The New York Power Authority

In Cooperation with

Arcadis

Geothermal Clean Energy Challenge Stage 3 Report

for

Ulster County Office Building

October 27, 2020

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Executive Summary

EXECUTIVE SUMMARY

The Geothermal Clean Energy Challenge (Challenge) is a joint venture between the New York Power Authority (NYPA) and the New York State Energy Research and Development Authority (NYSERDA) to provide technical support, financial assistance, and implementation services to stimulate and finance the installation of best-in-class, large-scale geothermal systems, known as Ground Source Heat Pump (GSHP) systems. These systems reduce energy costs and greenhouse gas emissions. Increasing the use of these systems will play a major role in achieving Gov. Andrew M. Cuomo's Renewing the Energy Vision (REV) goal to reduce New York State's greenhouse gas emissions 40 percent by 2030. Stages 1 and 2 of the Challenge have been completed for the Ulster County Office Building (Office Building). Stage 3 of the Challenge 'Targeted Geothermal Audit & Conceptual Design' involves the production of audit-grade detailed design studies and business planning reports before large-scale geothermal systems are deployed.

Arcadis performed a detailed energy and geothermal audit for the Ulster County Office Building on January 21, 2020. The Office Building is located at 240 Fair Street, Kingston, New York. The purpose of the audit was to identify and evaluate cost-effective energy savings opportunities in conjunction with identifying the feasibility of implementing a GSHP system to provide heating and cooling at the Office Building.

As a result of the energy audit, ten ECMs were identified and recommended for the implementation. Of the identified ECMs, two have low or no implementation costs and eight have larger capital expenditures. The most substantial ECM analyzed was the ECM 8b, which included the replacement of the existing boilers and chiller with a hybrid GSHP system. The analysis included a geothermal test well, thermal conductivity test, review of existing mechanical systems, load reduction measures, existing mechanical system upgrades, and four bore field options. The test concluded that the office building has an average conductivity of 1.49 Btu/(hr-ft-F) based on the national range of soil thermal conductivity. Analyses of the geothermal test well thermal conductivity test results and the typical heating and cooling loads were completed to estimate a conceptual GSHP loop design. Other ECMs were identified to reduce the Office Building's energy use, but none were determined to have a substantial effect on reducing the size of the GSHP system. A geothermal heat exchanger grid of 5x12 boreholes (60 total) at 499 feet deep will meet the required design inlet water temperatures required during heating and cooling operations. In order to implement the new GSHP system, the GSHP would need to be integrated into the existing core mechanical systems providing heating and cooling for the building. Based on the loop capacity, preliminary estimates for design includes one 200-ton mag chiller, one 40-ton heat pump chiller, and a closed-circuit cooling tower to meet all of the building's cooling loads and two 800 MBH condensing boilers to meet the building's heating loads. The overall estimated cost of the GSHP system including

NYPA CPC project implementation fees would be $2,663,804, or $44,397 per well, with a simple payback period of 127 years.

Table 1: ECM Summary Table

ECM #	Measure Description	Energy Saved (kWh)	Demand Saved (kW)	Fuel Savings (therms)	Annual Dollars Saved	Estimated Costs for Implementation	Simple Payback Period (years)	CO2e Reduction (tonnes)
1	Stairwell fin tube radiation adjustment	0	0.0	84	$78	$0	0	0.499
2	Replace CFL with LED	1,881	0.3	-36	$157	$502	3	0.254
3	Install control to reduce run time on EF-3	1,096	0.0	1,034	$1,153	$6,638	6	6.411
4	Install control to reduce run time on EF-5	6,127	0.7	0	$656	$3,361	5	1.523
5	Install VFD on AHU HW Loop Pump	6,282	0.0	0	$598	$8,907	15	1.526
6	Replace existing drive on AC-1 and convert to DCV	39,360	11.4	0	$4,252	$70,525	17	9.787
7	Convert AC-4 to VAV with DCV	22,372	0.0	421	$2,167	$101,885	47	8.062
8.a.1	Replace existing boilers	0	0.0	6,359	$5,938	$550,750[9]	93	37.750
8.b.1	Replace existing chiller	11,248	13.4	0	$7,520	$570,806	76	2.797
8b	GSHP System with Upgraded Chillers and Boilers	41,773	0.0	18,470	$20,942	$2,663,804[8]	127	120.035
9	Controls Upgrade	71,066	0.0	7,112	$12,277	$58,220	5	59.891
10	Building Envelope Upgrade	27,968	0.0	5,347	$7,211	$677,935	94	38.697

Notes:

1. Assuming average energy values of $0.07929/kWh (not including demand charges), demand value of $8.30/kW, and a natural gas value of $0.9338/therm from the most recent year of utility data.
2. There is not a summer peak demand savings for ECM8b but shoulder seasons provide savings.
3. ECMs were calculated independent of one another. Further measure interactions will be analyzed at the 60% design stage.
4. Project costs include NYPA CPC project implementation costs. Project costs were estimated using vendor quotes, driller quotes, and 2020 RS Means.
5. Refer to the Energy Conservation Measures section of the report for additional measure details.
6. The Simple Payback Periods were rounded to the nearest year in this Summary Table.
7. Currently available NYSERDA incentives of $279,600 were included in this cost. There is no guarantee that these incentives will be available.
8. Currently available NYSERDA incentives of $5,475 were included in this cost. There is no guarantee that these incentives will be available.

Section 2
Facility Description

FACILITY DESCRIPTION

The Office Building is in the Stockade District of historic Kingston approximately two miles west of the Hudson River. The surrounding area is primarily commercial and residential, with many buildings being preserved as historic landmarks.

Figure 1: Ulster County Office Building

Ulster County Office Building

The office building was constructed in 1964 and is 6-stories with a basement which total up to 62,396 square feet. These office spaces are occupied by a variety of County departments including the DMV, a records storage vault, financial offices and legislative spaces. The 6th floor houses a county executive meeting room with infrequent occupancy and other specialty offices. Many of these spaces have been renovated and reconfigured since its original construction which includes upgrades to the mechanical and electrical systems.

OCCUPANCY SCHEDULE

Typical occupancy is between 250 and 300 people. The building is typically occupied from 8:00 AM to 5:00 PM Monday through Friday. Employees can work outside of these windows as needed from 6:00AM to midnight. When the building is armed by security a midnight, general lighting is deactivated, and HVAC equipment is in unoccupied mode for the evening. When security disarms the building at 6:00AM, these systems are reenergized for the day. Specific controls and schedules for each type of equipment is noted in their respective sections.

LOCAL CLIMATE CONDITIONS

Since there are minimal internal heat loads in the Office Building, local climate has the largest impact on the Building's energy consumption. The building envelope is comprised of a curtain wall style system which is inherently inefficient, resulting in substantial heat loss and gains. Site weather patterns determine a typical meteorological year (TMY) and peak design conditions calculated by ASHRAE. These both have a large effect on energy calculations utilizing weather bin analysis and the peak loads that HVAC systems are designed for. The following are the ASHRAE design day conditions for the Poughkeepsie, New York and were used as the basis for the energy calculations. The design parameters are:

Cooling Season Design Day: 88.4 degree F Dry Bulb / 72.3 degree F Wet Bulb

Heating Season Design Day: 8.4 degree F Dry Bulb

HEATING, VENTILATION AND AIR CONDITIONING

The Office Building is maintained between 70- and 74-degrees Fahrenheit (F) depending on the zone during occupied hours. During unoccupied hours in the heating season, a typical temperature setback of 65-degrees F is used. During the cooling season a typical temperature setback of 75-degrees F is used. Humidity is only actively controlled for AC-4 as it serves the vault area. Dehumidification is controlled by regulation of the chilled water flow that supplies the chilled water coils in each AHU.

