has brick and masonry walls without insulation. The operable windows are double-paned, and the roof has rigid foamboard insulation under the membrane surface.

Pratt Studios is connected to Steuben Hall via the Design Center connection. The Design Center was added in 2010 with 5,000 ft² of floor area.

High pressure steam from the central plant is used in 8 AHUs within Steuben Hall (basement through the fourth floor), the steam radiators on the perimeter of Steuben Hall (all floors), and the steam radiators at Pratt Studios (second to fifth floors) and in the Design Center connection. Steam is converted to heating hot water via a HX within the basement of Pratt Studios and is distributed to the fin tube radiation located in the basement and first floor of Pratt Studios and reheat coils in the VAV boxes at Pratt Studios (basement and first floor). Centralized mechanical cooling is provided to seven of the eight AHUs in Steuben from the air-cooled chiller located just south of ARC. The DX chiller west of Pratt Studios serves cooling for Pratt Studio's basement and first floor. Two split system AHUs provide cooling to the facilities offices in Steuben and are equipped with steam heating coils.

The steam use for Steuben/Pratt Studios/Design Center from the central plant is not sub metered. Electricity is delivered by ConEdison to Pratt Studios and Steuben under their own independent services and meters under separate accounts. The electric switchgear with a 3000A 208V main breaker in Pratt Studios is relatively new: however, the Steuben switchgear likely from the 1950s has a 2000A 208V main breaker.

2.4.2 Pantas Hall

Pantas Hall is a residence hall with 122 rooms housing 227 students. The eight-story building with a basement was constructed in 1987 with 66,590 ft² of floor area. The walls are brick and masonry with foam-board insulation. The metal framed windows are double pane units. The roof has rigid foamboard insulation under the membrane surface.

In the basement of the building, high psi steam from the central plant is converted to heating hot water via a HX for use in the fin tube radiation and fan coil units within Pantas. The fan coil units are locally controlled and can allow ventilation air into the building. The BMS is limited to the control for the hot water converting station. The building has 2- to 80-gallon condensing gas-fired DHW heaters for DHW with two supplemental electric DHW heaters with an 85-gallon and 80-gallon tank respectively.

The steam use for Pantas from the central plant is not sub metered. Electricity is delivered by ConEdison to Pantas under an independent service and meter, and a separate account. The electric room at Pantas has a 1600A 208V main breaker feeding the switchboard.

2.4.3 Esther L. Jones Hall and Thrift Hall

Jones and Thrift Halls are located due west of Pantas Hall. Jones Hall is a six-story 44,801 ft² residence hall with basement originally constructed in 1920 with 60 dorm rooms housing 114 students. The walls are brick and masonry with no insulation. The windows are predominately double-pane units with single-pane units near the first floor entrance. The roof has rigid foamboard insulation under the membrane surface.

Thrift Hall is a two-story building containing the campus mail room and offices. The building was constructed in 1917 with 9,110 ft² of floor area. The walls are brick and masonry with no insulation. The windows are single-pane units with wood frames. The roof has rigid foamboard insulation under the membrane surface.

Both Jones and Thrift are heated using high-pressure steam reduced to low pressure and sent to radiators with the steam generated by the central plant. No cooling is present in Jones. Cooling is provided to Thrift via window air conditioners for the office area on the second floor and large split system for the mail room on the first floor. Neither building is connected to the BMS.

The steam use for Jones and Thrift Halls from the central plant is not sub metered. Electricity is supplied to Thrift Hall through an assumed 800A 208V fused service and then sent to Esther L Jones with an independent service and meter delivered by ConEdison to these buildings under the 193 Ryerson account. The electric service is quite old and should be replaced with a mechanical system upgrade.

Jones Hall has two atmospheric gas fired DHW boilers to provide DHW for the building. Thrift has a single electric DHW heater for the building.

2.4.4 DeKalb Hall

DeKalb Hall is a four-story 24,058 ft² building with a basement originally constructed in 1955 as a residence hall. The building has been converted to office space on the upper floors with a first floor gallery. The walls are brick and masonry with no insulation. The windows are the original single pane units with steel frames. The roof has rigid foamboard insulation under the membrane surface.

DeKalb is delivered steam from the central plant via the Pantas and Jones mechanical rooms. The building converts the steam to heating hot water via a HX. The heating hot water is delivered to fin tube radiation for the perimeter of the building via three heating zones. Based on the Roadmap report, this building is also over-heated during periods of moderate cold temperatures. The building is cooled using window air conditioning units and one circa 1975 DX AHU for the basement. The building is connected to the BMS for the steam to hot water converting station along with the three fin tube heating zones. The old pneumatic controls are not operational. Also, DeKalb has a steam heat exchange tank system with a 500-gallon tank to generate DHW.

Steam use from the central plant to DeKalb is not sub metered. Electricity is delivered by ConEdison to this building under the 193 Ryerson account via an independent service and submeter to a 300A 208V main breaker on the panelboard serving DeKalb.

2.4.5 Zone 5 Buildings (North Campus)

Zone 5 includes North Hall, Memorial Hall, and the Student Union. The building descriptions for these buildings are provided in the following subsections.

2.4.6 North Hall

North Hall is a four-story 67,026 ft² building with a basement that is closest to the main entrance gate on Willoughby Ave. The building was constructed in 1958 and includes the campus cafeteria and kitchen, along with classroom and office spaces. The walls are brick and masonry with no insulation. The windows are the double-pane units. The roof has rigid foamboard insulation under the membrane surface.

The building is heated using high-pressure steam energy from the central plant. Steam generates hot water for use in fan coil units and fin tube radiation via a heat exchanger (HX) to heat the building. Five AHUs and heating and ventilation (H&V) units provide heating to the common spaces including makeup air to the kitchen. These AHUs have old pneumatic controls that do not work. Cooling is provided by many window air conditioners, six Mitsubishi splits for the cafeteria, and a heat pump (HP) variable refrigerant flow (VRF) for the Provost area on the second floor. The AHUs are H&V units, no cooling. Heating is done with steam coils.

Steam use from the central plant to North Hall is not sub metered. Electricity is delivered by ConEdison to the 4000A, 208V switchboard at North Hall under the 193 Ryerson account via an independent service and meter, which then feeds North, Memorial, Union, Main, and East Halls. As stated earlier, three single-phase 167 kVA step up transformers in North Hall basement feed step down transformers in Main and East Halls. The other buildings are served directly from the North Hall service with 208V 3-ph power.

The North Hall sub-basement has a chiller plant with several DX air cooled chillers that serve Memorial Hall auditorium and the Pi shop⁴ in Memorial Hall basement. The DHW system at North Hall, which is currently a steam fired system with 2- to 500-gallon tanks that provides DHW to North Hall, Student Union, Memorial Hall, East Building, Main Building, South Hall, Chemistry, Engineering, and Machinery Building. A supplemental electric DHW system with 4–85 gallon water heaters are located in the North mechanical room that operate only during the summer when the steam plant is off.

2.4.7 Memorial Hall

Memorial Hall is a single story 18,524 ft² building with a basement constructed in 1927. The building contains the main auditorium and stage for the campus and is only used for major events. The walls are brick and masonry with no insulation. Most of the windows are single pane, while some units have storm windows added to the frame. The sloped roof has no insulation.

Memorial Hall has three AHUs providing heating and cooling to the building. The largest AHU serves the auditorium and is equipped with steam and chilled water coils. For this AHU, the steam is delivered from the central plant and the chilled water is delivered from the North Hall chillers. The other two AHUs provide only cooling for the control room and lobby with chilled water also provided by the North Hall chillers. Steam radiators are mounted around the perimeter of the auditorium with no automated control. Three split-system air conditioners provide cooling to the basement conference rooms. The AHUs are on the central BMS, while all the other distributed systems are only controlled locally.

Steam use from the central plant to DeKalb is not sub metered. Electricity is delivered by ConEdison to this building from North Hall at 208 V.

The Pi shop located in the basement has an AHU with a chilled water coil that is served by the DX chillers in the North Hall chiller plant.

2.4.8 Student Union

The Student Union is a two story 11,729 ft² building constructed in 1987. The building contains the PI Café, kitchen space, offices, conference area, and an open area that doubles as a theatre space. The walls are brick and masonry with fiberglass insulation. The windows are the double pane units. The roof has rigid foamboard insulation under the membrane surface.

Student Union has three rooftop units (RTUs) providing heating via natural gas furnaces and DX cooling to the building. The central steam plant serves a small HX for hydronic heat to several small radiators. The RTUs have DX cooling and are connected to VAV boxes. A split system provides cooling to the video control room. All of the RTUs and the room level VAV controls are within the BMS.

Steam use from the central plant to Student Union is not sub-metered. Electricity is delivered by ConEdison to this building from North Hall at 208 V.

2.5 Electric Service and Distribution on Campus

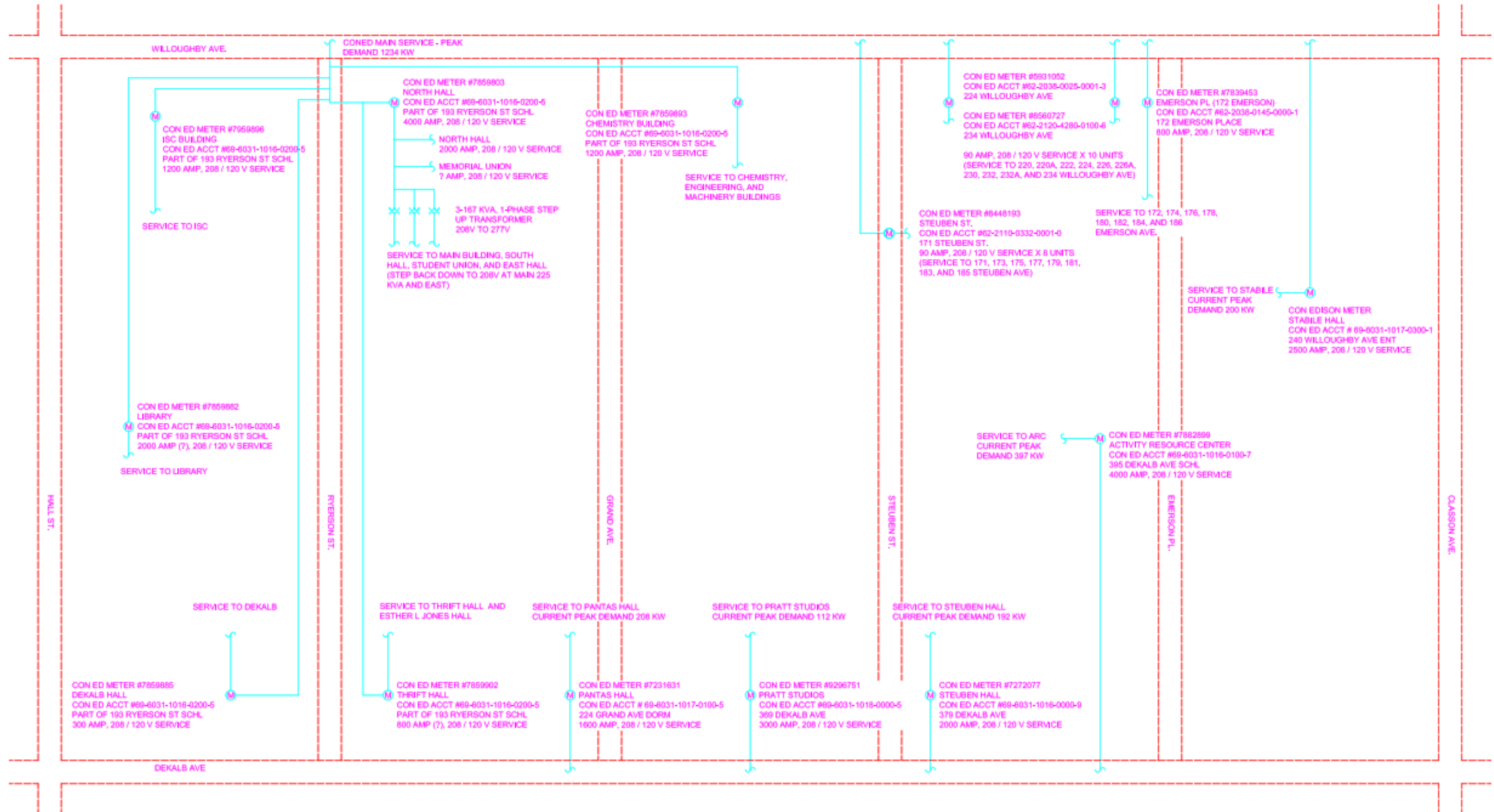
Electricity enters the Brooklyn campus at multiple locations from ConEdison (ConEd). Each service account information is summarized in Table 2 from information provided by Pratt and from the Roadmap Task 1 report. The schematic of the existing electric services to the campus is shown in Figure 9 that lists the voltage and amperage for each respective main breaker for either the metered or sub metered electric service from ConEd. Also, the schematic shows the peak electric demand currently known for each metered service from ConEd, where data was available.

Table 1. Electric Services for Pratt Brooklyn Campus

Bldg no.	Bldg Name	Other Bldgs Served	ConEd Acct no. Address	ConEd Acct no.	ConEd Meter no.
1	ISC	None	193 Ryerson	69-6031-1016-0200-5	7959896
2	Library	None	193 Ryerson	69-6031-1016-0200-5	7859882
3	DeKalb	None	193 Ryerson	69-6031-1016-0200-5	7859885
5	North Hall	Union (6), Memorial (7), Main (8), East (9), South (10)	193 Ryerson	69-6031-1016-0200-5	7859803
12	Thrift	Jones (11)	193 Ryerson	69-6031-1016-0200-5	7859902
13	Pantas	None	224 Grand	69-6031-1017-0100-5	7231631
18	Machinery	Chemistry (16), Engineering (17)	193 Ryerson	69-6031-1016-0200-5	7859893
19A	Pratt Studios	Connector (19B)	369 DeKalb	69-6031-1018-0000-5	9296751
19C	Steuben	None	379 DeKalb	69-6031-1016-0000-9	7272077
21	Willoughby Townhouses	None	224 Willoughby 234 Willoughby	62-2038-0025-0001-3 62-2120-4280-0100-6	5931052 8560727
21	Emerson Townhouses	All Emerson from 172 Emerson	172 Emerson	62-2038-0145-0000-1	7839453
21	Steuben Townhouses	None	171 Steuben	62-2110-0332-0001-0	8448193
22	ARC	None	395 DeKalb	69-6031-1016-0100-7	7882975
23	Stabile	None	240 Willoughby	69-6031-1017-0300-1	7882899
24	Cannoneer Court	None	280 Classon	69-6031-1017-0000-7	5922714

During the initial site visit, the service entrances to Engineering, North Hall, Steuben, and Pratt Studios were visited. The remaining service entrances at the Townhouses (Willoughby, Steuben, and Emerson), ARC, Pantas, Thrift, DeKalb, Stabile, Library, and ISC were visited in March 2022 for main breaker sizes, confirming meter numbers and information included in Exhibit 10.

Figure 8. Electrical Metered Connections at Pratt Institute



3 Existing Energy Use and Load Conditions

A total of 12 months of electric, natural gas, and fuel oil data was collected for the Pratt Institute Brooklyn Campus from January 2020 through December 2020. Compiled annual data for 2019 and 2018 is also provided as a reference. A discussion of the historical consumption and all-in utility rates are discussed below. Also presented is a discussion and modeling results of the estimated baseline heating and cooling loads for the campus by building.

3.1 Electric Metered Use and Costs

Electricity for the main campus is delivered by ConEd on SC-9 rate I, and supply is provided through the third-party supplier, Direct Energy. Service is provided at 208V.⁵ ARC has a 500 kVA transformer for 277/480V. The primary focus of this study will be on the electric accounts listed in Table 3 that serve most of a main campus, with the exception of Cannoneer Court. The total consumption for each of the three rows of townhouse buildings was estimated because data for these individual meters was not supplied by Pratt.

For the 12 months of electricity data from January 2020 through December 2020, the campus consumed a total of 8,896,640 kilowatt-hour (kWh) and had a peak demand of 1,841 kilowatt (kW)⁶ during the month of September 2020. Concurrent costs were not provided for the 2020 electricity consumption data, but assuming an all-in rate of \$0.157/kWh that was obtained from the Roadmap, Pratt Institute spent an estimated total of \$1,396,772 for their electricity during the 2020 calendar year.⁷ Also included are the 2019 and 2018 annual consumption data for the same accounts/buildings on campus. With recent price increases in electricity, Pratt has stated that its current rate for electricity is \$0.19 per kWh, which will be used in the economic analysis. Energy use in 2020 was assumed to be lower due to decreased occupancy and use of the buildings due to the COVID-19 pandemic.

Table 2. Total Electricity Consumption for 2020

Month-Year	Total kWh	Peak Demand, kW	Estimated Total Cost (\$)*
Jan-20	704,960	1,295	\$110,679
Feb-20	717,627	1,284	\$112,667
Mar-20	717,627	1,287	\$112,667
Apr-20	677,147	1,203	\$106,312
May-20	659,867	1,278	\$103,599
Jun-20	728,187	1,345	\$114,325
Jul-20	787,707	1,479	\$123,670
Aug-20	771,400	1,478	\$121,110
Sep-20	884,440	1,841	\$138,857
Oct-20	777,040	1,421	\$121,995
Nov-20	754,320	1,289	\$118,428
Dec-20	716,320	1,182	\$112,462
Total – 2020	8,896,640	-	\$1,396,772
Total – 2019	9,672,200	-	\$1,518,535
Total – 2018	9,778,543**	-	\$1,535,231

* Assuming \$0.157/kWh all-in rate from the Roadmap Report.

** 5 months of data were estimated for the 369 DeKalb account.

3.2 Natural Gas and Fuel Oil Metered Use and Costs

Natural gas for the central steam plant is delivered by National Grid under Service Classification 2, the general service (non-residential) delivery tariff. Additional natural gas services are delivered to the main Pratt campus for domestic water and non-heating purposes at buildings on the main campus that are served by the central steam plant for heating; however, those accounts are not of concern for this study effort. The other natural gas heating accounts for Pratt are for buildings outside the scope of this study that include Cannoneer Court, the north campus (Willoughby Hall, Myrtle Hall, and Film/Video), and other remote buildings (Pratt House, Higgins Hall, 100 Grand Ave).

Natural gas is supplied by the third-party supplier Direct Energy. For the most recent 12 months of data available from January 2020 through December 2020, the boiler plant on the campus consumed a total of 519,307 therms and spent an estimated total of \$436,218. The average all-in rate of \$0.84/therm was obtained from the Roadmap. Consumption data for 2019 and 2018 also provided for reference, but 2019 data is higher than 2020 or the preceding year of 2018.⁸

Pratt also purchases fuel oil, which is used for their rented boiler and as a secondary fuel for their main boiler plant. For the most recent 12 months of data available from January 2020 through December 2020, the boiler plant on the campus purchased a total of 33,364 gallons of fuel oil and spent an estimated total of \$87,080. The average all-in rate of \$2.61/gallon was obtained from the Roadmap. Pratt’s annual fuel oil purchases vary year to year depending on their rental boiler usage, and test firings in their main plant.⁹

Table 3. Total Fuel Oil and Natural Gas Consumption for 2020

Month-Year	Total Gas therms	Estimated Total Gas Cost (\$)*	Total no. 2 Fuel Oil, gallons	Total no. 2 Fuel Oil, MMBtu	Total Fuel MMBtu	HDD65
Jan-20	134,509	\$112,988	5,864	809		816
Feb-20	113,783	\$95,578	12,001	1,656		748
Mar-20	72,184	\$60,635	0	0		593
Apr-20	55,846	\$46,910	4,001	552		494
May-20	23,400	\$19,656	2,497	345		251
Jun-20	3,248	\$2,728	0	0		22
Jul-20	7,041	\$5,914	0	0		0
Aug-20	0	\$0	0	0		1
Sep-20	0	\$0	4,000	552		49
Oct-20	0	\$0	0	0		220
Nov-20	95,186	\$79,956	5,001	690		424
Dec-20	14,110	\$11,852	0	0		809
Total – 2020	519,307	\$436,218	33,364	4,604	56,535	4,427
Total – 2019	842,944	\$708,073	67,354	9,295	93,589	4,891
Total – 2018	503,506	\$422,945	194,258	26,807	77,158	4,992

* Assuming \$0.84/therm all-in rate from the Roadmap Report.