During the summer, the boilers are shut off to eliminate stand-by system losses and to prevent the building from unintentional simultaneous heating and cooling. Similarly, chilled water is shut off during the heating season. Even with these schedules, simultaneous heating and cooling does occur during the shoulder season when the systems overlap. Exact dates of when these systems are shut off annually are dependent on weather conditions, but the changeover periods are typically in October and May.

HEATING SYSTEM

Heating hot water (HHW) is provided by two natural gas fired Weil-McLain sectional cast iron boilers which were installed in 1988. The boilers are on an annual maintenance plan. They are at the end of their useful life and facility staff reported that the burners need continuous adjustments and excess air has become a greater issue. Two boilers are required to operate to meet the heating building load during times when the outdoor air temperature is 10 degrees F or lower. The boilers are controlled through the BMS and are enabled when the OA DB temperature drops below 58 degrees F and are in constant operation anytime the temperature is below 40 degrees F. During periods of lighter loads, the boilers are manually changed from lead to lag to balance hours of operation. The hot water supply (HWS) temperature is linearly reset based on OAT. At 0 degrees F the HWS is 180 degrees F and at 60 degrees F the HWS is at 120 degrees F.

Table 2: Boiler Plant Schedule

Tag	Manufacturer	Year Installed	Boiler Gas Input (MBH)	Boiler Water Output (MBH)	Description
No.1	Weil-McLain	1988	5,124	3,557	Gas Fired – Model 1688
No.2	Weil-McLain	1988	5,124	3,557	Gas Fired – Model 1688

Figure 2: Weil-McLain Boilers

The hot water produced by the boilers is supplied via three hot water pumps (HWP). One pump provides hot water to the AC units which utilize 3-way valves. The other two pumps provide hot water to the perimeter fin tube radiation which have 2-way valves. It is reported that the flow to Floor 5 and 6 is inadequate. The perimeter fin tube radiation units are controlled by unitary thermostats. Some areas are over or under heated due to a thermostat now being in a different room due to renovations. The northeast stairwell is in the corner of the building and contains fin tube radiation at intermediate landings between floors to maintain a setpoint temperature of approximately 70 degrees F. The units utilize self-contained thermostats with manual control via a dial on the enclosure. It was recognized that each unit was operating during the inspection and the upper portions of the stairwell were warmer than required as they are not typically occupied.

Table 3: Hot Water Pump Schedule

Tag	Manufacturer	Motor HP	Pump Flow (GPM)	Location	Serves
P3-1	B&G	7.5	390	Basement	AHU
P4-1	B&G	2	84	Basement	South Fin Tube
P5-2	B&G	3	106	Basement	North Fin Tube

COOLING SYSTEM

Chilled water (CHW) is provided by a singled water-cooled York variable speed drive (VSD) centrifugal chiller which is approximately 15 years old and not yet at the end of its useful life. The chiller is located in the basement and the cooling tower is located on the roof. The Frick counterflow cooling tower is original to the building but is currently operating without issue as reported by the building engineer. The cooling tower utilize two fans and operate to maintain a set return condensing water temperature back to the chiller. It is drained and cleaned at the end of each cooling season.

Table 4: Chiller Plant Schedule

Tag	Manufacturer	Model	Year Installed	Size (tons)	Description
CH-1	York	YT	2005	300 (est)	Variable Speed Drive

Figure 3: York Chiller

CHW is supplied to the AC units via a loop by means of two constant speed pumps. Control is accomplished by 3-way valves. Condenser water is circulated between the chiller sand cooling tower by means of two constant speed condenser water pumps (CWP). Pumps for both systems operate in a lead/lag sequence and a spare pump is available for redundancy.

Table 5: Chilled Water System Pump Schedule

Tag	Manufacturer	Motor HP	Pump Flow (GPM)	Location	Serves
P1-1	B&G	15	740	Basement	Chiller
P1-2	B&G	15	740	Basement	Chiller
P2-1	B&G	15	700	Basement	Cooling Tower
P2-2	B&G	15	700	Basement	Cooling Tower

AIR DISTRIBUTION

All air handing units contain chilled water (CHW) and hot water (HW) coils for cooling and heating, respectively. AC-1, 2, 3, and 5 were replaced in 1987. When replaced, AC-1, 3 and 5 were upgraded to include economizers and reheat coils. Each floor is separated into 4 major zones, with a cooling coil in the supply air duct of each zone which is supplied by a dedicated supply air ductwork that was originally designed as a hot/cold-deck multi-zone system, but these systems were retrofitted in 2003 to remove the hot/cold decks. As a result, only the cooling coils are used to for final tempering of zone supply air for cooling only.

AC-1 is in the basement and serves Floors 1 through 5. There is a manually operated variable speed drive on the supply fan motor that is used for balancing purposes and is typically manually adjusted between heating and cooling seasons to provide the proper airflow required. AC-2 is in the basement and serves the main lobby vestibule. The ductwork supplies air to the vestibule through floor discharges between the doors. This unit does not have outside air (OA) since it only recirculates air within the vestibule which receives OA via the doors. AC-3 is in the mechanical room behind the maintenance office and serves the basement. This unit has its own dedicated OA duct and has economizing capabilities that is manually operated by staff. AC-4R is in the basement next to AC-1 and shares a common OA plenum. This unit serves the document vault area that spans from the basement to Floor 3 and contains 3 coils; one direct expansion (DX), one CHW, and one HW. The DX coils are backups for when the chilled water system is off during the shoulder season. There are four condensing units that serve each of the DX coils. The unit utilizes hot water reheat coils for each zone, these reheat coils were previously electric. Each zone's ductwork has an independent electric steam generator for humidification. These are not currently being used as they have the tendency to over humidify and cause alarms. AC-5 is the only unit located on the rooftop and is dedicated to Floor 6. There is both a hot water and chilled water heat exchanger located on Floor 6 which separate the house's hydronic loops and the rooftop unit's glycol loops. Each glycol loop has its own dedicated circulation pump. The intent of this design is to avoid freezing but the glycol CHW is drained when the chiller is deenergized for the winter.

Table 6: Air Handling Unit Schedule

Tag	Manufacturer	Model	Location	Area Served	Cooling System Type	Heating System Type
AC-1	Unknown	Unknown	Basement	Floors 1-5	CHW	HHW
AC-2	Unknown	Unknown	Basement	Vestibule	CHW	HHW
AC-3	Carrier	39BA060D15	Basement	Basement	CHW	HHW
AC-4	Trane	MCCA021SDE	Basement	Vault	CHW/DX	HHW
AC-5	Unknown	Unknown	Roof	Floor 6	CHW	HHW

Note: AC units designated as "Unknown" did not had nameplates or other identifiable markings

Exhaust fans are integrated into the building's security system. When the security system is activated at night, exhaust fans are deactivated and vice versa in the morning when the security system is deactivated. No identifiable markings were located on the exhaust fan housings.

Table 7: Exhaust Fan Schedule

Tag	Location	Area Served
EF-1	Roof	Lavatories
EF-2	Roof	6th Floor Legislative Conference Room
EF-3	Roof	Storage Riser
EF-4	1st Floor	Generator Room
EF-5	Basement	Chiller Vault
EF-6	Roof	Janitor Closets

CONTROLS

The buildings HVAC system is controlled by a Johnson Controls Metasys Building Automation System (BAS) and the workstation is located in the basement maintenance office. The system has the capability to trend data but is not utilized to its full capabilities. A 3-degree F deadband has been programmed to reduce overlapping heating and cooling during the shoulder season. EmTech has taken over the maintenance of the system and has reported inaccuracies in some of the monitoring points. It appears that the system may not have been reconfigured accurately since the last renovation.

Figure 4: Johnson Controls Metasys Building Automation System

There are a mixture of direct digital controls (DDC) and pneumatic controls in operation throughout the building. A 1.5 HP, 80-gallon DeVilbiss compressed air system is located in the mechanical equipment room in the basement. The air compressor serves the pneumatic thermostats and control valves. It was observed to run for long periods of time and cycled frequently.

Figure 5: 1.5 HP DeVilbiss air compressor

BUILDING ENVELOPE

WALLS

The Building's exterior is curtain wall construction, consisting of glass windows and aluminum mullion framing members which make up the curtain wall. This is supported by a steel framed structure. The windows are single pane with insulated glazing and have not been upgraded since the original construction.

Due to the curtain wall's construction, maintaining comfort within the building around the perimeter is difficult due to the high conductive heat losses and gains due to thermal bridging through the aluminum framing and high infiltration rates.

Figure 6 shows the exterior view of the Documentation Vault area. This area spans from the basement to Floor 3 and is separated from the windows by concrete masonry unit (CMU) block. The first 2 floors appear to be cooler in color temperature than the 3rd floor since this floor is standard office space without a CMU barrier. The spandrel panels are also cooler in color temperature as they are more insulated than the single pane windows. Thermal bridging is apparent along all the aluminum framing.

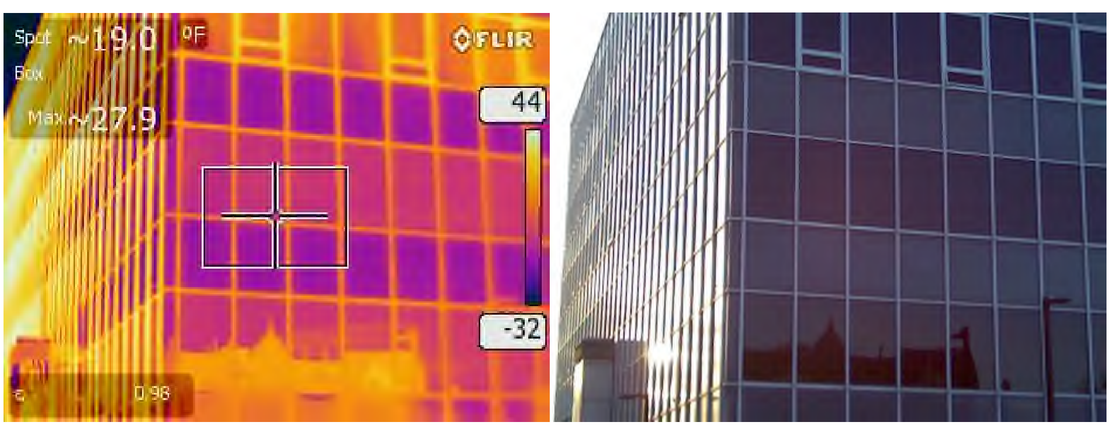


Figure 6: Southeast Envelope - Exterior View of Vault Area

Both main entrances have vestibules and are located on opposite ends of the building. The front entrance uses standard push/pull doors and the exterior doors were reported to break frequently due to the wind. The rear entrance uses automatic sliding doors without air curtains. These automatic doors were observed to stay open for a longer period of time than necessary once activated. Due to frequent pedestrian traffic for the DMV at the front vestibule, both vestibule doors are often open at the same time allowing a large volume of unconditioned outside air to enter the 1st floor during occupied times creating an uncomfortable environment and increased loading of the HVAC system.

Figure 7 shows the front vestibule area which is cooler than the main lobby located to the right of the photo. The vestibule is functioning as a barrier to the outside air but there are still large losses through the standard lobby window assemblies.

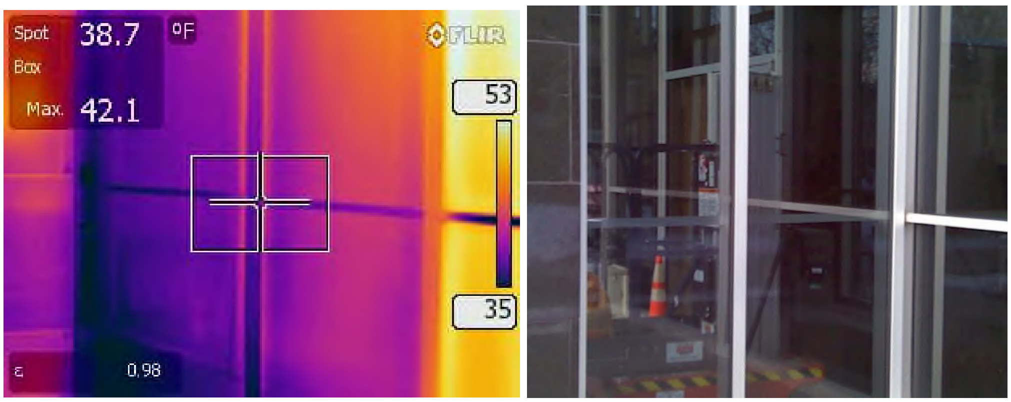


Figure 7: Northwest Envelope - Exterior View of Front Vestibule

ROOF

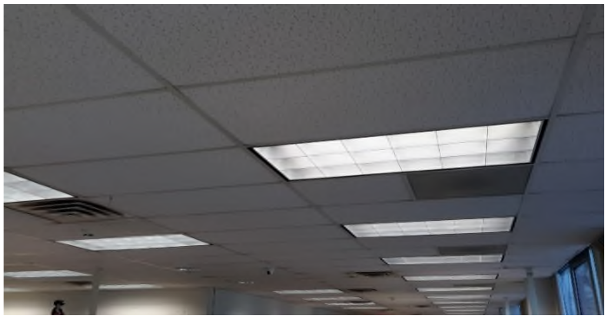
The existing black membrane rubber roof which is approximately 40 years old. The cooling tower, AC-5, and most of the exhaust fans are located on the rooftop. Funding has been approved for the replacement of the roof membrane. It is not known when the replacement will take place.

LIGHTING

INTERIOR

The light fixtures were recently upgraded to light emitting diode (LED) technology through a program with the building's utility provider, Central Hudson. Almost all the T8 linear fluorescent fixtures in offices, stairwells, mechanical rooms, and common areas were replaced with plug and play Philips InstaFit lamps. Many of the offices also utilize A/B switching which allows the occupancy to choose to only use half the number of lamps in their fixtures. This was observed to be commonly used by the occupants as the upgraded lamps have a higher lumen output. A small number of compact fluorescent light (CFL) cans and T8 fixtures were observed during the walkthrough. Exterior pole mounted lighting has been upgraded to Cree LED fixtures.

Hallway lighting is integrated into the building's security system. When the system is activated at night, all hallway lighting is deactivated and vice versa in the morning when the system is deactivated. Independent office areas are switch controlled and some areas have been upgraded to utilize occupancy sensors. Bathrooms also have ceiling mounted occupancy sensors. Staff are vigilant as almost all offices observed during the inspection had their lights off when they were unoccupied.



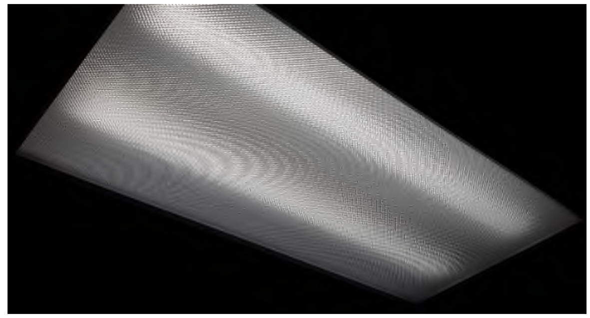


Figure 8: Typical LED Fixtures Located in Office Areas

EXTERIOR

Perimeter exterior lighting is present in the form of cobra head style LED streetlights and LED can style fixtures over the front entrance.

Figure 9: LED Streetlight in Parking Lot

DOMESTIC HOT WATER

An 80-gallon Bradford White water heater is located in the basement and is responsible for supplying domestic hot water (DHW) to the building. The hot water is delivered to each floor by a supply and return distribution loop with an aquastat.