Table 4. Total Fuel Oil Purchases for 2020

Month-Year	Total gallons	Total MMBtu	Total \$
Jan-20	5,864	809	\$15,305
Feb-20	12,001	1,656	\$31,323
Mar-20	0	0	\$0
Apr-20	4,001	552	\$10,443
May-20	2,497	345	\$6,517
Jun-20	0	0	\$0
Jul-20	0	0	\$0
Aug-20	0	0	\$0
Sep-20	4,000	552	\$10,440
Oct-20	0	0	\$0
Nov-20	5,001	690	\$13,053
Dec-20	0	0	\$0
Total-2020	33,364	4,604	\$87,080
Total-2019	67,354	9,295	\$175,794
Total-2018	194,258	26,807	\$507,013

For 2020, Pratt Institute consumed 56,534 MMBtu of thermal energy to heat the 1,041,820 ft² of building area served by the central plant. This equates to an energy requirement of 54.3 kBtu/ft² for these buildings, which is slightly higher than the average 48.0 kBtu/ft² listed in 2012 Commercial Buildings Energy Consumption Survey (CBECS).¹⁰

3.3 Existing Annual Greenhouse Gas Emissions

To reduce carbon emissions from buildings, the City of New York enacted Local Law 97 (LL97) in 2019 as a part of the Climate Mobilization Act. The legislation sets procedures for calculating carbon dioxide equivalent (CO_{2e}) emissions from on-site electricity, natural gas, and fuel oil consumption, and sets forth limitations for emissions based on building type and area. The legislation also sets aggressive timelines for facilities to reduce their overall building emissions.

Using the facility's historical electricity, natural gas, and fuel oil consumption as outlined in sections 4.1 and 4.2, a total of 5,670 metric tons of CO_{2e} of emissions consumption was calculated.

Table 5. Baseline GHG Emissions per LL97

Fuel Type	2020 Fuel Consumption	Metric Tons of CO_{2e}
Electricity	8,896,640 kWh	2,571
Natural Gas	519,307 therms	2,757
No.2 Fuel Oil	33,364 gallons	342
Total	-	5,670

The buildings on the Pratt Institute are categorized as either Group A (assembly) or Group R1 (residential, including dormitories) as defined by New York City Department of Buildings for the GHG accounting purposes.¹¹ Per the LL97 CO_{2e} allowances, it appears as if Pratt is well below the emissions allowance set forth for 2024 and is 1,003 MT (21%) above the limit set forth for 2030. Additional emissions for other buildings at Pratt are outside the scope of this study.

Table 6. LL97 GHG Limits for Pratt Main Brooklyn Campus

	Total Building Area (sq. ft.)	CO_{2e} Allowances 2024	CO_{2e} Allowances 2030
Group A	766,529	8,233	3,219
Group R1	275,291	2,717	1,448
Total	1,041,820	10,950	4,667

3.4 Steam Loads by Building

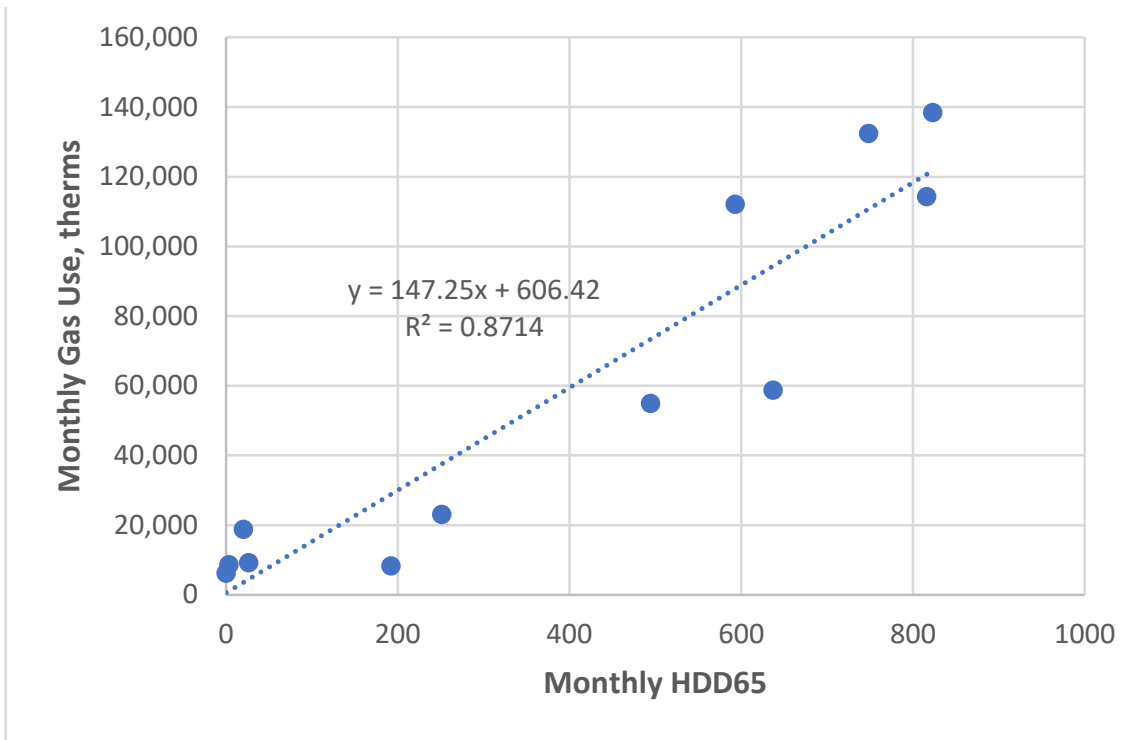
ANTARES estimated the peak steam loads for the connected buildings to the central steam plant. The first step was to estimate the peak steam load output from the central boiler plant,¹² using the monthly natural gas consumption data and the corresponding heating degree-days for the billed period. The gas heating degree day – 65F (HDD65) correlation is plotted on a monthly basis between June 2019 and June 2020 in Figure 10. The correlation chart shows the relationship between gas use at the central plant and the amount of heating degree-days for the local NYC area. The monthly correlation in Figure 10 was used to generate Equation 1 and estimate the peak hourly gas load for the existing central boiler plant.

Equation 1

$$\text{Peak Gas Load} \left(\frac{\text{therm}}{\text{hr}} \right) = \frac{(147.25 \times (65 - \text{Winter Design Temp}) \times 30) + 606.42}{720 \text{ hr}}$$

For a winter design temperature of 4°F,¹³ the peak gas load is 344 therms per hour or 34.4 MMBtu/hour. Assuming a boiler efficiency (fuel to steam) of 70% for the existing Boiler no. 1 & Boiler no. 2, the steam plant has a peak steam output of 24.1 MMBtu/hour or approximately 720 boiler horsepower.

Figure 9. Monthly Gas HDD Correlation for the Pratt Central Steam Plant

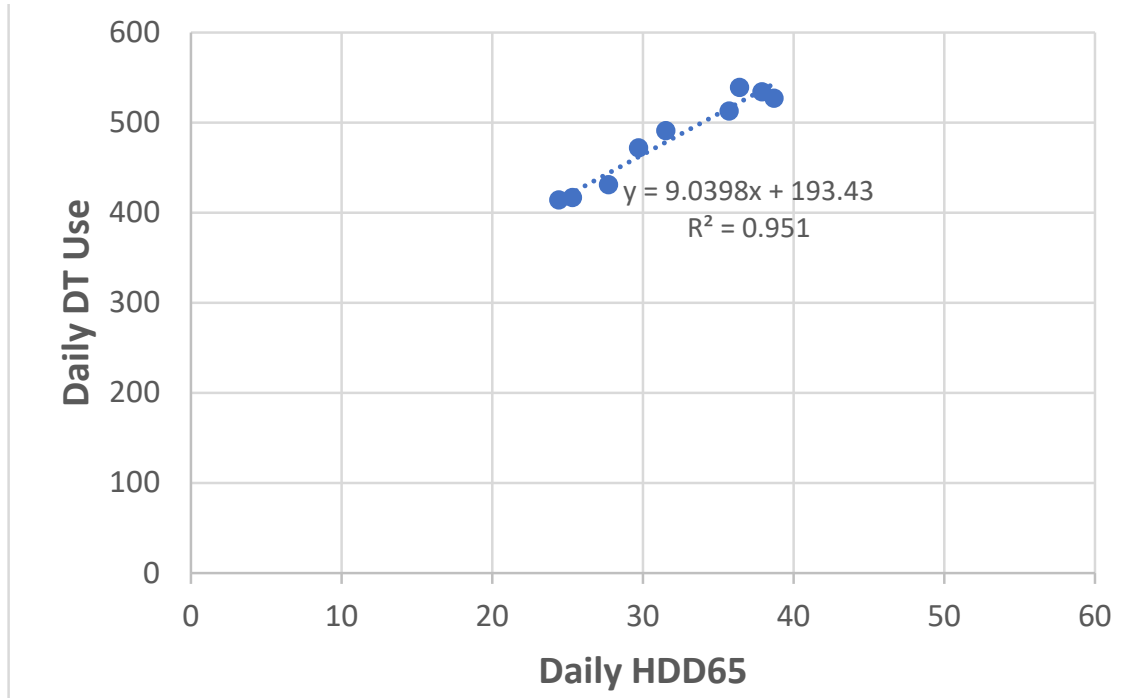


Also, an additional analysis for the central plant output was conducted using daily gas metered use for the central plant and the corresponding daily HDD65 values between December 15 and December 23, 2020. The daily correlation in Figure 11 was used to generate Equation 2 and estimate the peak hourly gas load for the existing central boiler plant.

Equation 2.

$$\text{Peak Gas Load} \left(\frac{\text{therm}}{\text{hr}} \right) = \frac{90.398 x (65 - \text{Winter Design Temp}) + 1934.3}{24 \text{ hr}}$$

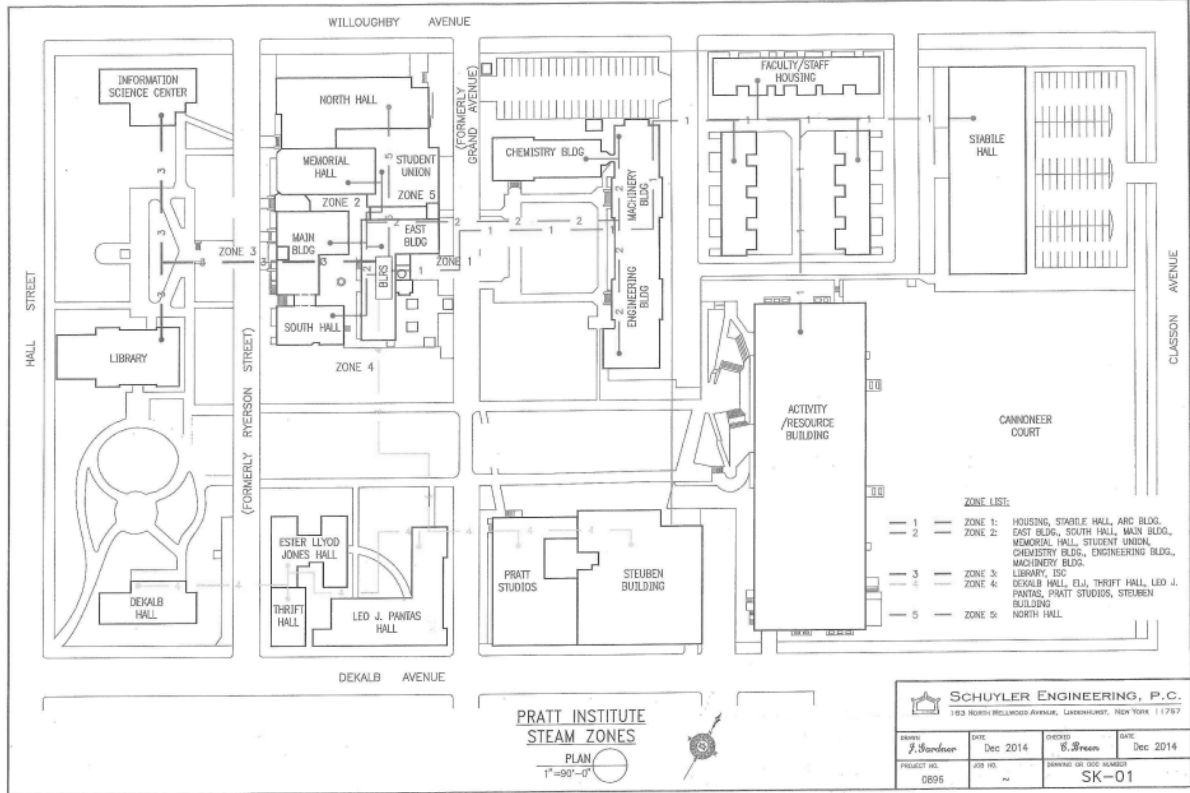
Figure 10. Daily Gas HDD Correlation for the Pratt Central Steam Plant



For a winter design temperature of 4°F,¹⁴ the peak gas load is 310 therms/hr or 31.0 MMBtu¹⁵/hr. Assuming a boiler efficiency (fuel to steam) of 70% for the existing boiler no. 1 and boiler no. 2, the steam plant has a peak steam output of 21.7 MMBtu/hr or approximately 650 boiler horsepower. With the monthly calculation providing a more conservative (i.e., higher) peak load than the daily peak load calculation, the peak steam output of the boiler plant is estimated at 24.1 MMBtu/hr.

The Pratt Institute central steam plant serves five zones on the main Brooklyn campus. A map of the steam distribution system is provided in Figure 11.

Figure 11. Existing Campus Steam Distribution



The five zones are comprised of the following buildings on the campus, along with the proposed peak steam flow from the Burns Engineering steam distribution study completed in November 2021:

- Zone 1 serves the east campus including ARC, Stable, and the Townhouses (Willoughby, Steuben, and Emerson). Burns estimated the peak steam flow of Zone 1 at 7,465 pound/hr or 27% of the total peak of 28,128 pound/hr.
- Zone 2 serves most of the central part of the campus including Engineering, Machinery, Chemistry, Main, South and East Buildings. Burns estimated the peak steam flow of Zone 2 at 8,406 pounds/hr or 30% of the total peak of 28,128 pound/hr.
- Zone 3 serves the western buildings of the campus including ISC and Library. Burns estimated the peak steam flow of Zone 3 at 1,827 pounds/hr or 6% of the total peak of 28,128 pounds/hr.
- Zone 4 serves the south campus buildings including DeKalb, Esther Lloyd-Jones (ELJ), Thrift, Pantas, and the Design Center (plus Pratt Studios and Steuben). Burns estimated the peak steam flow of Zone 2 at 7,112 pounds/hr or 25% of the total peak of 28,128 pounds/hr.

- Zone 5 serves the remainder of the central part of the campus including North Hall, Student Union, and Memorial Hall. Burns estimated the peak steam flow of Zone 2 at 3,318 pounds/hr or 12% of the total peak of 28,128 pounds/hr.

Based upon the less conservative peak steam output of 24.1 MMBtu/hr or approximately 26,300 pounds/hr¹⁶ from the boiler, these peak steam loads to the five zones were used in the calculation for the zone/building level peak heating input. While the boiler generates over 26,000 pounds/hr of steam at peak load, a significant portion of the steam is used to heat make up water and condensate return to 225°F within the existing de-aerator, which is assumed to operate at 5 psig. The steam flow to the de-aerator was estimated at 12% of the total or 3,100 pounds/hr,¹⁷ which leaves 23,200 pounds/hr to meet the peak steam flows at the five zones. Using the same percentages as developed by Burns for the peak loads by zone, Table 8 estimates the peak steam flow to the respective zones. A conservative estimate of 72%¹⁸ of the total steam energy departing the steam plant arrives at the buildings due to steam leaks and heat losses within the distribution piping. The estimated steam flows by building are shown in Table 9.

Table 7. Steam Requirements at Steam Header

	Header Steam Out (pounds/hr)–Burns	Header Steam Out (pounds/hr)–Adjusted
Zone 1	7,465	6,200
Zone 2	8,406	6,900
Zone 3	1,827	1,500
Zone 4	7,112	5,900
Zone 5	3,318	2,700
Total	28,128	23,200

Table 8. Steam Requirements at Building (Estimated)

	Building Steam Input (pounds/hr)–Estimated	Zone Total Building Input (pounds/hr)– Estimated
Townhouses (Emerson, Steuben, Willoughby)	1,357	4,490
ARC Building	1,847	
Stabile Hall	1,287	
Engineering, Machinery, Chemistry	2,435	5,050
Main Bldg, South Hall, East Bldg	2,615	1,100
ISC & Library	1,100	
DeKalb Hall	383	4,270
Esther Lloyd-Jones Hall	529	
Thrift Hall	108	
Pantas Hall	814	
Pratt Studios / Design Center	945	
Steuben Hall	1,491	
North Hall / Student Union / Memorial Hall	1,990	1,990
Total	16,900	16,900

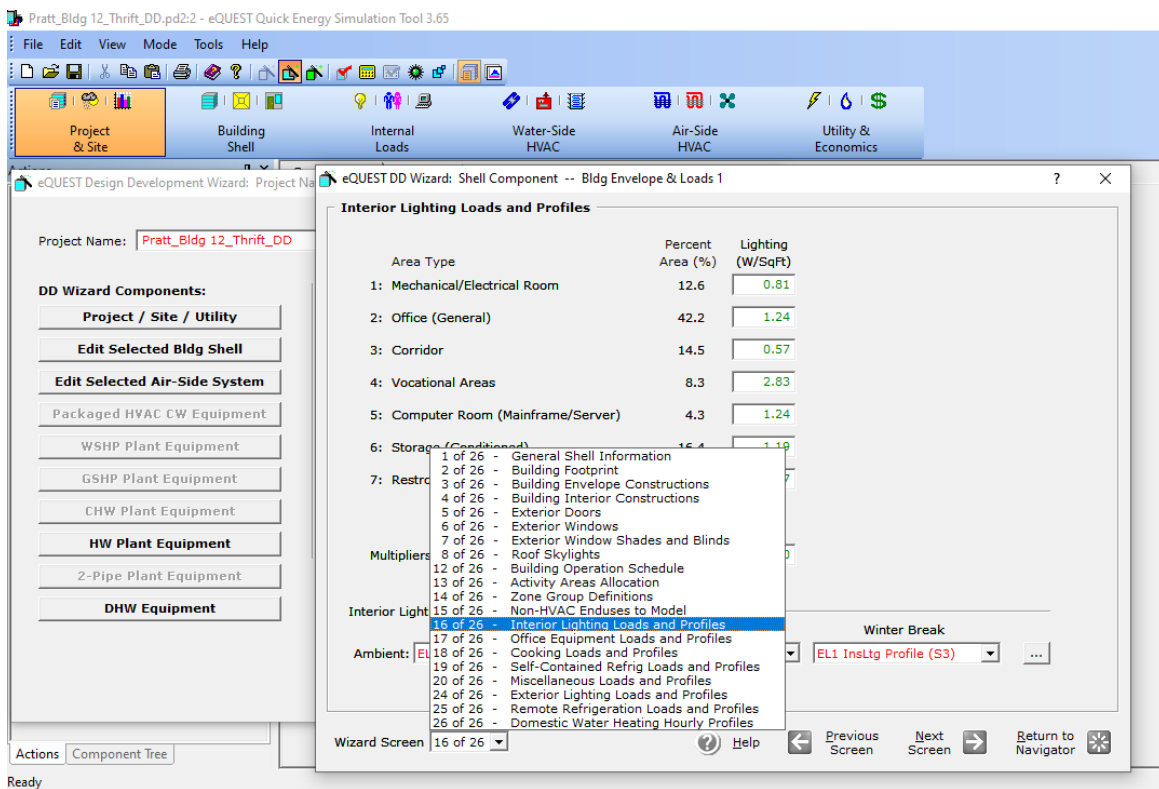
3.5 Modeled Existing Loads by Building

Modeling was done using eQUEST Version 3.65 to specifically develop the existing peak heating and cooling loads for each building on campus. Since many of the existing buildings on campus do not have central cooling or mechanical ventilation systems installed, historical utility data is not indicative of the expected future cooling requirements of the campus. Additionally, because Pratt Institute is in a heating dominant climate, the heating loads will be the determining factor for many potential heat pump systems during this preliminary review of potential configurations.