Figure 10: 80-gallon Bradford White DHW Tank

MISCELLANEOUS

Typical office spaces contain computers, printers, task lighting, and vending machines. Printers are centralized and there is typically one per department. Due to the exterior wall construction, there is excessive heat loss at the perimeter zones and personal electric unit heaters are being used. There is approximately one kitchenette per department which typically contain a refrigerator, microwave, toaster oven, and coffee pot. There is a DMV data closet and telecom closet which are both cooled by dedicated split DX systems.

Section 3
Energy Baseline

ENERGY BASELINE

UTILITY ACCOUNTS AND BILLING

ELECTRICITY

The electric utility provider is Central Hudson Gas and Electric (CHG&E). The building is listed under Service Classification No. 2 (E200-E290) for General Service Commercial/Industrial with demand less than 1,000 kW. While delivery is charged by CHG&E, the building is supplied through Constellation Energy for with fixed supply rate of $0.05844/kWh. Area (parking) lights are segregated from the other electric energy charges but on the same monthly bill. They are categorized as Service Classification No. 5 (E500) – Area Lighting Service. Since area lights are typically on during sundown, there are no demand charges for this service classification.

There are no opportunities to change rate class after a review of CHG&E's Summary of Proposed Monthly Electric Base Delivery Rates.

Table 8: Average Electricity Rates

Average Building Demand Rate ($/kW)	Blended Building Rate ($/kWh)	Non-Blended Rate Used for ECM Savings Calculations ($/kWh)	Blended Area Lights Consumption Rate ($/kWh)
8.30	0.106	0.07929	0.241

NATURAL GAS

Natural gas is charged on the same CHG&E bill as the electric charges. The building is listed under Service Classification No. 2 (G250-G450) Commercial and Industrial Rate for commercial and industrial heating, water heating, and cooking customers.

Table 9: Average Natural Gas Consumption Rate

Average Natural Gas Rate ($/therm)
0.9338

ANNUAL ENERGY USE

The total energy use and energy baseline for the Office Building over the past two years is shown in Table 10.

Table 10: Annual Energy Use Summary

Bill Date Range	Annual Electricity Use (kWh)	Natural Gas Use (therms)	Annual Energy (MMBtu)	Energy Use Intensity (kbtu/sqft)	Energy Cost Intensity ($/sqft)
November 2017 – October 2018	946,740	27,929	6,023	96.5	$2.08
November 2018 – October 2019	875,860	27,130	5,701	91.4	$1.89

Notes:
MMBtu = Million British thermal units
Kbtu = Thousand British thermal units
Sqft = square foot

ENERGY END USE BREAKDOWN

ENERGY

Figure 11 on the following page, displays the breakdown of energy (electricity and natural gas) by end user within the Office Building. Due to the lack of granularity for disaggregating loads like air compressors, office equipment, and data centers in eQuest, the energy end use breakdown was completed using ASHRAE Procedures for Commercial Building Energy Audits as well as data output from the eQuest energy model for accuracy. The top five energy intensive systems are space heating, lighting, cooling, and ventilation. The 2012 Commercial Building Energy Consumption Survey (CBECS) lists the top five systems based on energy intensity to be space heating, ventilation, computing, other, and lighting. Cooling may be higher on the list for this facility compared to CBECS due to the curtainwall envelope which allows more heat gain during the cooling season.

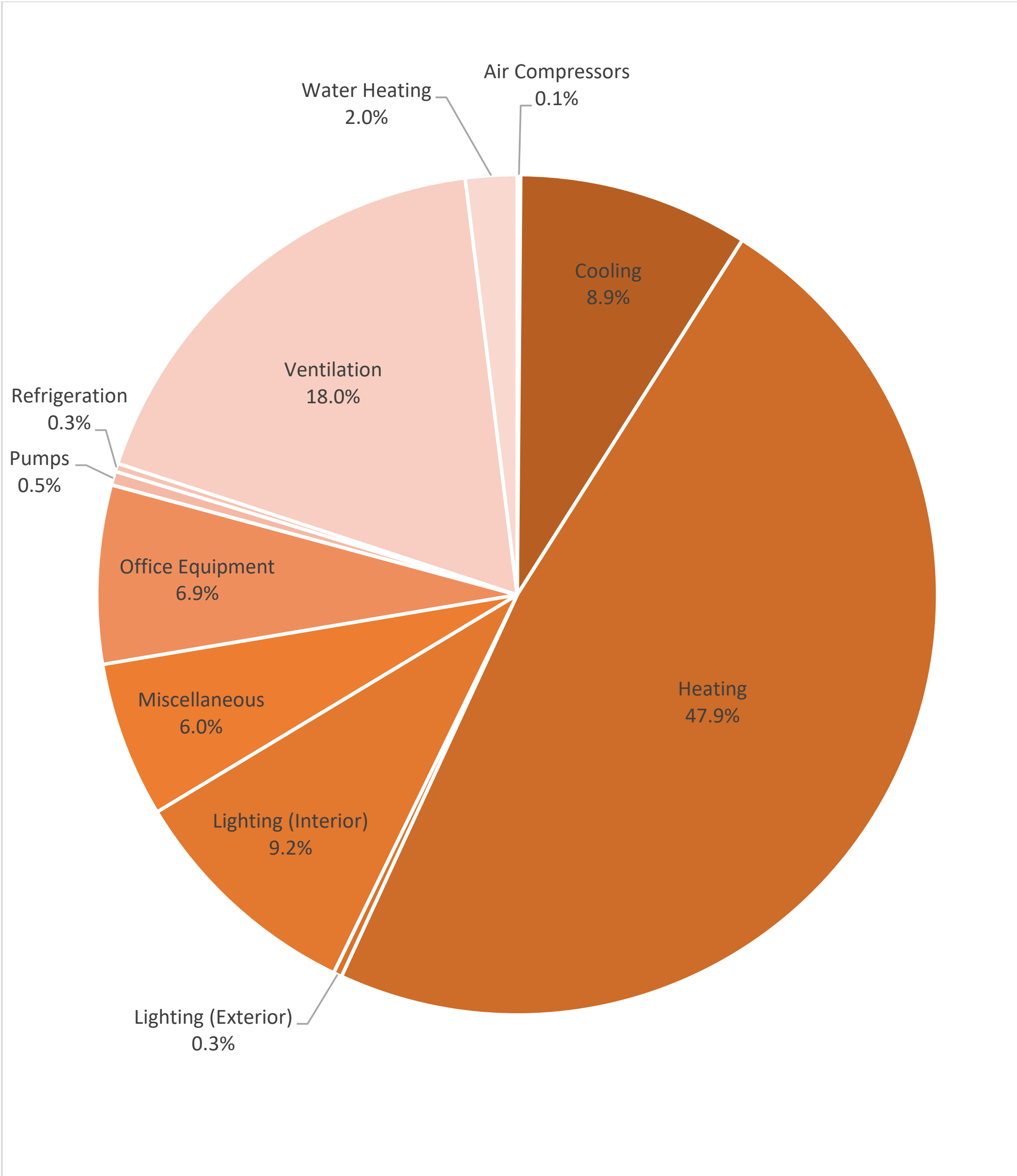


Figure 11: Estimated Annual MMBtu Usage by System Type

ELECTRIC ENERGY CONSUMPTION

The appropriate cooling degree days (CDD) were found by trial and error using regression analysis. The utility bills are invoiced mid-month which required the CDD to be customized to match that timeframe. The highest correlation to for electricity consumption and weather was at 61 degrees F. The building typically consumes between 55,000 and 76,000 kWh at baseload with the remaining spikes corresponding to temperature due to the large envelope load.

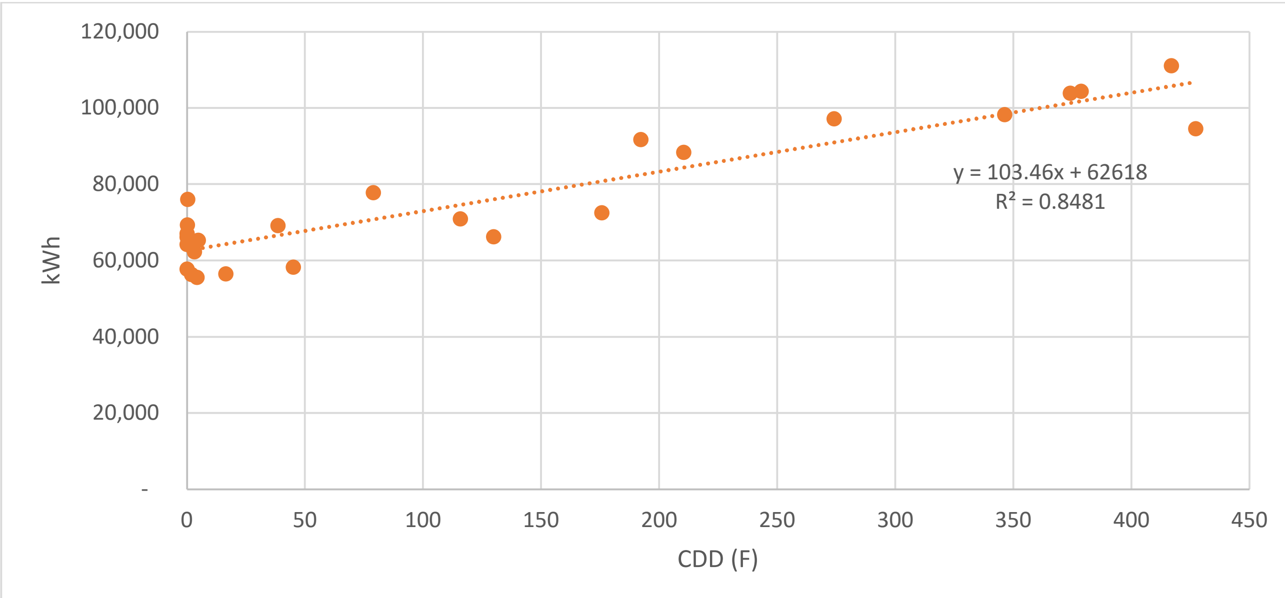


Figure 12: Regression Analysis for Electric Consumption and CDD

As cooling is provided by a chilled water system the electric energy consumption spikes during the summer. 2018 had a larger spike than 2019 but this is explained by the increase in the CDD for that timeframe. There are small spikes in December of each year which are likely due to the electric duct heaters for AC-4 and personal electric unit heaters in the office areas.

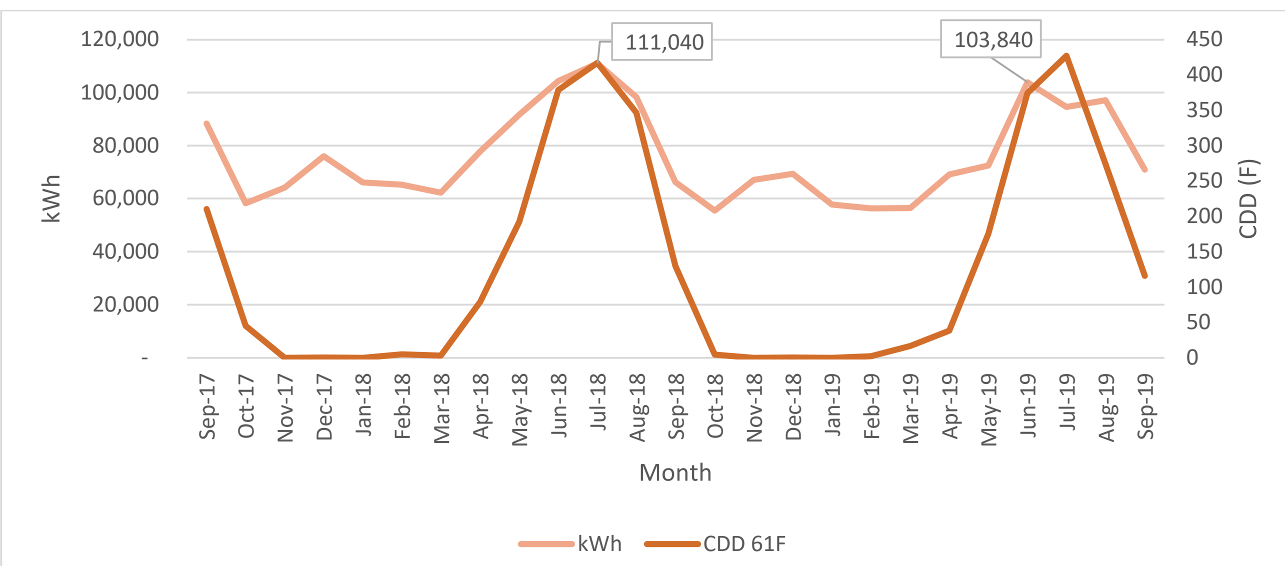


Figure 13: Past 2 Years of Electricity Consumption with CDD

ELECTRIC DEMAND

Understanding the demand portion of the electric bill is important since the demand cost for the building ranges from 17 to 28 percent of the total energy cost. The Office Building's peak demand profile ranges between 136 kW and 270 kW between November 2017 and October 2019, as shown in Figure *14*. Small spikes are present in the winter which is likely due to the electric duct heaters on AC-4 and personal electric unit heaters throughout the building.

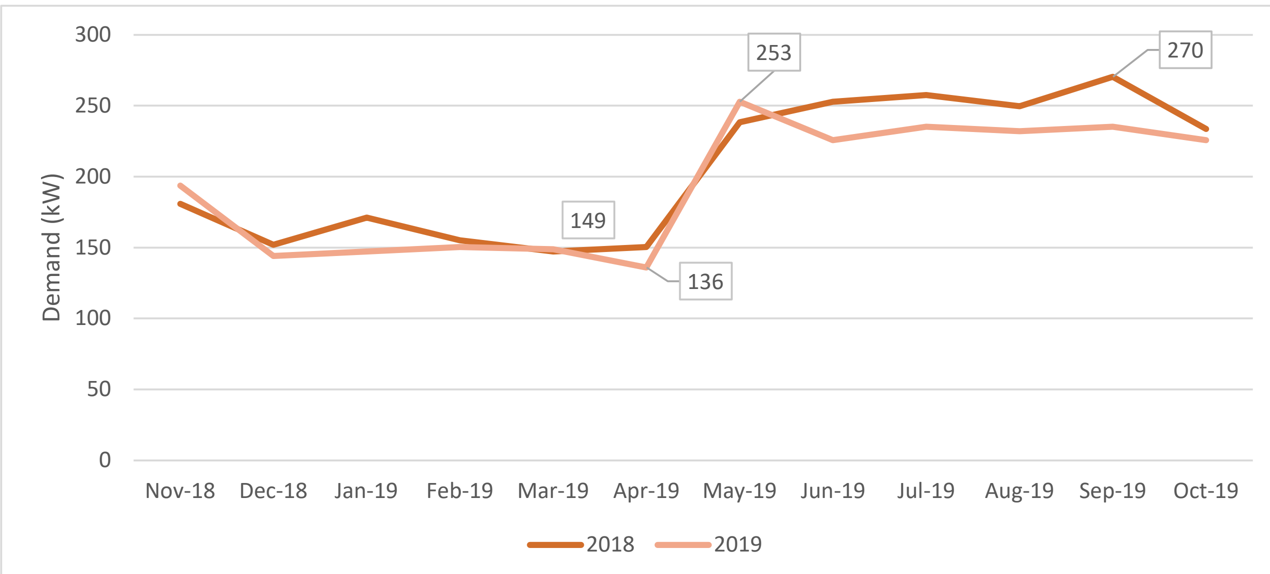


Figure 14: Peak Demand Profile

Table 11: Office Building Estimated Peak Demand Breakdown

End Use	kW	Percent (%)
Air Compressors	1.0	0.37%
Cooling	111.3	41.56%
Data Center/IT	1.0	0.37%
Lighting (Interior)	47.0	17.55%
Lighting (Exterior)	1.5	0.56%
Miscellaneous	32.7	12.21
Pumps & Aux.	16.5	6.16%
Ventilation	56.5	21.10%
Total Estimated	**267.8**	**100%**
Historical Billing	**253.0**	
Percent of Billing	**105%**	
Total per 1000 x sqft.	**4.3**	

NATURAL GAS CONSUMPTION

The appropriate heating degree days (HDD) were found by trial and error using regression analysis. Like with the CDD, the utility bills are invoiced mid-month which required the HDD to be customized to match that timeframe. The highest correlation to for natural gas consumption and weather was at 58 degrees F. The building typically consumes a very small amount of natural gas for hot water with most consumption corresponding to temperature due to the envelope, infiltration, and ventilation loads.