The eQuest software uses climate conditions for the nearest city and key building characteristics such as building area (square feet), building type and space activity, fan and building operational schedules, HVAC system type and efficiency, and overall building condition (insulation and infiltration rate) to determine the peak loads. For each building, these modeling inputs were primarily sourced from layout drawings and pictures taken on site. Building characteristics and operations were determined from on-site conversations with facility staff with input from the roadmap. Any unknown modeling inputs, such as building materials (building frame, insulation, window glass, etc.), exact HVAC system configurations, or equipment loads in each activity area, were estimated using eQUEST default values.

For each building type in eQUEST, the Department of Energy (DOE) has included a library of estimated values that are assumed based on a few user-specified inputs such as location and primary building use if specific input values are unknown. The library also includes climate and weather data for various locations (in this case, New York, New York) sourced from the U. S. National Weather Service for a typical meteorological year (TMY). A view of an example eQUEST input screen for “Interior Lighting Loads and Profiles” is shown in Figure 12 and includes default values for the lighting intensity for the different areas of the building.

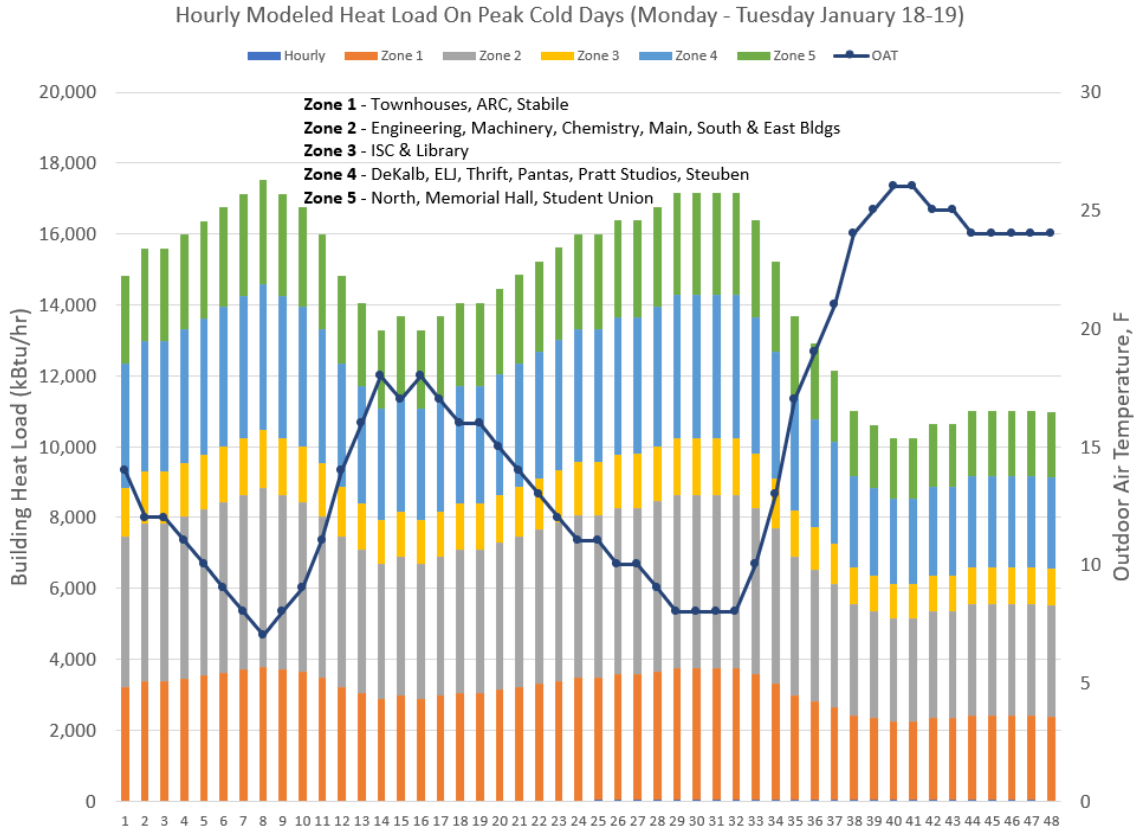
Figure 12. eQUEST Example Design Development Wizard Screen



Once the annual peak heating loads were estimated with eQUEST for each individual building, the peak heating loads for each zone were summed up and compared with the estimated steam output peaks that was previously described above in section 4.3. Outside dry bulb temperatures for the typical meteorological year (TMY) data sets provided by eQUEST were used to determine that the peak heating loads occur about halfway through January,¹⁹ on Monday and Tuesday, January 18 and 19 (based on the hourly temperature data set within eQuest). The hourly heating

loads for these two days were summed for buildings in each zone to estimate the peak heating profiles, shown in Figure 13. A similar graph for cooling loads was not performed as the heating load was the dominant load for the campus. These profiles show the expected inverse relationship between outside air temperature and heating load—as outside air temperatures drop, the heating requirements of the building increase.

Figure 13. Peak Cold Days Heating Profile per Zone



Hourly loads per building were estimated based on the assumed relationship between the outdoor air temperature, the peak hourly loads estimated in eQUEST, and building balance point of 50°F. As shown in Table 10, the peak heating loads were calculated using eQUEST and adjusted based on a winter design temperature of 2.5°F. Also provided for reference are the peak heating loads that were estimated using historical steam data previously in section 4.3. The peak heating loads listed indicate the modeled values are reasonable by being within 14% of the estimated values for the overall campus. Figure 13 shows the hourly steam load by zone for a peak heating day with a minimum outside air temperature of 8°F at 8 a.m.²⁰

Table 9. Peak Heating Load Summary—eQUEST and Estimated from Historical Data

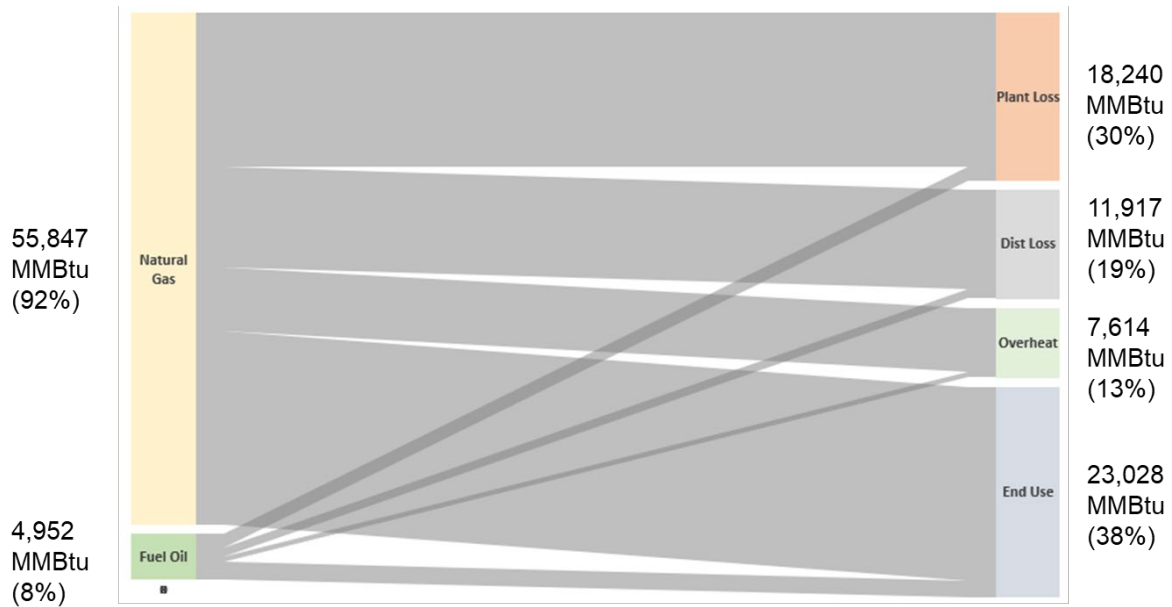
Zone	Buildings	Area (sq. ft.)	Peak Heat Loads (Mbtu/hr)		eQUEST Annual Heat Required (MMBtu/yr)
			Estimated Peak from Historical Consumption	eQUEST Modeled Peak*	
Zone 1	Townhouses (Emerson, Steuben, Willoughby); ARC Building; Stabile Hall	278,352	4,490	4,167	4,988
Zone 2	Engineering; Machinery; Chemistry; Main; South; East	244,945	5,050	5,514	6,600
Zone 3	ISC; Library	83,153	1,100	1,801	2,156
Zone 4	Dekalb; ELJ; Thrift; Pantas; Steuben; Pratt Studios	338,091	4,270	4,535	5,428
Zone 5	North; Student Union; Memorial Hall	97,279	1,990	3,222	3,857
Total		1,041,820	16,900	19,240	23,028
Btu/hr-sq.ft.			16.2	18.5	

* Adjusted to a peak winter outside air temperature of 2.5°F.

If a specific project is considered for implementation at a later date, ANTARES recommends that Pratt consider conducting steam and electric submetering on specific buildings to help focus the design of the system. The energy modeling effort was focused on quantifying the building heating and cooling loads solely and not the HVAC (pumps, fans, etc.) and non-HVAC (lighting, miscellaneous loads, plug loads and service water heating) loads.

With a weather adjusted annual energy use of 60,799 MMBtu²¹ in 2020 for the central steam plant, the overall efficiency of the steam system is 38%. The estimated boiler plant efficiency is 70% and distribution efficiency is 72%,²² which results in an overall efficiency of 50%. The difference between the 38% and 50% is the overheating of spaces, which was a common issue in the older buildings heated predominately by steam from the central plant. The energy flows are represented in the Sankey diagram provided in Figure 14.

Figure 14. Sankey Diagram for Existing Heating Plant Loads



Using the average utility all-in rate of \$0.84/therm for natural gas that was identified in section 4.2, the total annual heat load per zone, and the overall system efficiency of 38%,²³ the estimated annual costs are summarized in Table 11.

Table 10. Annual Energy Costs for Heating Buildings Per Zone

Zone	Area (ft ²)	Energy Required (MMBtu/year)	Energy Required (kBtu/ft ² -yr)	Total Costs (\$/year)	Total Costs (\$/ft ² /year)
Zone 1	278,352	19,904	71.5	\$167,197	\$0.60
Zone 2	244,945	17,625	72.0	\$148,054	\$0.60
Zone 3	83,153	4,842	58.2	\$40,671	\$0.49
Zone 4	338,091	11,456	33.9	\$96,232	\$0.28
Zone 5	97,279	6,971	71.7	\$58,558	\$0.60
Total	1,041,820	60,799	58.4	\$510,712	\$0.49

3.6 Modeled Baseline Loads by Building

Modeling was done using eQUEST Version 3.65 to specifically develop the baseline peak heating and cooling loads for each building on campus with code required heating, cooling, and ventilation. The baseline HVAC systems modeled for the buildings differed from the existing model for most buildings except Stabile Hall. The baseline HVAC systems modeled

for the buildings followed the HVAC System Types are summarized in Table 12. All baseline buildings remain having heating energy provided by the central steam plant; however, the building HVAC systems are expected to be under control and to not overheat the spaces.

Table 11. Modeled Baseline Buildings and HVAC Systems

HVAC System	Pratt Buildings
System 1–PTAC (Packaged terminal air conditioner, hot water boiler)	Townhouses, Pantas, and ELJ.
System 3–PSZ AC (Packaged single zone rooftop air conditioner with gas furnace)	ARC, Thrift, South, Memorial, and Student Union
System 5–Packaged VAV with reheat (DX cooling and hot water boiler)	Chemistry, Engineering, Machinery, Steuben, Pratt Studios, DeKalb, Main, East, ISC, Library, and North

The annual peak cooling and heating loads were estimated with eQUEST for each individual building, and the peak heating loads for each zone were summed up. The peak heating load increased from the existing condition due to increased mechanical ventilation loads. Hourly loads per building were estimated based on the assumed relationship between the outdoor air temperature, the peak hourly loads estimated in eQUEST, and building balance point of 50°F. The buildings have an annual heating requirement of 24,342 MMBtu as shown in Table 13. With the boiler plant efficiency of 80%, distribution efficiency of 72%, and no excess heating, the annual gas input requirement of the baseline systems is 42,261 MMBtu/yr, which is a reduction from the existing gas requirement of 60,799 MMBtu/yr.

Table 12. Annual Heating Loads—Baseline System

Zone Number	Buildings	Area (sq. ft.)	Modeled Peak Heating Load (Mbtu/hr)	Annual Heat Required (MMBtu/yr)	Annual Gas Input Req'd (MMBtu/yr)
Zone 1	Townhouses (Emerson, Steuben, Willoughby); ARC Building; Stabile Hall	278,352	4,522	5,431	9,429
Zone 2	Engineering; Machinery; Chemistry; Main; South; East	244,945	5,722	6,872	11,931
Zone 3	ISC; Library	83,153	1,790	2,150	3,732
Zone 4	Dekalb; ELJ; Thrift; Pantas; Steuben; Pratt Studios	338,091	4,535	6,679	11,595
Zone 5	North; Student Union; Memorial Hall	97,279	2,673	3,211	5,574
Total		1,041,820	20,267	24,342	42,261
Btu/hrsq. ft.			19.5		

Peak heating and cooling loads are summarized by building in Table 14, which show a total peak cooling load of 1,435 tons and heating load of 20.3 MMBtu/hr. The annual heating and cooling loads are shown in Table 15 along with the electric and natural gas input for the baseline systems. The annual energy input to the heating and cooling systems were estimated at 422,612 therms of natural gas for heating and 1,771,364 kWh of electricity for the building air-cooled chillers and 191,170 kWh of electricity for pumping heating water and chilled water. The campus loads are currently heating dominant with 24,342 MMBtu of annual heating loads and 19,520 MMBtu of annual cooling loads.

Table 13. Peak Heating and Cooling Loads—Baseline System

Building	Peak Heating, MBH	Peak Cooling (tons)
Townhouses	1,140	100
ARC	2,588	192
Stabile	793	106
Engineering	1,347	81
Machinery	913	54
Chemistry	686	43
Main	1,254	76
South	441	17
East	1,079	62
ISC	694	41
Library	1,095	69
DeKalb	579	37
ELJ	575	64
Thrift	197	13
Pantas	647	65
Steuben	1,903	134
Pratt Studios	1,659	106
North	1,820	128
Student Union	428	25
Memorial Hall	426	21
Total	20,267	1,435

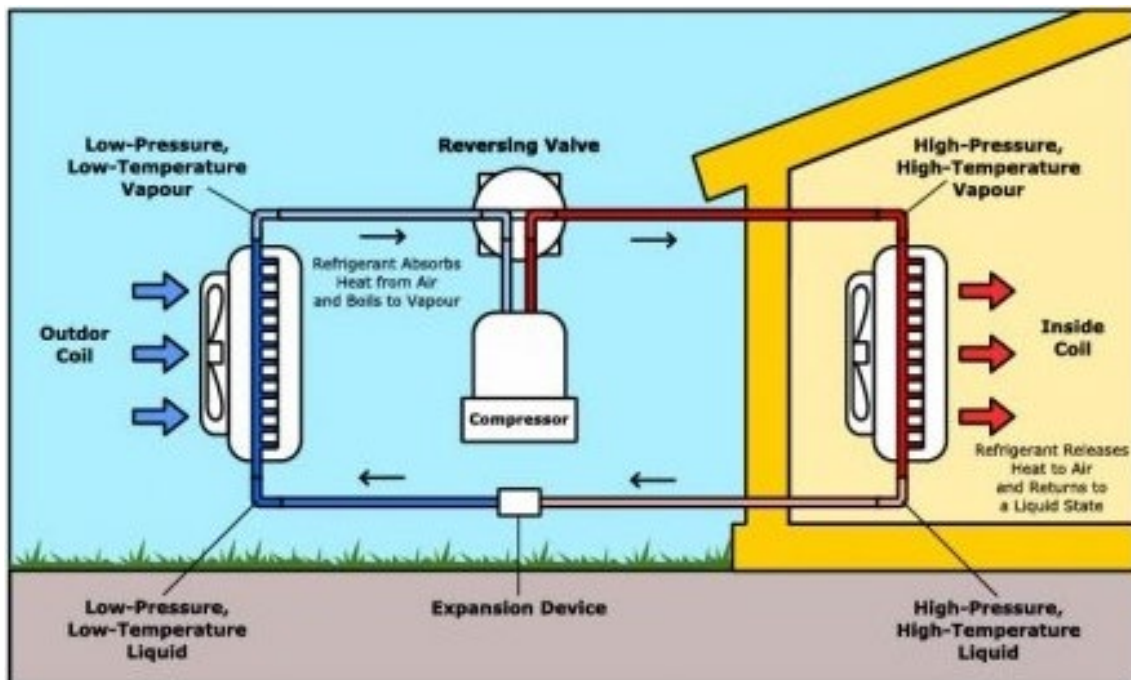
Table 14. Annual Heating and Cooling Loads and Energy Input—Baseline System

Building	Annual Heating, MMBtu	Annual Cooling, MMBtu	Annual Cooling, ton-hrs	Annual Compressor Electric, kWh	Annual Pump Electric, kWh	Annual Gas in, therms
Townhouses	1,370	781	65,073	71,581	0	23,788
ARC	3,108	2,959	246,559	271,215	1,900	53,967
Stabile	953	829	69,124	76,036	24,080	16,538
Engineering	1,618	1,247	103,880	114,268	12,180	28,096
Machinery	1,097	828	69,006	75,907	7,780	19,045
Chemistry	824	660	54,959	60,455	6,040	14,309
Main	1,506	1,175	97,898	107,688	22,080	26,148
South	531	257	21,388	23,527	2,290	9,215
East	1,296	953	79,397	87,337	19,640	22,496
ISC	834	632	52,641	57,905	12,450	14,481
Library	1,316	1,062	88,519	97,371	21,650	22,841
DeKalb	695	570	47,527	52,280	6,200	12,073
ELJ	690	502	41,822	46,004	1,250	11,982
Thrift	237	196	16,309	17,940	2,240	4,111
Pantas	778	510	42,528	46,781	16,070	13,500
Steuben	2,286	2,058	171,509	188,660	8,400	39,692
Pratt Studios	1,992	1,624	135,358	148,894	4,160	34,589
North	2,186	1,974	164,459	180,905	14,900	37,948
Student Union	514	384	32,006	35,207	3,250	8,917
Memorial Hall	511	320	26,679	29,346	4,610	8,874
Total	24,342	19,520	1,626,640	1,771,364	191,170	422,612

4 Potential Heat Pump Configurations

This section provides an overview of air source heat pumps (ASHP), water source heat pumps (WSHP) and geothermal or ground source heat pump (GSHP) options as well as the geothermal resource areas, the potential community geothermal options, and the potential to meet the Pratt Institute heating and cooling loads in the future. The measurement of efficiency in heat pumps is Coefficient of Performance (COP) for heat mode and Energy Efficiency Ratio (EER) for cooling mode. COP measures the effective useful energy output versus the energy input in the same units and is a dimensionless measurement. As will be discussed in the next few sections, the COP for heat pumps is much greater than 1 and is more efficient than electric resistance heating. The EER measures the effective useful peak cooling effect provided (in Btu/hr) versus the energy input (in watts).