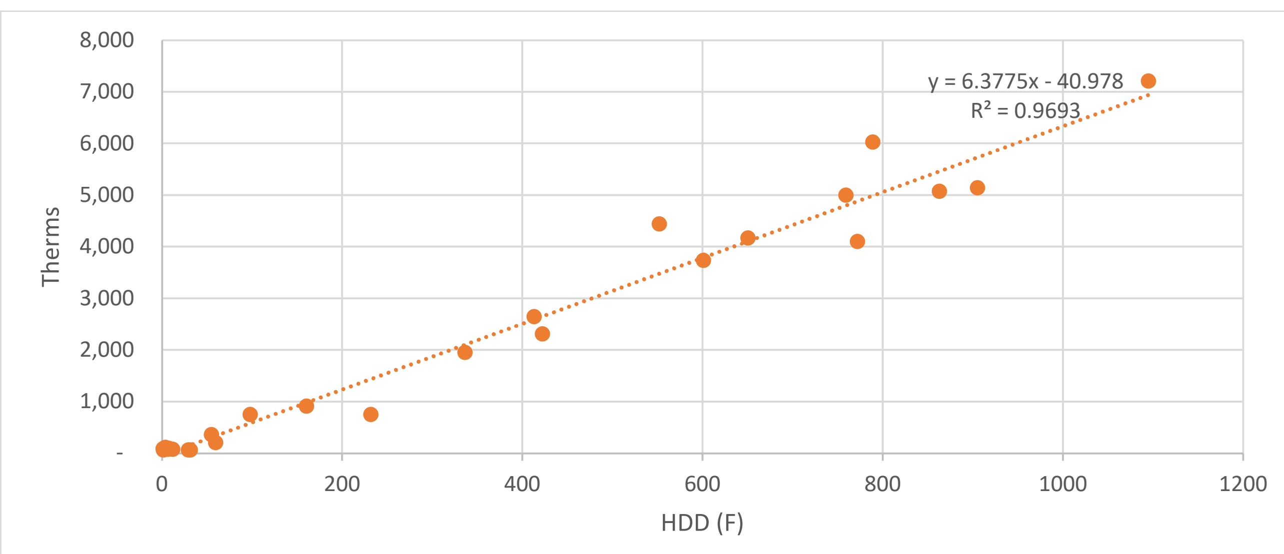


Figure 15: Regression Analysis for Natural Gas Consumption and HDD

As heating is provided by the hot water boilers the natural gas consumption spikes during the winter. 2018 had a larger spike than 2019 but this is explained by the increase in the HDD for that timeframe. The summer trends for domestic hot water consumption are consistent as this is only used for lavatory sinks and kitchenettes.

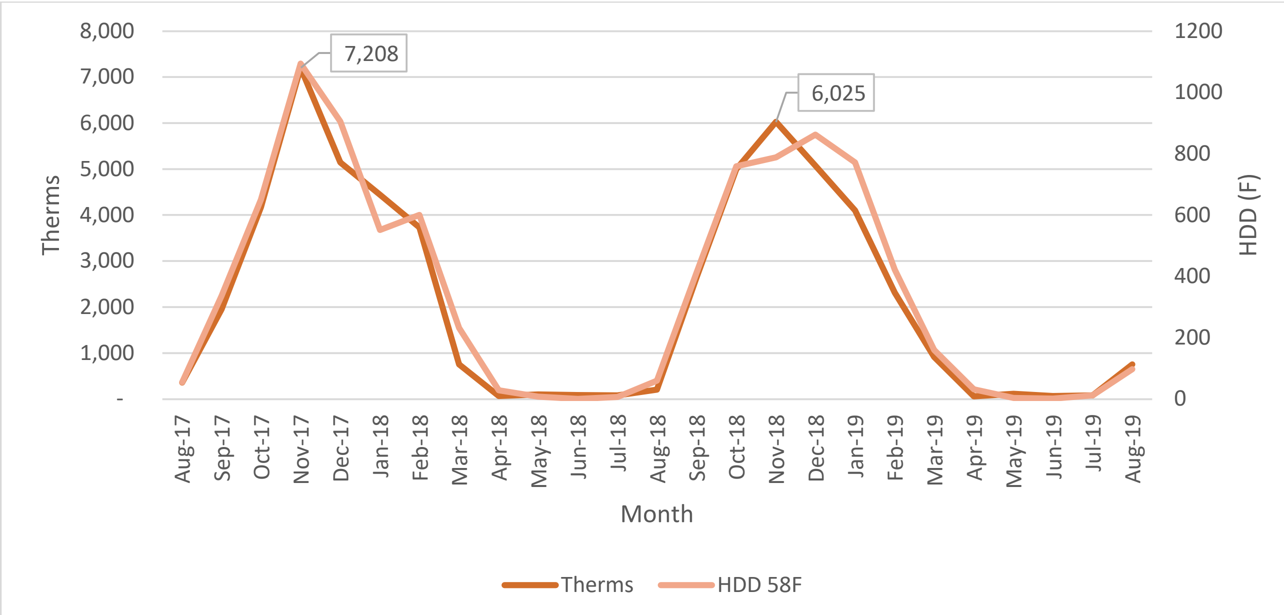


Figure 16: Past 2 Years of Natural Gas Consumption with HDD

Section 4
Energy Modeling Analysis

ENERGY MODELING ANALYSIS

The modeling program used for this analysis was eQuest, which was designed by James J. Hirsch & Associates. eQuest is a building energy use analysis tool that allows users to perform detailed comparative analyses of building designs and technologies using typical meteorological year (TMY3) data from the National Renewable Energy Laboratory (NREL). The program utilizes a combination of user inputs and software defaults to allow users to generate an accurate model of the building of study and provide estimates of energy consumption based on building envelope constructions, occupancy schedules, internal and external loads, and HVAC system operations and setpoints.

MODEL CREATION AND CALIBRATION

The baseline model was developed using eQuest's Schematic Design Wizard. The Schematic Design Wizard is intended for early-stage model development. Computer-aided design (CAD) drawings were imported into the program to accurately utilize the Office Building's exact layout. High level inputs including envelope constructions, interior finishes, windows and exterior doors, occupancy schedules, and HVAC equipment specifications and operations were entered into the model to establish a basic building footprint and building systems.

eQuest's Detailed Data Edit Mode was used to further refine the model's inputs. The Detailed Data Edit Mode allows users increased freedoms to revise operating schedules for fans, cooling, heating, occupancy, lighting, and miscellaneous equipment. Additionally, the Detailed Data Edit Mode allows further adjustment of envelope constructions for windows and skylights, doors, and building façade exteriors. The Detailed Data Edit Mode was utilized for the Office Building to provide greater detail on HVAC systems, building setpoints, building schedules, and sources of internal loads.