Figure 15. Air Source Heat Pumps—Heating Cycle



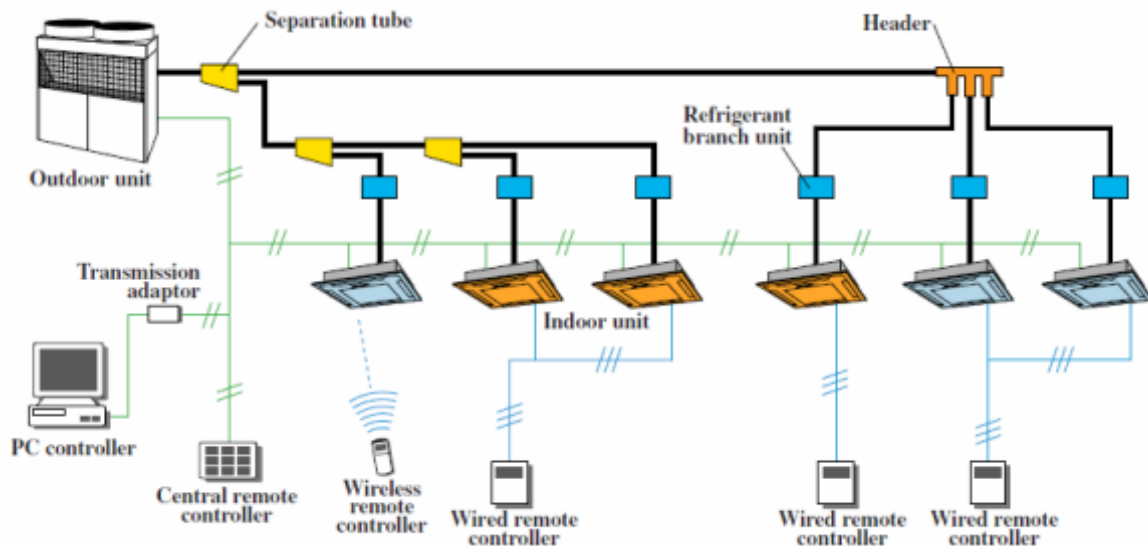
4.1 Air Source Heat Pumps

ASHPs are able to heat and cool an indoor space using an inside coil and an outside coil moving heat from one coil to the other. As shown in Figure 15,²⁴ during the heating season, heat from the outside is moved to the inside. ASHPs have been used for many years in areas

that do not experience extended periods of subfreezing temperatures. However, recent advancements and developments in the technology has allowed the ASHP technology to be used in colder regions of the country, including New York State, which are classified as cold-climate heat pumps.

ASHPs are able to deliver coefficient of performances (COPs) between 2.0 and 5.0 depending upon the heat pump selected and the ambient air temperature. The specific ASHP technology that is being explored for this project is a VRF system. The VRF system consists of multiple indoor units coupled to a single outdoor unit with the flow of refrigerant varying between each indoor unit through a modulating valve. The VRF system uses inverter-driven scroll compressors capable of changing the speed to follow the variations in the total heating/cooling load as determined by the suction gas pressure measured on the outdoor unit. Capacity control range can be as low as 6%, depending on the technology vendor. A schematic VRF arrangement is provided in Figure 16, which is provided by Fujitsu.

Figure 16. VRF Schematic Arrangement



The specific heat pump unit modeled for the air source heat pump technology considered was the Daikin VRV-IV²⁵ high-efficiency heat pump unit. The key performance data is provided in Table 16.

Table 15. Air Source Heat Pump Performance Data

Heating COP at 47°F (Non-ducted)	4.2
Heating COP at 17°F (Non-ducted)	2.5
Cooling EER at 95°F (Non-ducted)	15.0
Cooling IEER (Non-ducted)	26.5

Air source heat pumps were modeled as an alternative to the baseline technology for Library, ISC, North, Memorial, Student Union, Main, East, South, DeKalb, Thrift, ELJ, ARC, and the Townhouses (Willoughby, Steuben, and Emerson). The energy requirements using air source heat pumps were calculated for these buildings assuming the same heating and cooling loads for the baseline loads outlined in section 3 and Table 15. The Daikin heat pump listed in Table 16 was the basis for the energy requirements to heat and cool the buildings along with the binned heating and cooling requirements. The compressor electricity input to heat and cool these buildings was estimated at 2,277,224 kWh per year and is listed by building in Table 17.

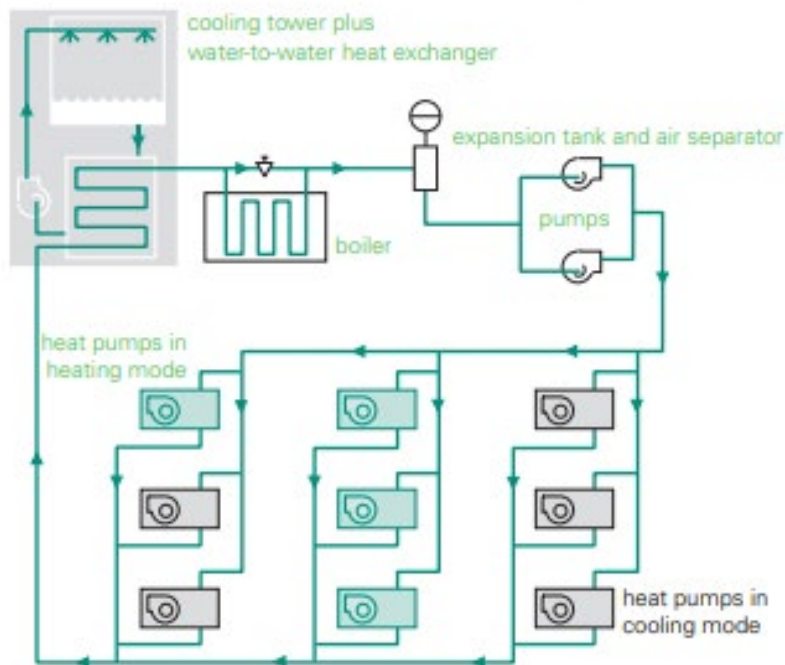
Table 16. Energy Requirements for ASHP Buildings (Compressors/Heat Pumps Only)

Building	Cooling Energy in kWh	Heating Energy in kWh	Peak kW in Summer	Peak kW in Winter
Townhouses	40,986	133,580	87	186
ARC	132,156	274,485	153	381
Engineering	65,783	134,078	76	186
Machinery	41,118	90,711	48	126
Chemistry	30,216	69,041	35	96
Main	49,131	174,626	57	243
South	14,357	49,719	17	69
East	39,167	146,416	45	203
ISC	30,492	63,162	35	88
Library	48,217	98,512	56	137
DeKalb	22,509	59,637	26	83
ELJ	25,461	62,559	54	87
Thrift	8,316	18,575	10	26
North	85,661	150,695	99	209
Student Union	16,388	44,639	19	62
Memorial Hall	13,687	43,147	16	60
Total	663,664	1,613,580	832	2,241

4.2 Water Source Heat Pumps

The WSHP technology employs a common water loop connecting distributed heat pumps throughout a building as shown in Figure 17. The heat pumps will reject heat into the water loop during the cooling season and absorb heat during the heating season. The common loop is connected to a central hydronic boiler that is used when the loop temperature drops and all heat pumps are in heating mode. The common loop is also connected to the central closed circuit cooling tower that is used when loop temperature rises when all heat pumps are in cooling mode. When simultaneous heating and cooling occurs within the building the energy is moved from one space to another efficiently.

Figure 17. Water Source Heat Pump System



The specific heat pump unit modeled for the WSHP technology considered was the Trane Axiom high-efficiency WSHP unit. The buildings considered for water source heat pumps were Stable Hall, Pantas Hall, Steuben Hall, and Pratt Studios as these buildings are already hydronic and are better suited to be converted to a water source heat pump technology. The key performance data is provided in Table 18.

Table 17. Water Source Heat Pump Performance Data (6-Ton Unit)

Heating COP at 68°F	5.4
Cooling EER at 86°F	17.3

The energy requirements using WSHP were calculated for Stabile Hall, Pantas Hall, Steuben Hall, and Pratt Studios assuming the same heating and cooling loads for the baseline loads outlined in section 3 and Table 15. The Trane heat pump listed in Table 18 was the basis for the energy requirements to heat and cool the buildings along with the binned heating and cooling requirements. Supplemental heating was estimated to be provided by the central steam heating plant with 5% and 50% of the building heating delivered by the boiler plant at ambient air temperatures of 47.5°F and 2.5°F, respectively. The compressor electricity input to heat and cool these buildings was estimated at 608,976 kWh and 2,077 MMBtu and is listed by building in Table 19.

Table 18. Energy Requirements for WSHP Buildings

Building	Cooling Energy in kWh	Heating Energy in kWh	Tower Energy in kWh	Steam Heat in MMBtu	Peak kW in Summer	Peak kW in Winter
Stabile	49,944	39,943	16,407	340	76	17
Pantas	31,067	35,412	9,436	238	47	29
Steuben	131,388	118,931	50,652	799	102	99
Pratt Studios	98,237	104,054	38,049	699	76	87
Total	310,635	298,340	114,543	2,077	302	232

4.3 Ground Source Heat Pumps

The WSHP technology can also be used for a ground loop application as well with a plate heat exchanger connected to the ground loop and the source loop in the building. If the geothermal field is sized appropriately, the ground loop can replace the boiler and cooling tower shown in Exhibit 34. The building side of the heat pump systems coupled to the geothermal field can also be (1) a VRF system using a water-cooled condensing unit and (2) a centralized chiller-heater to deliver heating and cooling using a two-pipe or four-pipe hydronic system. The GSHP configuration considered in this analysis is also a VRF-based system for each building for those buildings that were considered for ASHP retrofits, where the condensing

unit is water-cooled and is coupled to the ground source water loop. The buildings that were considered for the WSHP technology (the four hydronic buildings of Stabile, Pratt Studios, Pantas, and Steuben) were considered to use a centralized chiller-heater. The base analysis GSHP assumes a separate borefield for each building that is sized to meet both the peak heating and cooling loads.

While the campus building load is slightly heating dominant, the energy that is extracted and rejected to the loop is different. This is because a heat pump in the heating mode removes only two-thirds of its energy from the earth (the ratio depends on how efficient the equipment is) and the other one-third comes from the compressor (in the form of electrical energy). In the cooling mode 125% (depends on how efficient the equipment is) of the cooling energy (delivered load + compressor energy) must be rejected to the earth. In this case, the earth will absorb more energy during the summer than will deliver to the building during the winter. Therefore, the GSHP system would be likely cooling dominant, while the WSHP and ASHP systems would be heating dominant.

The specific heat pump unit modeled for the energy use for ground source heat pump technology considered was the water-cooled Daikin VRV-WIII heat pump unit for the ASHP buildings and a centralized Multistack chiller-heater for WSHP buildings. The key performance data is provided in Table 20.

Table 19. Heat Pump Performance Data for GSHP Applications

Heating COP – Multistack @ 55F EWT (source water)	3.79
Heating COP – Multistack @ 50F EWT (source water)	3.58
Cooling COP – Multistack @ 85F EWT (source water)	4.79
Cooling IEER – Water Cooled VRF	24.1

The compressor energy requirements using GSHPs were calculated for these buildings assuming the same heating and cooling loads for the baseline loads outlined in section 3. The heat pumps listed above with the performance data listed in Table 20 were used to estimate the energy requirements to heat and cool the buildings along with the binned heating and cooling requirements.²⁶ The heat pump compressor electric input to heat and cool these buildings was estimated at 2,648,540 kWh (9,037 MMBtu) and is listed by building in Table 21. The ground source heat pump alternative has a 27% reduction in heat pump compressor energy use over the standard air source/water source heat pump alternative and 83% reduction in energy use over the baseline. These reductions are due to the higher COP for the ground source heat pump system at low-ambient air conditions (3.1 vs 2.0) and higher EERs at high-ambient air conditions (16.4 vs 14.3).

Table 20. Energy Requirements for GSHP (Heat Pump Compressors Only)

Building	Cooling Energy in kWh	Heating Energy in kWh	Peak kW in Summer	Peak kW in Winter
Townhouses	31,798	122,485	76	123
ARC	102,197	251,686	133	252
Stabile	33,924	74,527	82	75
Engineering	50,870	122,941	66	123
Machinery	31,797	83,176	41	83
Chemistry	23,366	63,306	30	63
Main	37,993	160,121	50	160
South	11,103	45,589	14	46
East	30,288	134,254	39	134
ISC	23,580	57,916	31	58
Library	37,286	90,329	49	90
DeKalb	17,406	54,683	23	55
ELJ	19,753	57,363	47	57
Thrift	6,431	17,032	8	17
Pantas	21,102	52,187	51	52
Steuben Hall	83,114	175,271	109	175
Pratt Studios	62,143	153,347	82	153
North	66,242	138,178	86	138
Student Union	12,673	40,932	17	41
Memorial Hall	10,585	39,563	14	40
Total	713,653	1,934,887	1,049	1,935

4.4 Campus Ground Loop Locations

After a campus walking tour was conducted on October 28, 2021 and after reviewing the campus map for potential areas where vertical and horizontal bores could be drilled, the quantity of loops were determined and are summarized in Table 22. All areas combined in Table 22 have the potential to provide 678 loops based on 20 ft. spacing between vertical loops. The horizontal loops are 5 ft. apart in the North-South direction but are drilled at different depths. (15ft., 30ft., 45ft.). Figure 18 shows where these potential areas are located on campus. Red areas are where vertical bores could be drilled and the green areas are where horizontal bores could be drilled.

Table 21. Loop Field Potential

Vertical Loops Areas	Area (SF)	Width (FT)	Length (FT)	# of Loops
CCT Parking	43,700	167	265	133
SBL East Parking	25,000	50	470	86
SBL West Parking	20,000	55	345	68
SBL North Parking	6,200	125	50	25
Emerson Pl	6,500	30	230	31
Willoughby Townhouses	1,800	200	10	17
Steuben Townhouses	8,000	55	145	31
Steuben ST	13,500	35	400	58
Steuben Lot	5,900	35	170	26
CHEM Parking	14,200	195	76	52
Grand Ave	12,380	20	690	71
Library Quad	20,700	85	190	55

Horizontal Boring Areas	Area (SF)	Width (FT)	Length (FT)	# of Loops
Sculpture Park East/West	62,500	500	125	25

Figure 18. Map of Loop Field Potential



4.5 Building Loop Field Requirements

The data from the energy models is used as an input by the geothermal loop field modeling software (Loop Link PRO) to calculate a total design length for the loop field. Table 23 lists the input and assumptions in the loop field model. Information from the test bore conducted in 2007 for Myrtle Hall was used for these assumptions.²⁷

Table 22. Input Assumptions for Loop Field Model*

Input	Value	Input	Value
Model Time (Years)	25	Bore Diameter (in)	6
Deep Earth Temp. (°F)	58	Nominal Loop Size (in)	1.5
Formation Thermal Conductivity (Btu/hr. ft. °F)	1.4	Thermal Grout Conductivity (Btu/hr ft °F)	1.2
Formation Thermal Diffusivity (ft ² /day)	1.05	Min/Max Design Temperatures (°F)	30/90
Loop Spacing (ft. x ft.)	20 x 20	Circulating Fluid	20% PG

* The formation thermal conductivity and diffusivity are estimated.

The first evaluation of loop field sizing was to look at each individual building as if it had a stand-alone field. Table 24 shows how many loops are required to serve each building. If each building had its own loop field a total of 685 loops 500 ft. deep would be required. An additional 40 loops would be required if DHW energy would be met by geothermal.

Table 23. Loop Field Requirements by Building

Building	Total Length Required	No. of Loops at 500' per Bore
Townhouses	17,074	35
ARC	41,944	84
Stabile	19,464	39
Engineering	16,796	34
Machinery	10,826	22
Chemistry	35,168	71
Main	15,567	32
South	5,866	12
East	13,600	28
ISC	8,699	18
Library	13,570	28
DeKalb	7,327	15
ELJ	10,590	22
Thrift	2,479	5
Pantas	10,640	22
Steuben Hall	28,577	58
Pratt Studios	22,113	45
North	46,198	93
Student Union	5,355	11
Memorial Hall	5,376	11
Total	337,229	685
DHW–Townhouses	3,309	7
DHW–Stabile & Pantas Hall	10,391	21
DHW–ELJ	2,400	5
DHW–North Hall	3,168	7
Total with DHW	356,497	725

4.6 Community Heat Pump Configurations and Requirements

Community heat pump configurations have geothermal loop fields installed to serve multiple buildings, which will serve multiple types of buildings that have cooling and heating loads that vary based on occupancy and schedules. The study is proposing multiple community heat pump (CHP) configurations to evaluate for the detailed analysis effort. The four CHP alternatives that are considered include:

- CHP Alternative 1—Townhouses and ARC. This would be a relatively small project and provide the opportunity for Pratt to get acquainted with the technology and provide some load reduction on a steam line that is limited in capacity.
- CHP Alternative 2—Primary buildings (Zone 1 and Zone 4) with existing hydronic infrastructure. This option would build on option 1 and include the addition of geothermal for Stabile, Steuben/Pratt Studios, DeKalb, and Pantas. With this project, the existing steam plant could operate at low pressure year-round and peak demand would be reduced by 43%.
- CHP Alternative 3—Remaining primary buildings in Zone 4 plus secondary buildings. This option would further reduce the dependency on the central plant and include Jones and Thrift Hall, the Library, ISC, and Chemistry/Machinery/Engineering. This project would reduce the steam plant's peak demand by 72%.
- CHP Alternative 4—Remaining campus buildings in Zones 2 and 5. This option would shut down the central steam plant.

These CHP alternatives are going to be compared on an economic basis against the HVAC performance for the baseline, ASHP/WSHP, and single building GSHP alternatives. The CHP alternatives will require less loop field to meet the varying loads for multiple buildings. Less loop field is required due to the energy transfer pipe's ability to share heat between buildings and the multiple loop fields due to load aggregation and diversity throughout the year. Table 25 shows the CHP alternative loop field requirements and are compared to the individual buildings.

Table 25 provides the loop field requirements if (1) each individual building within the proposed community heat pump configuration had its own loop field and were not interconnected with an energy transfer pipe; (2) the individual buildings were interconnected with an energy transfer pipe to multiple loop fields; and (3) the individual buildings were interconnected with an energy transfer pipe to multiple loop fields and dry cooler(s). For example, in row 2, if the Townhouses and ARC had stand-alone ground loops, Pratt would need to install 125–500 feet deep bore holes.

Furthermore, in row three, if the Townhouses and ARC had a community heat pump system, Pratt would need to install 118–500 feet deep bore holes, which is seven less than the individual systems. Lastly, in row four, if the Townhouses and ARC had a community heat pump system with a shared dry cooler to meet peak demands, Pratt would need to install 106–500 feet deep bore holes, which is 12 less than the community system without a dry cooler.

Table 24. Community Heat Pump Loop Field Requirements

Buildings / CHP Alternative	Total Length Required	Number of Loops at 500 ft. per Bore	Dry Cooler Size (Tons)
Total Individual GSHP Alt 1 Buildings (Townhouses, ARC)	62,327	126	0
Total CHP Alt 1 Buildings	58,556	118	0
Total CHP Alt 1 + Dry Cooler	52,679	106	60
Total Individual GSHP Alt 2 Buildings (Alt 1 Buildings, Stabile, Steuben/Pratt Studios, DeKalb, Pantas)	153,512	326	0
Total CHP Alt 2 Buildings	139,628	280	0
Total CHP Alt 2 + Dry Cooler	133,023	267	160
Total Individual GSHP Alt 3 Buildings (CHP 1 & 2 Buildings, ELJ, Thrift, Library, ISC, Chem / Engr / Machinery)	280,032	531	0
Total CHP Alt 3 Buildings	215,534	432	0
Total CHP Alt 3 + Dry Cooler	197,440	395	200
Total Individual GSHP Alt 4 Buildings (CHP 1, 2 & 3 Buildings, Main, South, East, North, Student Union, Memorial)	356,497	725	0
Total CHP Alt 4 Buildings	278,996	558	0
Total CHP Alt 4 + Dry Cooler	256,332	513	240

Each scenario in Exhibit 43 shows that the buildings make the loop field cooling dominant. To reduce the field size a dry cooler was added to the analysis to bring the loop field into balance. The dry coolers would operate in spring to precool the field before summer and in the fall to remove excess energy from the system. Other ways to add balance would be to have heating loads during the summer. Examples are either process heating loads or reheat for dehumidification or adding snowmelt in some areas of campus. Items of note from Table 25 include:

- CHP Alt 1 requires eight less boreholes (6% less) in the loop field than the individual buildings combined. When a 60-ton dry cooler is added to the community loop field, the system requires 20 less boreholes (16% less) in the loop field to meet the load.

- CHP Alt 2 requires 46 less boreholes (14% less) in the loop field than the individual buildings combined. When 160 tons of dry coolers are added to the community loop field, the system requires 59 less boreholes (18% less) in the loop field to meet the load.
- CHP Alt 3 requires 99 less boreholes (19% less) in the loop field than the individual buildings combined. When 200 tons of dry coolers are added to the community loop field, the system requires 136 less boreholes (26% less) in the loop field to meet the load.
- CHP Alt 4 requires 167 less boreholes (23% less) in the loop field than the individual buildings combined. When 240 tons of dry coolers are added to the community loop field, the system requires 212 less boreholes (29% less) in the loop field to meet the load.

Pumping energy can be significant if not designed properly or managed well. Our pumping energy estimate is less than 5% of the total cooling energy that is rejected. The loop design software calculates only the vertical piping required to meet the load but does not account for the additional surface area that the approximately 6 miles of horizontal piping provides. In the end, all pump energy goes into the loop so designing the system with a low-pressure drop (20–30 FOH) will reduce pump size (first cost). In addition, appropriate control strategies such as Delta T control across the loop field and appropriate Delta-Pressure across the building pumps will manage the pump energy (operating cost) to exactly the amount needed to meet the load.

4.6.1 Energy Load Analysis for Community Heat Pump Alternatives

The energy loads for cooling and heating the four community heat pump alternatives were plotted in Figure 19 through Figure 22. These charts illustrate the existing energy requirements for the buildings and loads in each CHP Alternative described earlier. The charts show the monthly energy (in kBtu) and peak energy (in kBtu/hr.) requirements for both heating (red) and cooling (blue) as buildings are progressively added to the scope of the CHP project from alternative 1 (Townhouses and ARC) to alternative 4 (all buildings in scope).

Figure 19. CHP Alt 1 Annual Cooling and Heating Loads

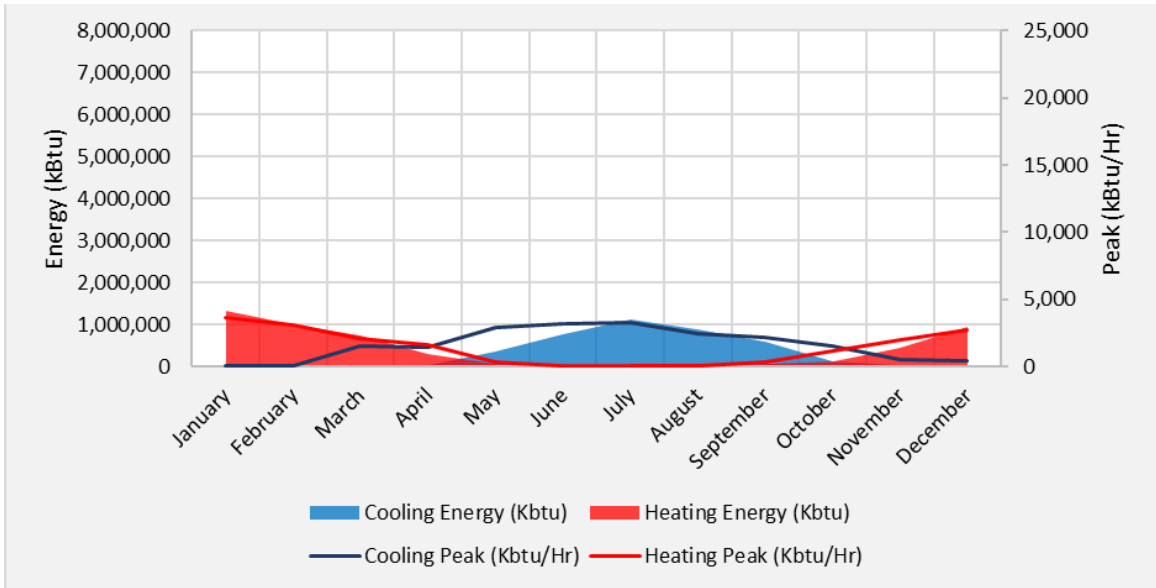


Figure 20. CHP Alt 2 Annual Cooling and Heating Loads

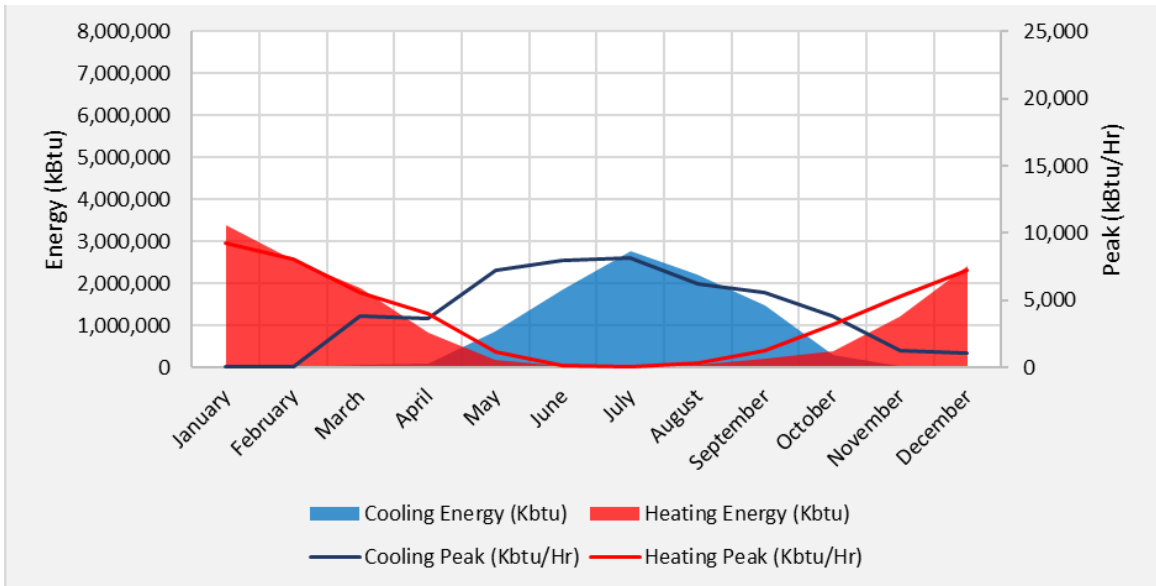


Figure 21. CHP Alt 3 Annual Cooling and Heating Loads

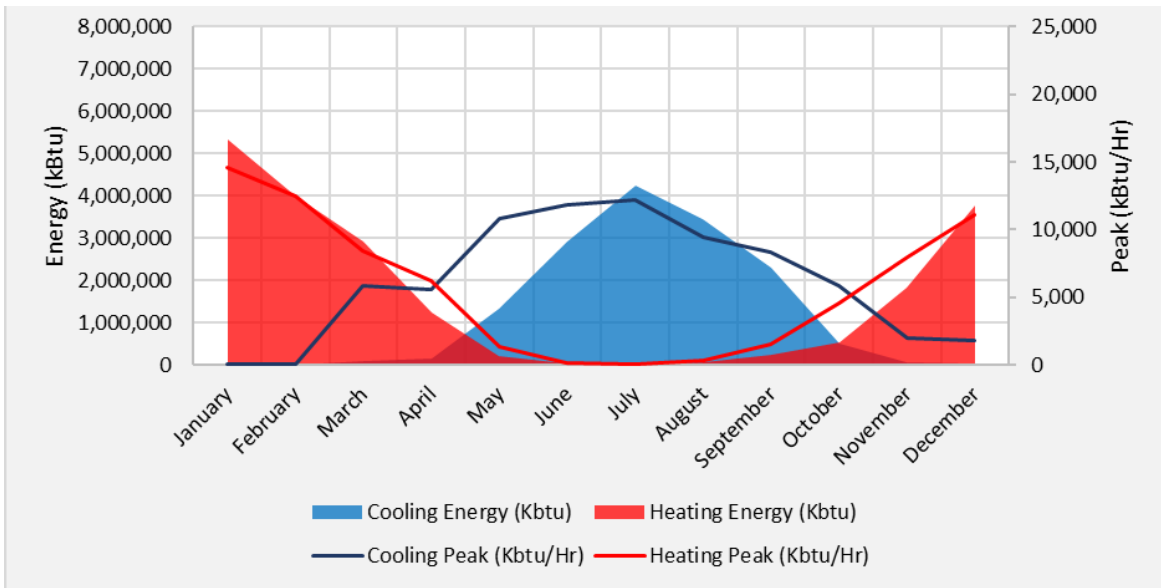
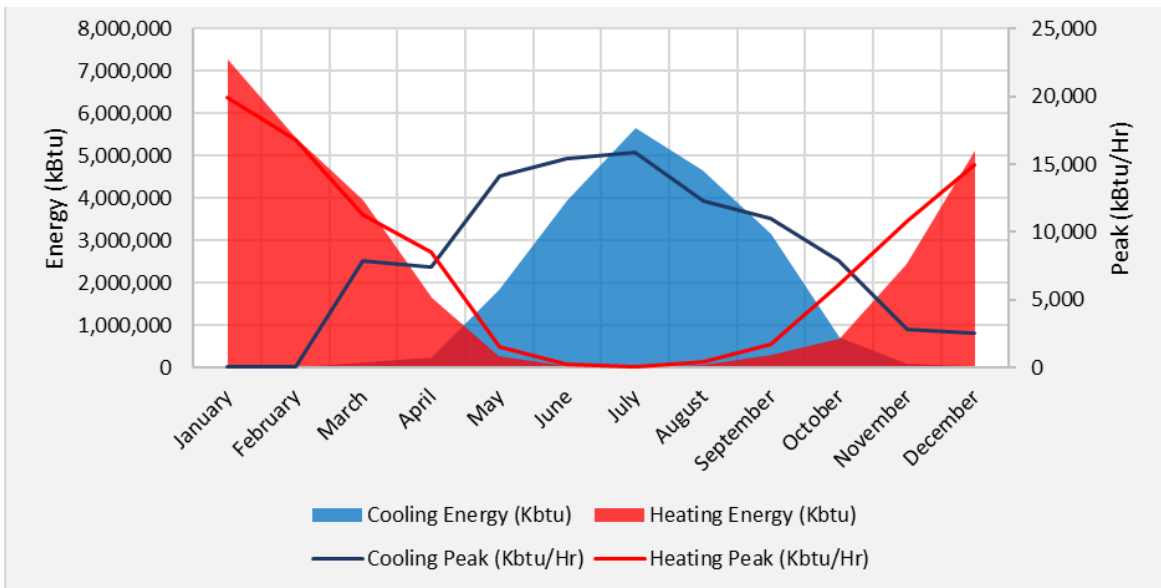


Figure 22. CHP Alt 4 Annual Heating and Cooling Loads



4.6.2 Interconnection of Loop Field Areas

To interconnect all the buildings and all the loop field areas, an energy transfer pipe (ETP) is recommended for this project (see Figure 23). The ETP is a single pipe loop that can have as many connections as needed to connect entire buildings, individual heat pumps, and loop fields. The connections are made using closely spaced tees to create a primary/secondary pumping arrangement. The downside of the ETP arrangement is that if too many buildings are connected in series on the ETP, the temperature can drop too low, requiring more flow on the one pipe and increasing the pipe size. To counter this, the loop field connections need to be distributed throughout the ETP to moderate the temperature going into each building. For example, the temperatures entering Esther L Jones Hall or ELJ are shown in Figure 25. At Pratt a large portion of the loops are located on the east side of campus but much of the load is in the central or west side of campus. It is recommended that some fields be piped to different locations to even out the distribution.

The use of a two-pipe or a four-pipe system with load-side water circulating throughout campus was considered but this type of system has many downsides that include costs, flexibility, and performance. Specific issues include:

- Pipe and insulation capital: Increased buried piping material due to more length of pipe and larger pipe diameter required and significant increase in insulation costs. Source side does not require insulation when buried underground.
- Central plant capital: The upfront capital costs associated with a central plant to produce hot and chilled water are reduced by using a distributed source piping. The buildout of loop fields and buildings can be done as needed and over a longer time frame.
- Using load-side distribution would lock the campus into specific design temperatures and decrease the flexibility of different building design needs.
- A two-pipe system would have no simultaneous heating/cooling on campus. Therefore, the distribution system would need to be a four-pipe system distributed to the campus. Pratt needs the ability to have simultaneous heating/cooling.
- Pratt wanted to be able to use different solutions for each building such as VRF systems, hydronic systems, and other solutions not currently available. Distributing source fluid is the right solution for this kind of flexibility to provide the different solutions needed for each building on campus.
- A four-pipe system would have to sequence construction, the load-side distribution, and the source-side piping back to a central plant. This type of design is not conducive to adding buildings or loop fields anywhere on campus.

- System Losses: Distribution warm/cold fluid (load-side fluids) underground creates distribution losses between the fluid and the ground, whereas source-side piping systems buried underground will benefit by increasing the moderation of the fluid temperature by the earth. Distributing source-side to buildings is a system benefit rather a system loss.
- A campus wide 4-pipe distribution system would have reduced performance due the setpoints of the system being driven by the worst-case building. Whereas individual buildings served by source-side fluid will allow each building to operate at the lowest temperatures required to meet the need and thus increasing COP and/or EER of the equipment.

To understand the flow rate required in the ETP we modeled the system in TRNSYS (model input screen shown in Figure 24) to maintain a building entering water temperatures (EWT) at each building with the goal of maintaining EWT between a minimum of 30°F and a maximum of 90°F. The model showed a minimum flow rate of 135 gallons per minute (GPM) and increased to a maximum of 675 GPM on extreme days (see Figure 26). The pump operates at a minimum flow rate when temperatures are in the range of 45°F–65°F.

The ETP can be in the ground uninsulated or insulated in basement areas of buildings (insulation is used to prevent sweating). An 8-inch HDPE pipe would be sufficient to have a reasonable pressure drop in the pipe. Figure 23 shows the possible location of the ETP. The pump location is shown outside in a small structure like a shed, but the pumps could be located anywhere in the ETP. For example, Steuben Hall has a basement mechanical space that could be used.

The building nomenclature used in the TRNSYS model input screen is as follows:

- GHX-1—Loop field pumps connected to 80–500 feet deep closed loops, 520 gpm total flow.
- GHX-2—Loop field pumps connected to 80–500 feet deep closed loops, 520 gpm total flow.
- GHX-3—Loop field pumps connected to 45–500 feet deep closed loops, 293 gpm total flow.
- GHX-4—Loop field pumps connected to 40–500 feet deep closed loops, 260 gpm total flow.
- GHX-5—Loop field pumps connected to 80–500 feet deep closed loops, 520 gpm total flow.
- GHX-6—Loop field pumps connected to 60–500 feet deep closed loops, 390 gpm total flow.

- GHX-7—Loop field pumps connected to 70–500 feet deep closed loops, 455 gpm total flow.
- GHX-8—Loop field pumps connected to 50–500 feet deep closed loops, 325 gpm total flow.
- GHX-9—Loop field pumps connected to 80–500 feet deep closed loops, 520 gpm total flow.
- GHX-10—Loop field pumps connected to 80–500 feet deep closed loops, 552 gpm total flow.
- THRF_LJP_PS—Building pumps for Thrift, Pantas, and Pratt Studios, 625 gpm total flow.
- ELJ—Building pumps for Esther L Jones, 180 gpm total flow.
- DKLB_LIB_SH—Building pumps for DeKalb, Library and South Hall, 515 gpm total flow.
- EAST_MAIN—Building pumps for East Hall and Main Building, 565 gpm total flow.
- ISC_MEM—Building pumps for ISC and Memorial Hall, 275 gpm total flow.
- NH_SU—Building pumps for North Hall and Student Union, 575 gpm total flow.
- CHEM_MACH_TWNH—Building pumps for Chemistry, Machinery, & Townhouses, 675 gpm total flow.
- ENG_SBL—Building pumps for Engineering and Stabile Hall, 540 gpm total flow.
- ARC—Building pumps for ARC, 625 gpm total flow.
- STE—Building pumps for Steuben, 465 gpm total flow.