A model of the Office Building was generated based on data provided by Ulster County staff as well as data gathered during the site walkthrough. Where data was available, inputs were provided to eQuest, and where data was unavailable, ASHRAE and building code estimates or program defaults were used to generate an accurate model of the Office Building's operation and energy consumption. Calculated energy consumption was calibrated with utility bill data and ASHRAE's Procedures for Commercial Building Energy Audits tool to ensure the accuracy of the generated model.

PEAK LOAD CALCULATION

Simulation of the Office Building using eQuest provides a multitude of reports concerning energy consumption, heating and cooling loads for each zone, heating and cooling load components such as conduction through windows, ventilation, and internal heat gains, and HVAC loads. Peak heating loads were calculated for just the hot water circulation loop that serves the heating coils assuming typical operation at the Office Building, as shown in Table 12.

Table 12: eQuest peak heating loads for the boiler during normal Office operation

Month	Heating Energy (MMBtu)	Maximum Heating Load (kBtu/h)
Jan	486	1,956
Feb	401	1,966
Mar	242	1,482
Apr	150	1,171
May	22	459
Jun	0	0
Jul	0	0
Aug	0	0
Sep	0	0
Oct	26	1,156
Nov	194	1,391
Dec	384	1,632

Similarly, peak cooling loads were calculated assuming typical operation at the Office Building, as shown in Table 13.

Table 13: eQuest peak cooling loads for during normal office operation

Month	Cooling Energy (MMBtu)	Maximum Cooling Load (kBtu/h)
Jan	0	0
Feb	0	0
Mar	0	0
Apr	0	0
May	77	1,488
Jun	226	1,936
Jul	247	1,725
Aug	291	1,712
Sep	89	1,516
Oct	22	1,538
Nov	0	0
Dec	0	0

Section 5
Energy Conservation Measures

ENERGY CONSERVATION MEASURES

ECMs were developed to support the Office Building in reducing overall energy consumption resulting in the reduction of heating and cooling loads in conjunction with design and construction of a GSHP system. In order to model energy consumption and calculate energy savings throughout the year, Microsoft Excel Bin analyses methods was performed for each measure, where appropriate. Of all the ECMs considered, seven had attractive payback periods, additional maintenance savings, or would be a reference for future projects when pricing becomes more reasonable. Project cost estimates were determined using manufacturer and distributor quotes as well as the 2020 RS Means handbook, with contingency added, as appropriate. Estimated accuracy of implementation costs is based on The Association for the Advancement of Cost Engineering's (AACE) Class 3 cost estimate. The expected accuracy range with a Class 3 cost estimate is between -10 percent and 30 percent of the calculated cost for implementation of each measure. A summary is provided in Table 14 below.

Table 14: ECM Summary Table

ECM #	Measure Description	Energy Saved (kWh)	Demand Saved (kW)	Fuel Savings (therms)	Annual Dollars Saved	Estimated Costs for Implementation	Simple Payback Period (years)	CO2e Reduction (tonnes)
1	Stairwell fin tube radiation adjustment	0	0.0	84	$78	$0	0	0.499
2	Replace CFL with LED	1,881	0.3	-36	$157	$502	3	0.254
3	Install control to reduce run time on EF-3	1,096	0.0	1,034	$1,153	$6,638	6	6.411
4	Install control to reduce run time on EF-5	6,127	0.7	0	$656	$3,361	5	1.523
5	Install VFD on AHU HW Loop Pump	6,282	0.0	0	$598	$8,907	15	1.526
6	Replace existing drive on AC-1 and convert to DCV	39,360	11.4	0	$4,252	$70,525	17	9.787
7	Convert AC-4 to VAV with DCV	22,372	0.0	421	$2,167	$101,885	47	8.062
8.a.1	Replace existing boilers	0	0.0	6,359	$5,938	$550,750[9]	93	37.750
8.b.1	Replace existing chiller	11,248	13.4	0	$7,520	$570,806	76	2.797
8b	GSHP System with Upgraded Chillers and Boilers	41,773	0.0	18,470	$20,942	$2,663,804[8]	127	120.035
9	Controls Upgrade	71,066	0.0	7,112	$12,277	$58,220	5	59.891
10	Building Envelope Upgrade	27,968	0.0	5,347	$7,211	$677,935	94	38.697

Notes:

1. Assuming average energy values of $0.07929/kWh (not including demand charges), demand value of $8.30/kW, and a natural gas value of $0.9338/therm from the most recent year of utility data.
2. There is not a summer peak demand savings for ECM8b but shoulder seasons provide savings.
3. ECMs were calculated independent of one another. Further measure interactions will be analyzed at the 60% design stage.
4. Project costs include NYPA CPC project implementation costs. Project costs were estimated using vendor quotes, driller quotes, and 2020 RS Means.
5. Refer to the Energy Conservation Measures section of the report for additional measure details.
6. The Simple Payback Periods were rounded to the nearest year in this Summary Table.
7. Currently available NYSERDA incentives of $279,600 were included in this cost. There is no guarantee that these incentives will be available.
8. Currently available NYSERDA incentives of $5,475 were included in this cost. There is no guarantee that these incentives will be available.

ECM 1: STAIRWELL FIN TUBE RADITIATION ADJUSTMENT

The northeast stairwell is heated by hot water fin tube radiation units located on the landings in between each floor. During the inspection it was noticed that the 6th floor was unnecessarily warmer than the floors below due to stratification. Most pedestrian traffic is through the elevators and the stairwells are not commonly used by staff. As each unit has a self-contained manual dial thermostatic control mounted on it, it is proposed to turn down the setpoints of units located on the upper floors. This is a no-cost measure so it can be done in small increments to test the changes and ensure satisfactory heating of all floors.

ECM 2: REPLACE CFLs WITH LEDs

Facility staff is in the process of upgrading the remaining CFL fixtures to LED technology. During the inspection a total of 32 can downlight fixtures were identified have 2 pin type CFL bulbs each. These 13W CFL lamps can easily be replaced by a comparable 8W LED lamp upon failure or before failure. No additional modifications to the fixture will be required. The calculations were completed assuming that all lamps were replaced at once.

ECM 3: INSTALL CONTROL TO REDUCE RUN TIME ON EF-2

EF-2 serves the 6th Floor Legislative Conference Room and is in operation even when meetings are not taking place. Since this fan is scheduled to run on a set schedule it is proposed to revise the schedule to make the existing occupied periods unoccupied which will be activated by ceiling mounted occupancy sensors within the space. Once the occupancy sensors are triggered, EF-2 will stay on for an hour from the last detected motion in the room. This will greatly reduce the amount of exhaust air from the space, saving on heating and cooling energy supplied from AC-5.

ECM 4: INSTALL CONTROL TO REDUCE RUN TIME ON EF-5

EF-5 serves the chiller vault in the basement to ventilate the space for safety. There is a refrigerant alarm in the space to alert the building engineer if there is a leak but the fan itself is manually controlled and currently kept in the ‘on’ position. The fan was found to be operating during the audit in heating season even though the chiller was not in use. If the fan is controlled by the refrigerant sensor instead of the manual switch, it will still be code compliant. The fan control integration into the refrigerant sensor will allow the fan to run only when a refrigerant leak is detected. Staff will still have the ability to override the fan control if work is being completed in the chiller vault. This retrofit will greatly reduce the ventilation within the space saving heating and cooling energy supplied from basement unit AC-3.

ECM 5: INSTALL VFD ON AHU HOT WATER LOOP PUMP

All AC units are served by the boiler by a hot water distribution loop, utilizing three-way control valves on the heating coils of the AC units. It is proposed to either convert the three-way valves to two-way valves or replace the three-way valves at each unit with a two-way valve and install a VFD on the HWP that serves the loop. The VFD will allow the pump to respond to unit demand based on system static pressure utilizing static regain controls. Due to the limited capabilities of the existing BMS system, the VFD will not be integrated into the system. It will be controlled locally at the panel, as required.