Figure 24. TRN SYS Model Input Screen for Community Heat Pump Modeling

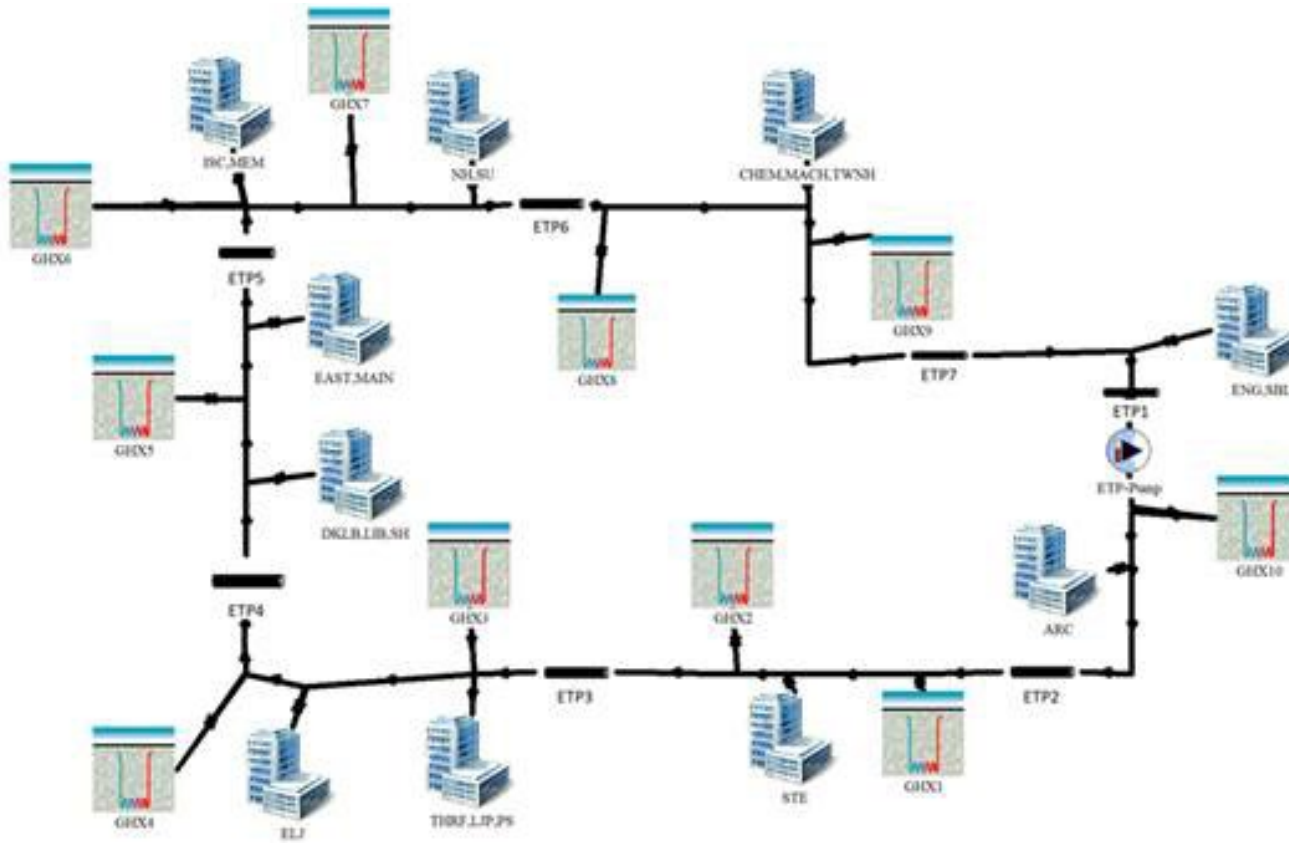


Figure 25. Hourly Building Entering Water Temperature from Loop Fields—ELJ

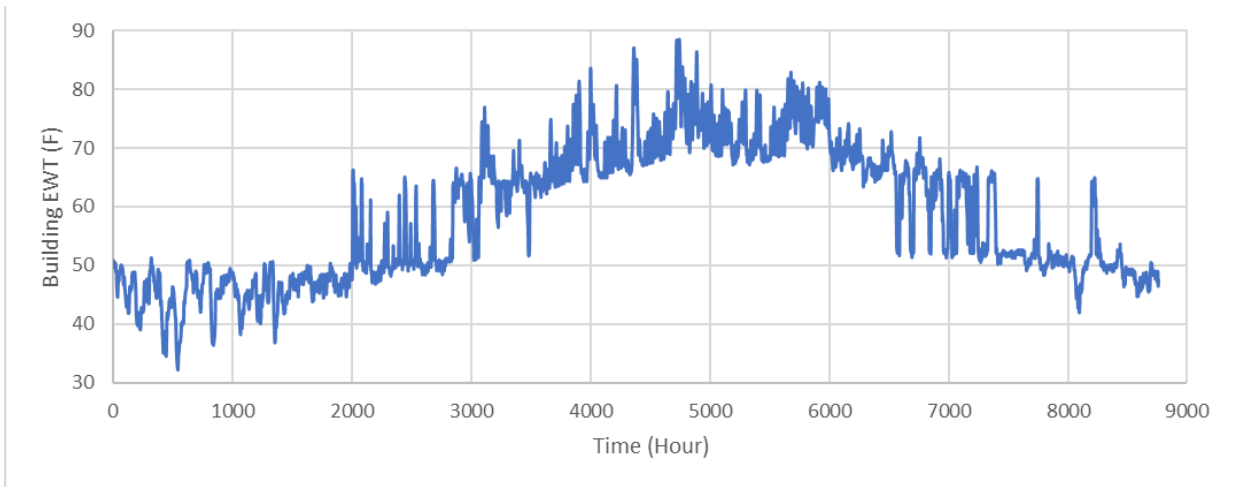
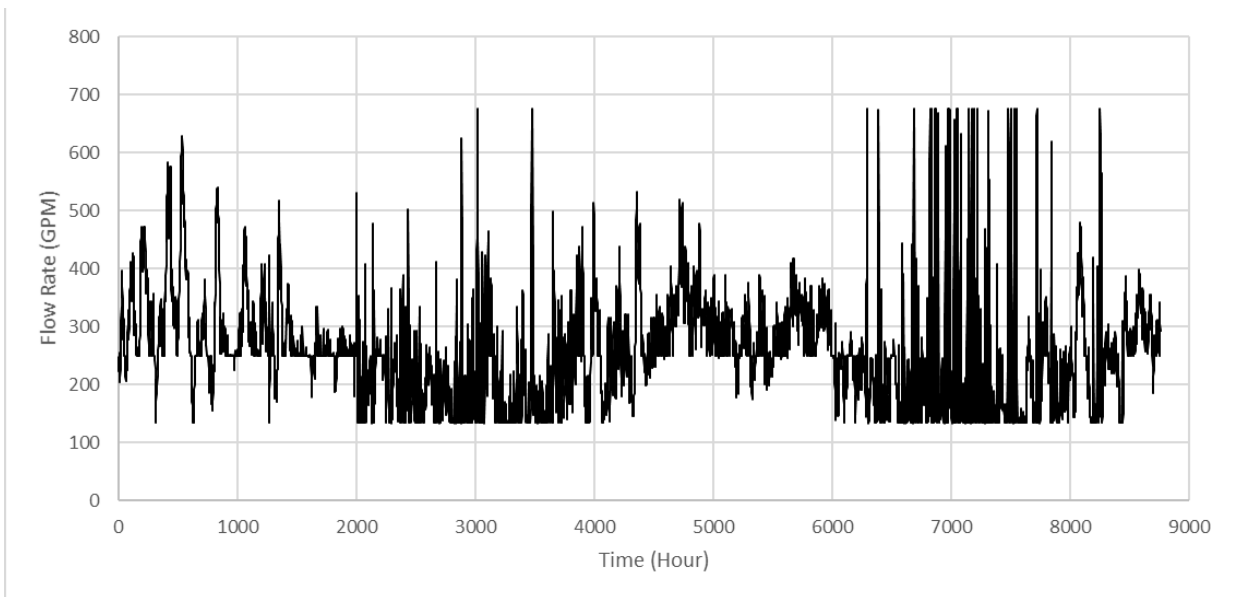


Figure 26. Hourly Pumping Flow Rate through ETP



4.6.3 Overview of Potential Open Loop and ATEs Options

Open loop geothermal systems can be used when an aquifer, well, or surface body water as the heat exchange fluid that moves through the geothermal heat pump system. Once the fluid moves through the system, the water returns back to the well through a discharge well or surface discharge. The option could be practical for applications with relatively clean water and if local codes/regulations permit.

The existing open loop wells (2 supply and 1 discharge) that were installed for ARC in the 1970s. This system has been inactive for many years as the discharge screen would clog with the high iron content in the water and is a concern for expanding the system at Pratt in the future. An open loop system with a renewal of the system at ARC as part of the open loop system could be used with a heat exchanger to interface with the ETP to moderate the closed loop system, but it would require attention and maintenance to clean the discharge screen regularly. An open loop system could be used instead of dry coolers, or it could be used to reduce peak and thus reduce the total number loops required. Assuming a peak flow of 250 gpm from the open loop, and if used to remove the dry coolers, the CHP Alt 4 field would be reduced by 45 loops from 558 loops to 513 loops. If used to reduce the peak load for CHP Alt 4, then 118 loops could be removed from 558 loops to 440 loops. Although the number of open loop wells need to be determined based on (1) the extent that Pratt would be willing to rely upon this system, which has failed in the past, and (2) the maintenance that it requires to insure its use in the future.

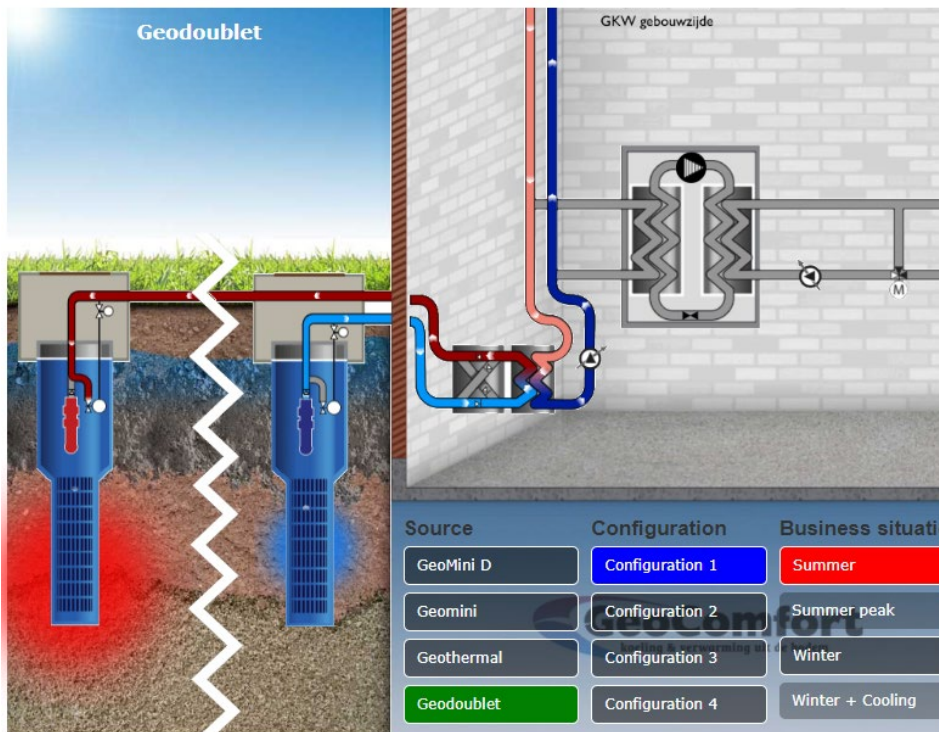
Aquifer thermal energy storage (ATES) is a technology like the open loop system. However, the system (shown in Figure 27) has a hot well and a cold well. These wells are kept pressurized to reduce the amount of sediment, debris, and mineral build up within the piping and the geothermal source loop. The system would require more investigation to move forward. For this analysis, the closed loop bore field systems will be evaluated as the prime source for the GSHP system due to the lower maintenance requirements and known performance over time. Due to the savings on reduced drilling on-campus, along with the reduced capital cost and impact to the grounds at Pratt a further investigation of the ATES may be warranted.

The ATES system does not “dovetail” nicely with the one-pipe source side approach that has been considered in this study effort. The one-pipe approach would merely be looking for the ATES (or open loop) to moderate the source temperatures back toward the 50–60 F range. The benefit of the ATES is maximized when direct cooling can be captured from the “cold” source/storage that is created in the heating season. The open loop will perform the function of moderating our one-pipe source loop far more economically than the ATES.

For the open loop, we would recommend a yield, discharge, and water quality tests, which are further detailed here:

- Yield Test
 - Purpose is to determine the yield, or maximum sustainable flow rate.
 - A constant flow rate pump (250-300 gpm) test for 24 hrs. be performed to confirm how much water can be produced. This test should be run on both wells simultaneously discharging into storm drainage system (if permitted). The flow rate at the end of the 24 hr. period will indicate the yield.
- Each injection well shall undergo a discharge rate test
 - Using the supply well(s) as a source of water to inject into injection wells and a means to vary the flow rate being injected into the injection wells.
 - Water level in each injection well should be monitored as flow rates are increased.
 - The flow rate associated with water levels reaching within 5 feet of the surface would define a maximum injection rate (with a 5 foot “safety factor”).
- Water Quality Tests
 - Perform a water quality test to understand if any special materials are required in the pumps, piping, and heat exchanger to be used in the system.
 - The testing should include total dissolved solids (TDS), specific minerals present, alkalinity, salinity as well as presence and type of bacteria.

Figure 27. Schematic of ATEs



4.7 Summary of Options for Techno-Economic Analysis

The following options are evaluated in the techno-economic analysis for this study effort:

- **Baseline**—For all buildings studied, the HVAC equipment and associated electrical infrastructure are upgraded to comply with current energy and building codes with conventional HVAC equipment. The baseline option includes central cooling (air-cooled chillers), heating (fin tube radiation with heating water generated by the steam system) and ventilation systems (central AHUs). The option also includes upgraded BMS to properly control heating and cooling within the building (i.e., eliminates overheating currently experienced from central steam system).
- **Option 1**—For all buildings studied, the HVAC equipment and associated electrical infrastructure are upgraded to comply with current building codes with conventional heat pump-based equipment. For most buildings studied, the HVAC equipment is VRF based equipment with air-cooled condensers (air to air heat pumps) except for Stabile, Steuben, Pratt Studios and Pantas. For those four buildings, those HVAC systems have distributed water source heat pumps (water to air heat pumps). No finned tube radiation is included in these approaches; however, ventilation is included. This option has no connections to a central ETP or the existing steam plant. It assumes small gas-fired condensing boilers for the supplemental heating and cooling towers for the four buildings equipped with water source heat pumps. Includes upgraded BMS to properly control heating and cooling within the building (i.e., eliminates overheating currently experienced from central steam system).
- **Option 2**—For all buildings studied, the HVAC equipment and associated electrical infrastructure are upgraded to comply with current building codes with VRF based equipment with water-cooled condensers coupled to the closed loop vertical borefields (numbers in Table 24). No finned tube radiation is included in these approaches; however, ventilation is included. This option has no connections to a central ETP or the existing steam plant. Includes upgraded BMS to properly control heating and cooling within the building (i.e., eliminates overheating currently experienced from central steam system).
- **Option 3**—This is a combination of CHP Alternative 1 for the Townhouses and ARC and the baseline HVAC equipment for the remaining buildings. This option includes the central ETP and the number of closed loop vertical borefields specified in Table 25 for CHP Alternative 1. The option still relies upon the existing steam plant for the baseline equipment. Includes upgraded BMS to properly control heating and cooling within the building (i.e., eliminates overheating currently experienced from central steam system).
- **Option 4**—This is a combination of CHP Alternative 2 for the Townhouses, ARC, Stabile, Steuben/Pratt Studios, DeKalb, and Pantas and the baseline HVAC equipment for the remaining buildings. This option includes the central ETP and the number of closed loop vertical borefields specified in Table 25 for CHP Alternative 2. The option still relies upon the existing steam plant for the baseline equipment; however, the steam plant will be able to operate at low pressure. Includes upgraded BMS to properly

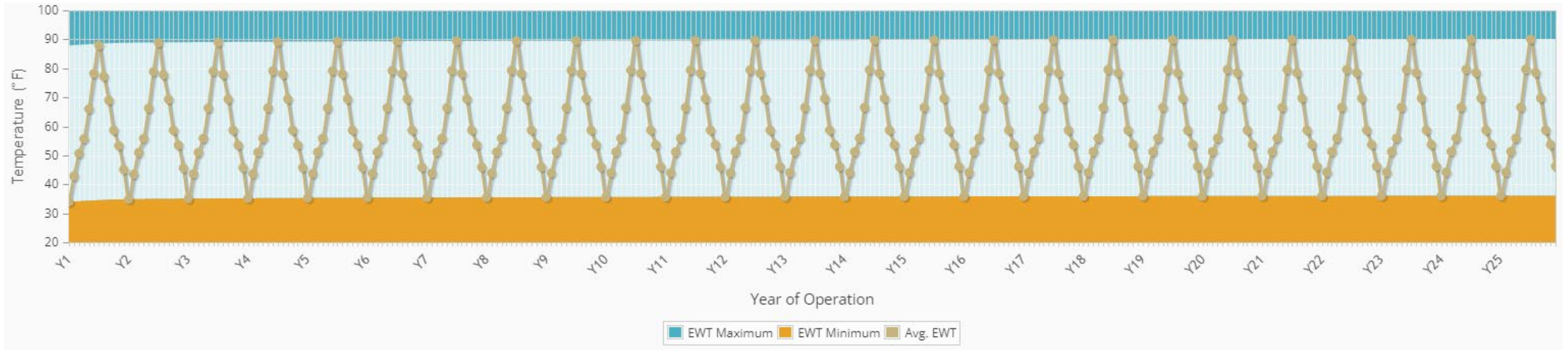
control heating and cooling within the building (i.e., eliminates overheating currently experienced from central steam system).

- **Option 4A**—This is a combination of CHP Alternative 2 for the Townhouses, ARC, Stabile, Steuben/Pratt Studios, DeKalb, and Pantas and the VRF air-source HVAC equipment for the remaining buildings. This option includes the central ETP and the number of closed loop vertical borefields specified in Table 25 for CHP Alternative 2. This option includes upgraded BMS to properly control heating and cooling within the building.
- **Option 5**—This is a combination of CHP Alternative 3 for the Townhouses, ARC, Stabile, Steuben/Pratt Studios, DeKalb, Pantas, Thrift, ISC, Library, Engineering, Machinery, and Chemistry and the baseline HVAC equipment for the remaining buildings. This option includes the central ETP and the number of closed loop vertical borefields specified in Table 25 for CHP Alternative 3. The option still relies upon the existing steam plant for the baseline equipment; however, the steam plant will be able to operate at low pressure. The option includes upgraded BMS to properly control heating and cooling within the building (i.e., eliminates overheating currently experienced from central steam system).
- **Option 6**—For all buildings studied, the HVAC equipment and associated electrical infrastructure are upgraded to comply with current building codes with VRF based equipment with water-cooled condensers coupled to the central ETP and the number of closed loop vertical borefields specified in Table 25 for CHP Alternative 4. The option includes upgraded BMS to properly control heating and cooling within the building.
- **Option 6A**—This option will modify Option 6 and reduce the number of vertical bores (number specified in Table 25 for CHP Alternative 4) by adding dry coolers to the energy transfer pipe to reject excess heat during the summer.

The peak building loads and the energy loads are greater in heating. But the loop field will see the imbalance as greater in cooling due to the heat pumps rejecting the building cooling load + compressor energy + pump energy (approximately 125% of the building load) to the ground. Whereas in heating the heat pump extracts about 75% of the building load from the ground and the compressor energy goes directly to the heat load.

The heat pump system in an average year will reject about 24,500,000 kBtu and extract about 18,840,000 kBtu each year. The loop field was modelled for 25 years with the same loads repeated every year. To balance the system either more heating load would need to be added to the system (DHW or process heating) or heat needs to be rejected during the shoulder seasons to reduce the amount energy in the system and therefore keep the temperatures lower to prevent build up to temperature in the system. The image in Figure 28 shows the temperature swing over the 25-year time frame without a dry cooler.

Figure 28. Simulated Ground Water Temperature for Proposed System over the 25-Year Project Life



4.8 Energy Requirements for Options

The additional pumping energy requirements for the geothermal options (Options 2 through 6) was estimated for the ETP, the loop fields and the buildings. The pump sizes and associated energy use for the loop fields, buildings and the ETP are shown in Figure 28, Table 26, and Table 27, respectively. The pumping energy requirements for the source water from the loop field is added to the individual building level GSHP system option and the community heat pump options. The pumping energy to the buildings (and the groups of buildings) were calculated based on the results of the TRNSYS analysis effort. The pumping energy for the ETP is only added for the community heat pump options.

Table 25. Loop Field Pumping Energy Requirements

Loop Field No.	Number of Loops	Max Flow, GPM	Max TDH	Pump Energy kWh
Option 2– GSHP	670	4,360	30	77,599
Option 3–CHP Alt 1	125	815	30	13,093
Option 4–CHP Alt 2	285	1,855	30	33,990
Option 4A– CHP Alt 2A	285	1,855	30	33,990
Option 5–CHP Alt 3	455	2,960	30	47,964
Option 6–CHP Alt 4	585	3,803	30	66,858
Option 6A– CHP Alt 4A	513	3,336	30	56,393

Table 26. Building Level Pumping Energy Requirements

Buildings	Max Flow, GPM	Max TDH	Pump Energy kWh
Thrift, Pantas, Pratt Studios	625	60	24,712
ELJ	180	60	7,312
DeKalb, Library, South	515	60	20,285
East, Main	565	60	25,115
ISC, Memorial	275	60	10,849
North, Student Union	575	60	25,462
Chemistry, Machinery, Townhouses	675	60	24,742
Engineering, Stabile	540	60	24,114
ARC	625	60	26,917
Steuben	465	60	19,857
Total	5,040		209,364

Table 27. ETP Pumping Energy Requirements

Buildings	Max Flow, GPM	Max TDH	Pump Energy kWh
ETP–All Buildings	675	45	18,433

The project analyzes in the next section the life-cycle cost for the various options from the baseline configuration, the conventional heat pump configuration, the individual building geothermal heat pump configuration, and the four community heat pump alternatives. The resulting energy requirements provided earlier in this section are summarized for the reader in Table 28 (electric use broken down by heating, cooling, and pumping in Table 29). These energy requirements are limited to the chiller/heat pump input energy requirements, the building pumping, geothermal loop field pumping (including the ETP if applicable), and boiler fuel input (for space heating).

Table 28. Summary of Energy Requirements for Heat Pump Options

Option Name	Electricity Use in kWh	Natural Gas Use in MMBtu	Total Energy Use in MMBtu	Energy Cost in Dollars
Baseline	1,980,474	42,261	49,018	\$731,282
Option 1 – ASHP / WSHP	3,053,453	2,077	12,495	\$597,603
Option 2 – GSHP	2,935,503	0	10,016	\$557,746
Option 3 – CHP Alt 1	2,202,387	34,486	42,001	\$708,136
Option 4 – CHP Alt 2	2,423,998	18,858	27,129	\$618,967
Option 4A – CHP Alt 2 / ASHP Hybrid	2,953,794	0	10,078	\$561,221
Option 5 – CHP Alt 3	2,666,132	10,692	19,789	\$596,378
Option 6 – CHP Alt 4	2,943,194	0	10,042	\$559,207
Option 6A – CHP Alt 4A	2,973,651	0	10,146	\$564,994

Table 29. Supporting Electric Energy Data for Heat Pump Options

Option Name	Total Electricity Use in kWh	Heating Electric Use in kWh	Cooling Electric Use in kWh	Pumping Electric Use in kWh
Baseline	1,980,474	0	1,789,304	191,170
Option 1 – ASHP / WSHP	3,053,453	1,911,921	1,088,822	52,710
Option 2 – GSHP	2,935,503	1,934,887	713,653	286,963
Option 3 – CHP Alt 1	2,202,387	374,171	1,580,504	247,712
Option 4 – CHP Alt 2	2,423,998	884,186	1,285,544	254,268
Option 4A – CHP Alt 2 / ASHP Hybrid	2,953,794	2,030,065	819,678	104,051
Option 5 – CHP Alt 3	2,666,132	1,376,249	1,008,779	281,104
Option 6 – CHP Alt 4	2,943,194	1,934,887	713,653	294,654
Option 6A – CHP Alt 4A	2,973,651	1,934,887	754,574	284,190

4.9 Required Infrastructure Upgrades

Additional detail including the peak electric demand for heating and cooling HVAC loads, the peak electric demand for non-HVAC loads, and the total coincident peak demand are provided in Table 30. To keep the peak electric demand detail in Table 30 succinct, only the existing, option 1 (ASHP/WSHP) and option 2 (GSHP) are featured. Option 1 represents the highest peak electric demand, while option 2 represents the peak demand with the advantage the GSHPs offer as opposed to the ASHPs. Options 3, 4, and 5 represent a mixture of the baseline equipment with the proposed equipment and would therefore have electric peak demand values that would fall somewhere in the middle of option 1 and 2. Option 6 would have a peak demand similar to Option 2. Option 4A would have peak demands that would fall in between option 1 and 2.

Table 30. Summary of Peak Electric Demands for Options

Option Name	Peak Electric Demand for Heating HVAC Loads in kW	Peak Electric Demand for Cooling HVAC Loads in kW	Peak Electric Demand for Non-HVAC Loads in kW	Total Coincident Peak Demand in kW
Existing	0 ²⁸	640	1,718	2,338
Option 1–ASHP/ WSHP	2,473	1,754	1,718	4,191
Option 2–GSHP	1,935	1,669	1,718	3,654

Based on the analysis, the projected peak loads for the metered connections are provided in Table 31 for the winter with either ASHPs or GSHPs. The projected peaks are estimated by adding the peak heating input from the compressors at the winter design temperatures to the existing winter peak demands provided to ANTARES by Pratt. Based on the modeling estimates and the results in Table 30, winter peak loads are expected to be higher than the summer peak loads. The additional load for the campus will increase from 113% to 144% for the GSHP and conventional ASHP approaches respectively.

As shown in Table 31, the connections at DeKalb and Machinery (shown in bold italics) will need upgrading to a higher amperage and new switchgear / panelboards and connections for the new heat pump equipment. The connections at Thrift, Steuben, and North Hall (shown in underline italics) will need new switchgear/panelboards and connections to accommodate the new heat pump equipment. The potential additional demand for these buildings has been requested from ConEd to ensure that the power is available from the utility to meet these

future potential electric loads. Load letters have been issued to obtain answers that were not readily provided for this study effort. A potential configuration for a single metered service to the campus along with a new Pratt-owned substation and medium voltage distribution has been developed.

Table 31. Proposed Peak Demands for Metered Services

Metered Connection	Existing Winter Peak kW	Additional Load, ASHP, kW	Additional Load, GSHP, kW	Projected Winter Peak kW (ASHP)	Projected Winter Peak kW (GSHP)
193 Ryerson	676	1,266	836	1,942	1,513
<i>North Hall</i>	<u>390</u>	<u>846</u>	<u>559</u>	<u>1,237</u>	<u>949</u>
ISC Building	47	88	58	134	105
Library	101	137	90	238	191
DeKalb	43	83	55	126	97
<i>Thrift</i>	<u>96</u>	<u>113</u>	<u>74</u>	<u>208</u>	<u>170</u>
Machinery	217	408	269	625	486
Pantas	59	29	52	89	111
Pratt Studios	112	87	153	199	265
<i>Steuben Hall</i>	<u>168</u>	<u>99</u>	<u>175</u>	<u>267</u>	<u>343</u>
ARC	304	381	252	685	556
Stabile	132	17	75	149	207
Total	1,718	2,473	1,935	4,191	3,654

The connections for the Townhouses were not listed in Table 31; however, those electrical services for the Steuben and Willoughby Townhouses will likely need to be aggregated in a similar manner as was done for the Emerson Townhouses. The existing connections, shown in kVA, within Table 31 were calculated based on the main breaker size on the service to each building. The actual transformers serving these locations are owned by ConEd and were not provided as of the issuance of this report. Conversations have been initiated with ConEd to state these increased electrical demands to understand what limitations, if any, are on the local grid for Pratt to electrify their heating loads using heat pumps. An electric load letter for a single-metered approach will be provided to ConEd for electrifying the campus. ConEd was unresponsive to any planning conversations that would have been helpful in the development of the study effort.

A schematic campus one-line has been generated for Pratt to consider that will have a single metered service with ConEd. The single metered service that would cost an additional \$7.75 million to aggregate the multiple buildings into a single account where Pratt would own medium voltage infrastructure to be routed around the campus. The infrastructure considers the potential future incorporation of on-site renewable energy generation through solar photovoltaics, energy storage, and electric vehicle charging stations on campus. The single metered service is not included in the life-cycle cost analysis for the heat pump options as this would be an improvement for the facility that should be considered regardless of heat pump adoption or not. The single metered service may provide a reduced electric rate through ConEd on a potential high-tension service; however, that is not analyzed in this study effort as ConEd was not responsive to multiple attempts to discuss this project. This aggregated electrical service is a campus-wide facility upgrade that should be considered for the future and sized for heat pump adoption/campus electrification.

4.10 Regulator/Legal/Environmental Issues

The proposed project is assumed to be subject to NYS DEC regulations for drilling within the top 500 feet below the surface. As the pipes do not cross any property boundaries, the project is assumed not to be subject to any legal issues. As the ETP and the borefields will be carrying water without glycol, there are no issues with spillage of glycol into the local groundwater supply. The existing open-well system tied to the aquifer below the ARC building may be rejuvenated to temper the loop temperature in the future, and it is not expected that the project will extract aquifer water and dump that water into the either New York City storm water or sewage systems.

5 Economic Analysis

Using the energy requirements on the various options evaluated, ANTARES has performed a detailed review of the project’s estimated cost savings compared to the existing utility consumption, projected capital costs required to implement the project, and overall lifecycle cost analysis (LCCA). The life-cycle analysis considers that the existing mechanical equipment on campus will likely need upgrades or improvements within the lifespan of a new heat pump system, supplying the campus with additional economic benefits over the status quo. The life-cycle cost analysis (LCCA) assumes direct financing of the in-building equipment and the geothermal borefields/equipment. A third-party ownership of the borefield was not evaluated in this analysis. As the projects are to be built, owned, and operated by Pratt, no contractual relationship between external organizations was evaluated in this study.

5.1 Estimated Energy Costs and GHG Emissions

The energy costs from the baseline system and the various heat pump options are provided in Table 33. Electricity and natural gas costs were estimated at \$0.19 per kWh and \$0.84 per therm respectively. A rate tariff analysis was not conducted for this study effort.

Table 32. Energy Costs for the Baseline and Heat Pump Options

Option Name	Electricity Cost, \$/YR	Natural Gas Cost, \$/YR	Energy Cost, \$/YR
Baseline	\$376,290	\$354,992	\$731,282
Option 1 – ASHP / WSHP	\$580,156	\$17,447	\$597,603
Option 2 – GSHP	\$557,746	\$0	\$557,746
Option 3 – CHP Alt 1	\$418,454	\$289,682	\$708,136
Option 4 – CHP Alt 2	\$460,560	\$158,407	\$618,967
Option 4a – CHP Alt 2 + ASHP Hybrid	\$561,221	\$0	\$561,221
Option 5 – CHP Alt 3	\$506,565	\$89,813	\$596,378
Option 6 – CHP Alt 4	\$559,207	\$0	\$559,207
Option 6A – CHP Alt 4A	\$564,994	\$0	\$564,994

The GHG emissions that result from the baseline system and the heat pump options are provided in Table 34. The GHG emissions are based on the metrics provided within Local Law 97 of 2019 (LL97) and the estimated energy use for the systems discussed in section 4. GHG emissions have a cost of \$268 per ton per LL97 and are included in the life-cycle cost analysis starting in 2030, which assumes that Pratt is in compliance with LL97 between 2024 and 2029.

Table 33. GHG Emissions—Various Heating and Cooling Systems

Option	GHG Emissions MT CO _{2e}
Existing	3,229
Baseline	2,817
Option 1—Conventional Heat Pump –ASHP/WSHP	993
Option 2—GSHP—Individual Buildings	848
Option 3—CHP Alt 1	2,468
Option 4—CHP Alt 2	1,702
Option 4A—CHP Alt 2 / ASHP Hybrid	854
Option 5—CHP Alt 3	1,338
Option 6—CHP Alt 4	850
Option 6A—CHP Alt 4A	859

5.2 Estimated Project Capital Costs

This section will review the estimated project costs for the selected heat pump configurations. It will include HVAC material and labor costs, as well as any applications/permits and infrastructure upgrades that will be needed for the installation. Table 35 provides the baseline capital cost estimated by ANTARES using RSMeans cost per square foot data. Capital costs were estimated on a cost per square foot basis using the energy supply, cooling generating systems, distribution systems, and electrical service/distribution RSMeans data. Gathered square footage of the buildings was used with the cost per square foot data to estimate the total cost for each building.

Table 34. Baseline Estimated Mechanical and Electric Costs for Pratt Buildings

Building Name	Total Cost \$/ft²	Total Cost \$
Townhouse	55	\$4,645,800
ARC	91	\$10,387,800
Stabile	41	\$3,253,800
Engineering	104	\$6,090,000
Machinery	104	\$3,775,800
Chemistry	112	\$3,027,600
Main	100	\$5,272,200
South	112	\$1,792,200
East	99	\$5,307,000
ISC	114	\$2,992,800
Library	94	\$5,341,800
Dekalb	125	\$3,010,200
ELJ	43	\$1,914,000
Thrift	124	\$1,131,000
Pantas	41	\$2,749,200
Steuben	97	\$11,066,400
Pratt Studios	95	\$7,516,800
North	96	\$6,420,600
Student Union	136	\$1,600,800
Memorial Hall	118	\$2,192,400
Total All Buildings		\$89,488,200

The capital costs for the heat pump alternatives within the buildings were based on a dollars per square foot cost for a VRF-based heat pump project for the mechanical infrastructure. The build-up of the mechanical costs were based on a cost estimated for a NYC-based project for another higher education facility. The mechanical portion of the cost for the VRF-based heat pump project was estimated at approximately \$76 per square foot. The electrical portion of the cost for the project was assumed to be equal to the in-building costs estimated in the baseline option developed by Sightlines.

The line-item cost estimate for the VRF based project included direct costs (\$44.59 per sq. ft.) and indirect cost (\$32.02 per sq. ft.). The cost estimate includes HVAC equipment (fan coils, condensing units, refrigerant piping, dedicated outside air systems, ductwork, and refrigerant line controllers); plumbing; controls; structural; and rigging. The cost estimate includes indirect costs (engineering, contractor overhead and profit, subcontractor bonding, general conditions, and insurance) and contingency.

The in-building heat pump projects for the geothermal and air source heat pumps were estimated at \$76 per square foot, with the exception of the Townhouses, which was estimated at \$20 per square foot due to the smaller equipment and scale of project. The water source heat pumps projects (Stabile, Steuben, Pratt Studios, and Pantas) were estimated at \$60 per square foot, which assumed a re-use of the existing hydronic systems for those buildings. The geothermal projects included the cost of the vertical bore fields at \$25,000 per 500 ft borehole. The energy transfer pipe and central pump station was estimated at \$670,000, which assumed about 2400 linear feet of 8 inch HDPE pipe. Each building connection was assumed to be \$50,000 to connect the bore field(s) and the building equipment.

The project costs for the campus options are estimated below by option in Table 35. The in-building project costs for integrating heat pumps were 18% lower than the baseline conversion costs for ARC. The costs for integrating heat pumps within the buildings at Stabile, Steuben, Pratt Studios, and Pantas were between 2% and 4% lower, but most heat pump conversion costs within the building were 14% to 22% higher.

Table 35. Capital Cost Summary—Heat Pump Options

Option Name	In-Building Mechanical Cost, \$MM	In-Building Electrical Cost, \$MM	Geothermal Field Cost, \$MM	Total Cost, \$MM
Baseline	\$84.3	\$5.2	\$0	\$89.5
Option 1—ASHP/WSHP	\$79.8	\$15.6	\$0	\$95.5
Option 2—GSHP	\$79.8	\$15.6	\$18.8	\$114.3
Option 3—CHP Alt 1	\$85.1	\$6.4	\$3.7	\$95.2
Option 4—CHP Alt 2	\$90.7	\$6.6	\$8.0	\$105.3
Option 4a—CHP Alt 2 Hybrid	\$79.8	\$15.6	\$8.0	\$102.7
Option 5—CHP Alt 3	\$83.6	\$13.5	\$12.2	\$109.3
Option 6—CHP Alt 4	\$79.8	\$15.6	\$15.7	\$111.2
Option 6A—CHP Alt 4A	\$79.8	\$15.6	\$14.5	\$110.0

5.3 Life-Cycle Cost Analysis

The LCCA is used to compare the total cost of each scenario over a 25-year period, based on the inputs and assumptions for costs and savings associated with each option. The results are based on sections 6.1 and 6.2 for both the heat pump options and baseline systems.

The general analysis inputs which are the same for all options are summarized in Table 37 included in this report. These values are the base inputs, some of which will be varied in sensitivity analyses to determine the impact of the assumptions on analysis results.

Table 36. General Analysis Inputs

Discount Rate	5%
Project Life (years)	25
Electricity Escalation Rate	3.5%
Natural Gas Escalation Rate	10.0%
O&M Escalation Rate	2.5%
Inflation Rate	2.1%

For the life-cycle cost analysis, the baseline and options 1 through 6A assumed that the projects were design in 2022, financed in 2023, and GHG savings were realized in 2030.

Other inputs vary for each option, particularly the initial investment and energy costs. The operation and maintenance (O&M) cost is based on cost allocated to boiler and chiller plant maintenance. The energy cost is varied based on energy usage, which is calculated based on the existing annual energy consumption values and the energy savings for each option. These assumptions were used for the analysis:

- The boiler plant maintenance cost is based upon the annual steam output of the plant and an assumed cost of \$5 per 1,000 pounds of steam produced for consumables (chemicals, make up water) and system maintenance.
- The boiler plant operations cost for plant engineers with a high-pressure steam plant is estimated at \$248,000 per year. The cost for watch engineers for a low-pressure steam plant is estimated at \$173,000 per year.
- The chiller plant maintenance cost is estimated at \$0.05 per ton-hour.
- The heat pump maintenance cost is estimated at \$0.10 per ton-hour, which assumes year-round compressor use.

Table 37. Initial Investment Costs and O&M Costs for Each Option

	Baseline	Option 1	Option 2	Option 3	Option 4	Option 4A	Option 5	Option 6	Option 6A
Total Initial Investment	\$89,488,200	\$95,500,000	\$114,340,000	\$95,263,600	\$105,337,200	\$102,720,000	\$109,275,200	\$111,210,000	\$110,010,000
Annual O&M Costs, Year 1									
Boiler Plant Maintenance	\$121,710	\$0	\$0	\$99,320	\$65,800	\$0	\$32,715	\$0	\$0
Boiler Operations	\$248,000	\$0	\$0	\$248,000	\$173,000	\$0	\$173,000	\$0	\$0
Chiller Plant Maintenance	\$81,333	\$0	\$0	\$65,750	\$42,450	\$0	\$21,092	\$0	\$0
Other O&M, heat pump systems	\$0	\$162,667	\$162,667	\$31,167	\$77,767	\$162,667	\$120,483	\$162,667	\$162,667
Total O&M	\$451,043	\$162,667	\$162,667	\$444,237	\$359,017	\$162,667	\$347,290	\$162,667	\$162,667
Energy Costs, Year 1									
Electric costs	\$376,290	\$580,156	\$557,746	\$418,454	\$460,560	\$561,221	\$506,565	\$559,207	\$564,994
Gas costs	\$354,994	\$17,447	\$0	\$289,682	\$158,407	\$0	\$89,813	\$0	\$0

The 25-year LCCA results for the status quo scenario and each option considered are shown in Table 38. Based on the inputs and assumptions described previously, option 1 has the lowest life-cycle cost. The next three lowest cost options ranked in Table 39 are options 4A, 4, and 3 respectively. However, in terms of electric energy use, the results show that all options yielded increased average electricity consumption compared to the status quo, leading to the negative savings shown in Table 38. With respect to percent fuel savings, all options yielded positive energy savings compared to the status quo. Since both option 2 and option 6 are geothermal heat pump selections for all buildings at Pratt, they have the most fossil fuel energy savings at 100% each. Option 4A also provides 100% fossil fuel energy savings. Option 1 provides 95% fossil fuel savings, as some natural gas use is needed for the water source heat pump systems for Pantas, Stabile, Steuben, and Pratt Studios.

Table 38. LCCA Results by Scenario

Scenario	Total Present Value	Rank	Average Annual Energy Use		% Savings	
			kWh	MMBtu	electric	fuel
Baseline	\$125,762,000	7	1,980,474	42,261	0%	0%
Option 1	\$110,804,000	1	3,053,453	2,077	-54%	95%
Option 2	\$128,518,000	8	2,935,503	0	-48%	100%
Option 3	\$122,932,000	3	2,202,387	34,486	-11%	18%
Option 4	\$123,679,000	4	2,423,998	18,858	-22%	55%
Option 4A	\$120,523,000	2	2,953,794	0	-49%	100%
Option 5	\$129,238,000	9	2,666,132	10,692	-35%	75%
Option 6	\$125,415,000	6	2,943,194	0	-49%	100%
Option 6A	\$124,333,000	5	2,973,651	0	-50%	100%

A sensitivity analysis was performed to determine the impact of varying key inputs on LCCA results. This included evaluating different values for discount rate, electric escalation rate, and natural gas escalation rate based on the table under Table 40. For the analysis, each factor was varied individually, holding the other factors constant at the base rate to evaluate the specific impact of each variable.

Table 39. Input Factors for Sensitivity Analysis

	Base	Low	High
Discount Rate	5.0%	4.0%	10.0%
Electric Escalation Rate	3.5%	1.7%	4.2%
Natural Gas Escalation Rate	9.0%	2.5%	10.0%

The discount rates included in the analysis covers the range of reasonable potential values. For the natural gas escalation rates, the low value is based on historical natural gas escalation rate for commercial prices in New York State over a 25-year period (data from the U.S. Energy Information Administration [U.S. EIA]). The high value is based on the projected escalation rate from the U.S. Department of Energy Escalation Rate Calculator for commercial prices in the State with high carbon price policy in place. For electric escalation rates, the low value is based on historical electric rate for commercial prices in NYS over a 25-year period using data from U.S. EIA, similar to the method applied for the low natural gas rate. The high value is based on historical electric rate for U.S. average commercial prices over a 25-year period, again using data from U.S. EIA.

The sensitivity analysis results are shown below. Table 41 shows the calculated present value for each scenario and input variation. A color-coded and numbered ranking for each combination is shown in Table 42. As the Tables indicate, option 1 ranked best for both natural and electric escalation rates (high and low), while ranking first and third for the low and high discount rate, respectively. This was followed by option 4A, which ranked second in most scenarios, and option 4, which ranked third. Conversely, the baseline had the lowest rank in most scenarios as shown in Table 42. The results of the LCCA analysis indicate that option 1 has the best present value based on the relatively lower initial investment than the geothermal options and overall O&M cost.

Table 40. Sensitivity Analysis Results (Total Present Value)

Scenario	Base	Discount Rate		Electric Escalation Rate		Low	High
		Low	High	Low	High		
Baseline	\$125,762,000	\$130,890,000	\$109,810,000	\$124,456,000	\$126,370,000	\$118,467,000	\$127,658,000
Option 1	\$110,804,000	\$112,751,000	\$104,632,000	\$108,785,000	\$111,742,000	\$110,445,000	\$110,895,000
Option 2	\$128,518,000	\$130,304,000	\$122,848,000	\$126,580,000	\$129,418,000	\$128,518,000	\$128,518,000
Option 3	\$122,932,000	\$126,727,000	\$111,122,000	\$121,474,000	\$123,609,000	\$116,977,000	\$124,475,000
Option 4	\$123,679,000	\$126,178,000	\$115,908,000	\$122,082,000	\$124,423,000	\$120,427,000	\$124,526,000
Option 4A	\$120,523,000	\$122,751,000	\$113,440,000	\$118,568,000	\$121,427,000	\$120,523,000	\$120,523,000
Option 5	\$129,238,000	\$131,839,000	\$121,039,000	\$127,476,000	\$130,053,000	\$127,390,000	\$129,715,000
Option 6	\$125,415,000	\$127,206,000	\$119,731,000	\$123,472,000	\$126,320,000	\$125,415,000	\$125,415,000
Option 6A	\$124,333,000	\$126,138,000	\$118,606,000	\$122,370,000	\$125,245,000	\$124,333,000	\$124,333,000

Table 41. Ranking of Sensitivity Analysis Results

Scenario	Base	Discount Rate		Electric Escalation Rate		Natural gas Escalation Rate	
		Low	High	Low	High	Low	High
Status Quo	7	8	2	7	7	3	7
Option 1	1	1	1	1	1	1	1
Option 2	8	7	9	8	8	9	8
Option 3	3	5	3	3	3	2	4
Option 4	4	4	5	4	4	4	5
Option 4A	2	2	4	2	2	5	2
Option 5	9	9	8	9	9	8	9
Option 6	6	6	7	6	6	7	6
Option 6A	5	3	6	5	5	6	3

Note: Color Gradient works like this: lowest present value in green, and highest gradients go up to red

6 Solar Photovoltaics Analysis and Electric Vehicle Charging

This section provides an analysis of the potential project value improvement and techno-economic feasibility of integrating solar photovoltaics (PV) and electric vehicle charging capabilities at the Pratt Institute. The first section discusses the potential for solar PV and is followed by a discussion on electric vehicle charging.

6.1 Solar PV Potential

An analysis on the addition of solar photovoltaic (PV) technology as a method of on-site renewable electric energy generation and storage for the Pratt Institute was conducted. The HelioScope solar sales software was used to complete this analysis. It is important to note that the trees throughout the campus have the potential to shade the PV system in the preliminary layout. Shading losses were considered in the simulation with an estimated height of the trees. The actual tree height would be required at a later stage to update the estimated production.

Figure 29. Buildings Providing Shade to South Campus for PV



As shown in Figure 29, three large buildings each about 25 stories high are located to the south across the DeKalb Avenue. These buildings introduce a heavy layer of shade to the rooftops of Pratt Studios, Steuben, Pantas, ELJ, Thrift, and DeKalb during the peak sun hours. Therefore, rooftop solar PV was not considered for those buildings. ARC was not considered due to the unique roof structure of the building and the potential shading introduced by the 25 story buildings across DeKalb Avenue.

The rooftops for the library was filled with HVAC and other equipment that would prohibit solar PV from being installed. Shading from nearby trees would limit the production of solar PV for ISC, Chemistry, and the south end of Machinery. The rooftops on East, Memorial Hall, and Student Union were also excluded in the preliminary layout since they are shaded by a taller adjacent roof and the stack from the central heating plant. Main Building roof was considered too small for the assessment.

The rooftops for the Townhouses (Willoughby, Steuben, and Emerson) can be used for the Solar PV system. However, these rooftops individually do not have enough PV array space with applicable code setbacks from the ridge and side edges for a conventional string inverter. If those roofs want to be utilized for the PV system, micro inverters will need to be used.

The parking lots north of the Chemistry building for the main visitor entrance and east of Stable were also heavily shaded by the adjacent buildings and trees for most of the day. Therefore, parking lot canopy solar PV was not considered in this analysis.

These remaining buildings were considered for a total of 141.8 kW_{DC} of rooftop solar PV:

- North Hall (67.5 kW)
- South Hall (22.5 kW)
- Engineering (33.3 kW)
- Machinery (18.5 kW)

These four solar PV rooftop applications could provide an annual total energy generation of 182,318 kWh that would be consumed by the buildings. The monthly kWh energy production is provided in Figure 30. A breakdown of the components in this analysis is listed in Table 43.

Figure 30. Energy Generation by Month for Solar PV Analysis

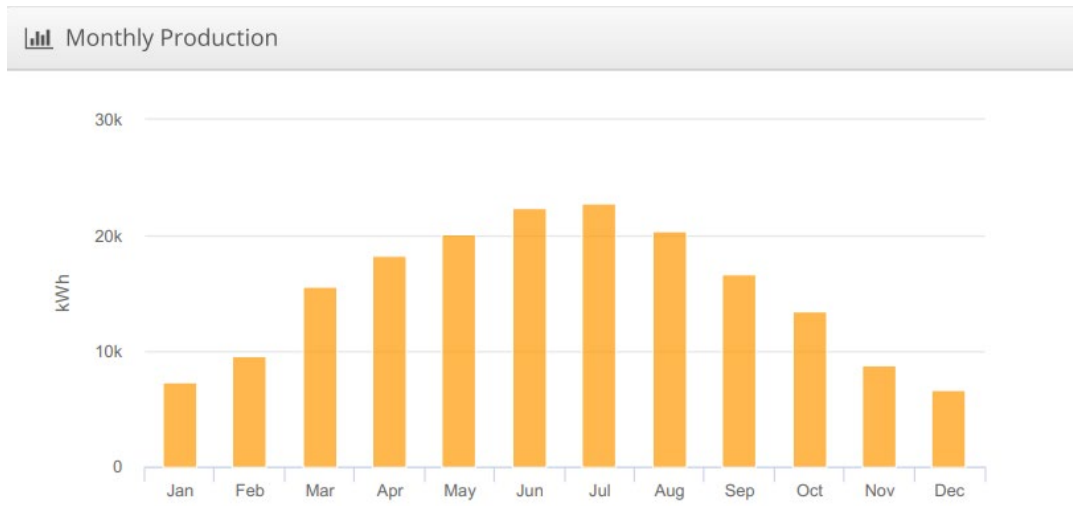


Table 42. Components for Solar PV Analysis

Component	Name	Quantity	Wattage (kW)
Inverters	SE9KUS (Solar Edge)	3	27.0
Inverters	SE17.3KUS (Solar Edge)	5	86.5
Strings	10 AWG (Copper)	25	1,746.7
Optimizers	P485 (Solar Edge)	74	35.9
Optimizers	P1100 (Solar Edge)	124	136.4
Module	Canadian Solar, CS3W-450MS (450W)	315	141.8

6.2 EV Charging Potential

The potential for EV charging on the campus was considered for the main visitor parking lot north of Chemistry and the overflow lot east of Stabile Hall. The lots have 37 and 90+ parking spaces in the respective lots. Of these spaces, the 15 parking spaces closest to Chemistry and 36 spaces closest to Stabile were considered for EV charging stations. The spaces that would require trenching across the paved surfaces were not considered.

Level 2 non-networked charging stations were considered for these parking spaces. Level 1 and 3 charging stations were not considered. Level 1 stations provide a minimal amount of power (between 3.5 miles and 6.5 miles per hour of charging) and are best suited for emergency or backup purposes. Level 3 stations (also referred to as DC fast chargers) provide about 100+ miles of battery charge in 30 minutes. The non-networked charging stations were proposed as these don't require an internet connection and are less costly to purchase and maintain.

The total charging requirement for these EV chargers is listed in Table 44. Based on the current electrical infrastructure for the Chemistry Building, it is not recommended that all 15 spaces be connected to the building until those electrical distribution issues are addressed. However, a couple spaces could be installed for the moment. As adequate power is available at Stabile, the EV charging stations for some spots near Stabile could be considered for the first adoption of the EV chargers. Dual charging stations (similar to the ClipperCreek HCS-D unit) are assumed for the application where two cars can be charged simultaneously. The charging station will charge one vehicle at a full 32A or 40A, or two cars at 16A or 20A by automatically splitting the power.

Table 43. EV Charging Requirements for Parking Lots

	Total Spaces	Volts/Amps per Space	Total Power (kW) Connected/Expected Peak
Chemistry Lot	15	240 / 40	144 / 72
Stabile Lot	36	240 / 40	346 / 173
Per Space	1	240 / 40	9.6 / 7.2

6.3 Summary for Solar PV and EV Charging

The rooftop solar PV projects are estimated to cost about \$2.30 per installed DC watt or \$326,000 for the four buildings. The project may be able to generate the interest of someone doing a power purchase agreement (PPA) where these projects are built and operated by a third-party for a 15- or 20-year life. The economics below are based on a self-financed project, which provides a payback period under 10 years for the project based on the current rate of \$0.19 per kWh.

Annual Electric Generation	182,318 kWh
Project Cost	\$326,000
GHG Savings	52 MT CO _{2e}
Project Payback	9.5 years

As the solar PV projects are all less than 50 kW_{AC}, the interconnection process would follow the Small DC Application process set forth by ConEd. Given the lack of response by ConEd on the available power for the heat pump feasibility until they see a load letter, ConEd will not likely provide any specific information until an actual project application and interconnection is submitted to ConEd. No interconnection issues are apparent from Antares' point of view for these rooftop solar PV projects.

Each dual charging station has a retail cost of approximately \$1850 with the pedestal mounting kit; however, the cost for running the wire from the building to the parking lot is an additional \$7,000. The total estimated cost is approximately \$9,000 per dual charger. With the current EV Make-Ready Program, the charging stations could be cost-shared by ConEd²⁹ by 50%.

The EV charging has the potential to reduce Scope 3 GHG emissions; however, those are not included in LL97-2019. The electric use for the campus will increase through the EV chargers and the project will provide a benefit to visitors and employees at Pratt.

7 Lessons Learned, Recommendations, and Next Steps

7.1 Lessons Learned

The following lessons learned were gathered through this feasibility study:

- The peak electrical demand for campus will shift from the summer to the winter with the adoption of heat pumps across the 20 buildings studied in this report.
- The ground source heat pump system will reduce the overall peak electric demand compared to the air source heat pump system (4,191 kW vs 3,654 kW).
- Air source heat pumps provide a significant savings over the ground source heat pump and community heat pump systems.
- Community heat pump systems do provide an economic benefit over the individual ground source heat pump systems by building. This particular example shows about a \$3 million decrease in the 25-year life-cycle cost between the two options due to 140 less vertical bores at 500 feet would be required (725 versus 585).
- The best performing community heat pump system option focuses on select buildings in the south and east portion of the campus that will allow the new steam plant to operate at low pressure (<15 psig). When additional buildings are added to the community heat pump (option 3 and 4), those options do not provide additional life-cycle cost savings. The bulk of the economic savings are tied to reducing the campus' demand for reducing high-pressure steam and operating the system on low pressure (<15 psig).
- Due to the significant capital outlay required to install the community heat pump, it may be wise to recruit a design-build engineer/contractor to move forward with a category B application under NYSERDA PON 4614. The team should evaluate the economics for Pratt to purchase the thermal energy over time from the contractor in the category B application. Also, the category B application should compare implementation of a community heat pump system against other lower cost options presented to Pratt to reduce steam system pressure.

7.2 Recommendations

Based on the techno-economic analysis results and discussions with Pratt, ANTARES recommends that heat pumps be further pursued for the campus. Specifically, option 4A should be studied further in a subsequent PON 4614 category B application, which would be developing design development drawings for the infrastructure of a community heat pump loop to meet the future needs for ARC, Townhouses, Stable, Steuben, Pratt Studios, Pantas, and DeKalb. It will further develop capital costing for these buildings for the in-building costs

(both mechanical and electrical) and the geothermal system costs (for the loopfields, ETP, and integration of the existing open well system). Option 4A provides flexibility for the campus to expand geothermal to the campus later or install air source heat pump-based mechanical systems to the campus for the future. With any roadmap or long-term planning effort, Pratt should keep flexibility where possible and not be tied to any one technology.

In addition to further developing the community heat pump loop for the seven buildings on east and south campus, ANTARES recommends that Pratt do the following:

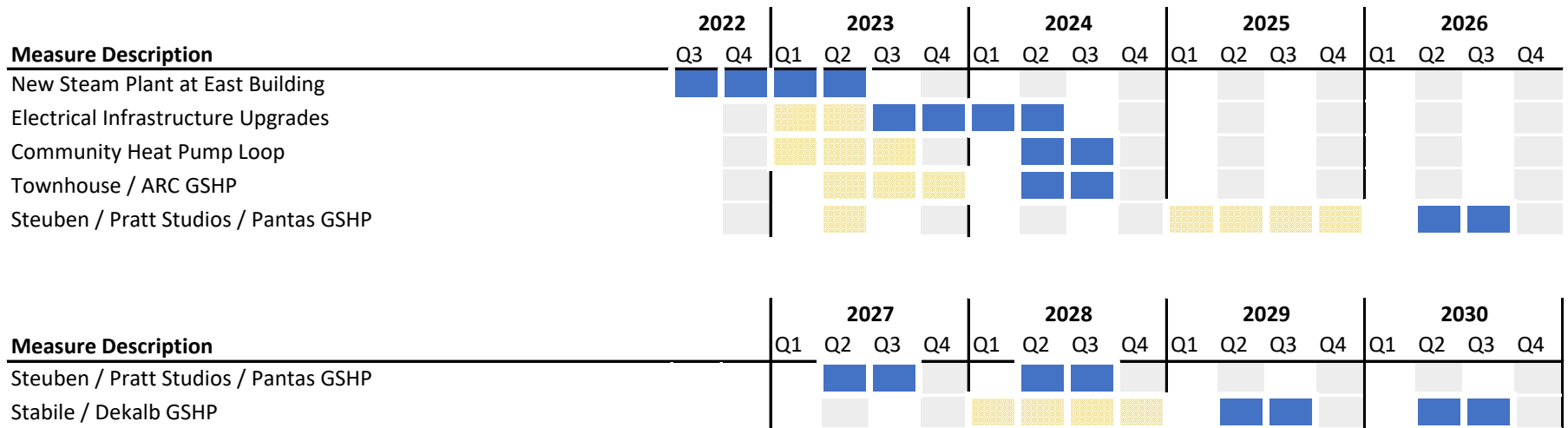
- Develop the electrical engineering documentation to distribute medium voltage around the campus to have a single metered service with ConEd. The engineering effort should design a looped or radial feed system ideally building off of the service for 193 Ryerson. The system should provide flexibility for adding existing buildings onto the service and provide Pratt-owned submetering for future LL84 and LL97 reporting purposes and energy management. The submetering would be an improvement over the data (or lack of data) currently provided by ConEd.
- Upgrade the existing electrical infrastructure within Steuben, DeKalb, Thrift, Machinery, and North Hall should be considered to move forward, which will provide the infrastructure needed on campus to meet the future electrification loads at Pratt. The in-building electrical service and equipment would be sized to meet future heat pump loads for heating these buildings.
- Implement energy conservation measures as prescribed in the roadmap to reduce the demand for steam heating until the electrified solutions are able to be implemented. Measures include updating HVAC controls to reduce overheating and improving the steam condensate system.
- Start design of a community heat pump system to serve east and south campus and allow the flexibility for adoption by other buildings on the campus in the future. The community heat pump loop should be adopted in the next eight years (prior to 2030) to meet the GHG limits set by LL97. The buildings that should be considered include Stabile, Townhouses, ARC, Steuben, Pratt Studios, Pantas, and DeKalb. The heat pump adoption for those buildings will allow the central plant to operate at low pressure and provide some additional maintenance and operational cost savings for Pratt.
- Adopt heat pumps for the renovations at other select buildings when possible. Buildings that have mechanical systems that were not part of the initial community heat pump system and should be upgraded over the next 10+ years include ISC, Library, Engineering, Chemistry, Machinery, ELJ and Thrift.

The suggested timeline for implementation of heat pump projects/mechanical and electrical system renovations at Pratt Institute is provided in Figure 31. This timeline closely matches the one for the Energy Roadmap.

Figure 31. Recommended Implementation Schedule

Pratt Institute - Implementation Plan Schedule

Engineering and Procurement
 Construction and Implementation



Quarters on calendar year schedule

- Q1: January - March
- Q2: April - June
- Q3: July - September
- Q4: October - December

Endnotes

- 1 Utility bills for these accounts for the townhouses were requested to confirm the number of ConEdison accounts that serve the Townhouses. Actual meters were not seen during the walkthrough on 3/14/2022.
- 2 The transformer at East Building was not witnessed on the 3/14/2022 site visit.
- 3 The main breaker size was not seen on the switchboard at Library. The switchboard fed two subpanels rated at 1200A and 1600A.
- 4 Pi shop is a dining area in Memorial Hall basement.
- 5 For Main Building, East Building, and South Hall, the electricity is stepped up from 208V to 480V at North Hall. Then the voltage is stepped back down to 208V.
- 6 Demand is calculated by the sum of peak demands for the multiple electric accounts.
- 7 Buildings outside the scope of this study are not included in the 8,896,640 kWh consumption, and are served by additional accounts that are not quantified here. The actual cost data was not provided by Pratt for 2020 or 2021. The additional buildings owned by Pratt include Cannoneer Court, Higgins Hall, Willoughby Hall, Pfizer Building, Film/Video Building, Myrtle Hall, Pratt House and 100 Grand.
- 8 2020 use was likely lower due to buildings having lower use after the COVID-19 pandemic shutdown starting in mid-March 2020. Likely steam system inefficiencies were worse in 2019 than 2018 caused the increase in central plant fuel usage.
- 9 Fuel oil is used as back up in additional buildings on campus, but those are deliveries are not relevant to this study and are not quantified.
- 10 This value is derived from Table C25 for Education facilities in the Northeast Census Region and converting 46.6 ft³ of natural gas energy per ft² using a natural gas heating value of 1030 Btu/ft³ to 48.0 kBtu/ft.²
- 11 Listing of classification groups can be found on UpCodes website: https://up.codes/viewer/new_york_city/nyc-building-code-2014/chapter/3/use-and-occupancy-classification#3
- 12 Steam metering within the central plant is not accurate, therefore the estimates based on fuel use was performed.
- 13 The design winter temperature for Brooklyn of 4°F was used for this analysis and a peak heating day having 56°F-days based on the weather data set in the eQuest modeling for January 23. The peak day average load would assume a monthly HDD65 value.
- 14 The design winter temperature for Brooklyn of 4°F was used for this analysis and a peak heating day having 56°F-days based on the weather data set in the eQuest modeling for January 23. The peak day average load would assume a monthly HDD65 value.
- 15 1 DT is equal to 1 MMBtu of thermal energy.
- 16 Based on an approximate enthalpy of 915 Btu/lb for steam between saturated vapor and saturated liquid states at 45 psig steam.
- 17 Using estimates from the DOE Steam System Modeler Tool for the flow to the DA tank, which assumes 50% make-up water and 150° condensate return back to the plant.
- 18 The US Army Corp of Engineers estimates that over 40% of energy is lost from typical military steam distribution system (CRREL Report 95-18, 1995). International District Energy Association (IDEA) suggest that losses of 15-20% are common for well-maintained steam distribution systems. ANTARES assumes the existing system at Pratt has 28% energy losses.
- 19 Sunday, January 23 had the coldest hour of the year but was not used since it was not during the work week.
- 20 A similar chart was not developed for the existing cooling loads as not all buildings are cooled during the summer and no existing centralized chiller plant meets this load for back-checking the numbers presented, like it was done for the central heating plant.
- 21 The weather adjusted fuel input was calculated to be 60,799 MMBtu with a baseline HDD65 of 4,761 for JFK airport in ASHRAE 2021 Fundamentals Climatic Design Tables. 2020 had a total of 4,427 HDD65 and 56,534 MMBtu of fuel input to the central steam plant.
- 22 Based on ANTARES experience with other steam piping networks, the distribution efficiency can vary between 50% and 80% depending on the size and age of the system.

- ²³ As a reference, the Roadmap estimated 22,165 MMBtu of annual thermal savings through ECM-2, HVAC Controls Upgrades. This measure would reduce / eliminate the overheating of spaces, which is prevalent at the campus. If ECM2 were to be implemented, this would reduce 36% of the total annual fuel input to the central steam plant. This estimate is stating that the amount of overheating is about 7,614 MMBtu or about 34% of the estimated amount in the Roadmap.
- ²⁴ Graphic founds at <https://www.energy.gov/energysaver/air-source-heat-pumps>
- ²⁵ Daikin refers to their technology as variable refrigerant volume or VRV instead of VRF.
- ²⁶ ANTARES varied the heating COP for the GSHPs between 3.1 at the 2.5°F temperature bin (assuming a source water temperature of 40°F and 4.0 at the 47.5°F temperature bin with a source water temperature of 60°F. ANTARES varied the cooling COP for the GSHPs between 4.8 at the 97.5°F temperature bin (assuming a source water temperature of 85°F and 10.2 at the 62.5°F temperature bin with a 60°F source water temperature).
- ²⁷ According to the report that was issued along with the test bore for Myrtle Hall, the Upper Glacial Aquifer is located between 42 – 172' in depth beneath the surface.
- ²⁸ The pumping and fan loads were not included in this analysis.
- ²⁹ As of this report's issuance, the incentive program information is provided on the Joint Utilities of New York website: <https://jointutilitiesofny.org/ev/make-ready>

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