ECM 6: REPLACE EXISTING DRIVE ON AC-1 AND CONVERT TO DCV

AC-1 is the largest unit in the building and serves floors 1 through 5 except for the Vault areas. The outside air damper is maintained at 10 percent open during typical operation and only opens further when economizing. It is recommended to monitor CO2 through each floor's return air plenum and adjust outside air to maintain the minimum required by ASHRAE 62.1. This will allow for ventilation savings during early morning and evening periods when occupancy is typically at its lowest.

As the existing drive on AC-1 was installed to manually balance the supply air fan. It is sometimes adjusted by facility staff seasonally to accommodate changes in pressurization. It is recommended to replace this drive with a variable frequency drive which will be able to adjust based on the demand from each floor.

ECM 7: CONVERT AC-4 TO VAV WITH DCV

The vault area is served by AC-4 and typically has low occupancy due to the nature of the space. Each floor has its own dedicated supply air duct. It is recommended to retrofit the existing constant air volume (CAV) system to variable air volume (VAV) with additional DCV controls. This will allow the system to greatly reduce the volume of air it is currently delivering to the space which will reduce cooling and heating loads. Additionally, less ventilation air will require less dehumidification during the summer as well as less humidification in the winter.

ECM 8.a.1: REPLACE EXISTING BOILERS

The existing heating system is original to the Office Building's construction. Staff expressed interest in replacing the two existing boilers. Since these units are past their end of useful life, the baseline scenario for this ECM assumed replacement of the boilers with modular condensing boiler units. Modular condensing boilers are able to operate at a much higher efficiency than the existing boilers and would be more appropriately sized to the building load. This ECM assumed that the associated equipment like circulation pumps would be maintained but should be assessed for potential upgrades in design.

ECM 8.a.2: REPLACE EXISTING CHILLER

The existing chiller is approximately 15 years old but based on the buildings cooling appears to be oversized, therefore operates outside its optimal efficiency. As a result, the chiller was evaluated to be replaced with a high efficiency variable speed chiller. The savings for this ECM came from the increased efficiency of the new chiller but additional chiller plant optimization strategies should be assessed once in design. The other associated equipment like circulation pumps will be maintained but should also be assessed for potential upgrades in design.

ECM 8b: GSHP SYSTEM WITH UPGRADED CHILLERS AND BOILERS

GEOTHERMAL SAMPLE WELL AND TESTING RESULTS

The geothermal test well in the Ulster County Office Building parking lot was initiated on January 31, 2020 and completed on February 3, 2020. The test well was drilled to 126-feet at a diameter of 8 inches and to 499-feet at a diameter of 6 inches. The test loop piping utilized 1.25-inch DR11 high-density polyethylene (HDPE). The formation makeup at the test well site consisted of sand from 0 to 110-feet and gray shale from 110 to 499-feet. The grout mixture was composed of 100-pounds TG Lite, 32-pounds of PowerTEC, and 30-gallons of water.

After sufficient curing of the grout, the thermal conductivity (TC) test was completed for 70.3 hours to determine ground thermal properties. The TC test was performed by injecting a known and constant heat power into the borehole heat exchanger and measuring the temperature response of the surrounding formation. This method is used to determine the undisturbed formation ground temperature, the TC, the borehole thermal resistance, and an estimate of thermal diffusivity (TD). In the test borehole, an average heat flux of 20.1 W/ft was injected into the heat exchanger.

Geothermal Resource Technologies Inc. (GRTI) completed the analysis of the TC test results. The loop temperature and input heat rate data were plotted against the natural log of elapsed time are shown below in Figure *17*. The temperature versus time data was analyzed using the line source method in conformity with ASHRAE and IGSHPA guidelines. A linear curve fit was applied to the average of the supply and return loop temperature data between 10 and 48 hours. The slope of the curve fit was found to be 3.69 which was then used to calculate the TC.

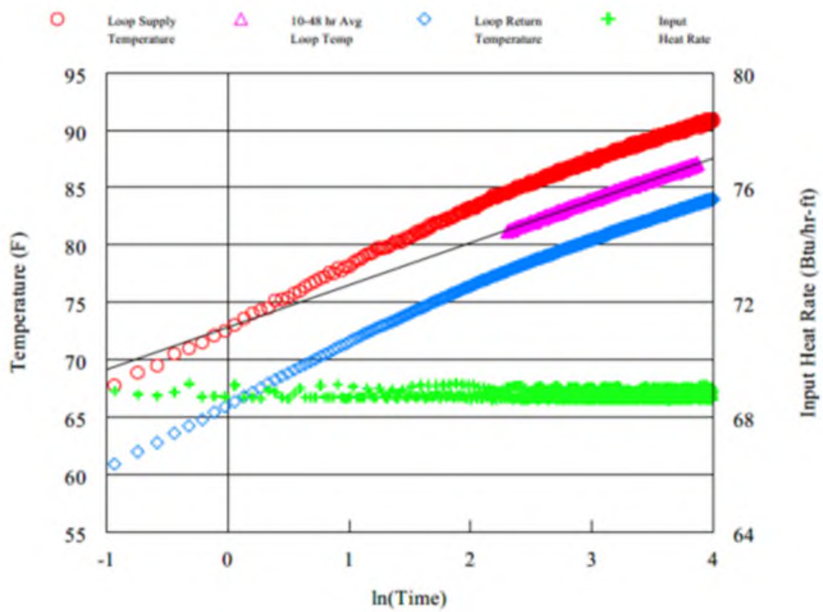


Figure 17: Thermal Conductivity Test Results

The resulting TC value of 1.49 Btu/hr-ft-°F calculated is considered average as the typical values range between 0.6 to 2.5 Btu/hr-ft-°F across the United States. A heat capacity value for shale was calculated from specific heat and density values for the formation. A weighted average of heat capacity values based on the indicated formation was used to determine an average heat capacity of 30.8 Btu/ft^3 -°F . A diffusivity value was then found using the calculated formation thermal conductivity and the estimated heat capacity. The thermal diffusivity for this formation was estimated to be 1.16 ft^2/day. TD is more of a determining factor than TC for the balance of heating and cooling loads. Results of the thermal conductivity test are shown in Table *15*.

Table 15: Thermal Conductivity Test Results

Parameter	Result	Unit
Thermal Conductivity	1.49	Btu/hr-ft-°F
Thermal Diffusivity	1.16	(ft^2/day)
Borehole Average Heat Capacity	30.8	Btu/ft^3-°F
Undisturbed Ground Temperature	54.3 - 55.5	°F

GEOTHERMAL SYSTEM CONCEPTUAL DESIGN

Based on the site area restrictions and the existing constraints of the parking lot area, it is recommended to implement a vertical, closed-loop U-bend geothermal heat exchanger system. Four types of vertical, closed-loop options were assessed as part of the preliminary design. The primary difference between each option was bore depth, piping configuration and or piping material. Each option was analyzed to understand the best thermal transfer efficiency with the least implementation cost, resulting in the best return on investment. These options offered a unique perspective on how the various combinations impacts the thermal efficiency and ultimately the quantity of bore holes required to meet a predetermined build heating and cooling load.

The four options analyzed were;

1. Single HDPE 1-1/4" U-Bend 499 foot depth: This is a typical option for vertical wells and does not require permitting due to the depth of the well. The test well was also drilled to 499 feet, so the well test results did not have to be extrapolated to estimate available resource. This option was selected due to cost, driller availability, and simplicity of the system.
2. Double 1-1/2" U-Bend 900 foot depth: This option utilizes a high-density polyethylene filled with highly conductive carbon-type nanoparticles which gives the material up to 75% higher thermal conductivity than the conventional HDPE option above. Since the material can improve drilling efficiency and provide additional savings over HDPE, it is proposed to drill to 900 feet which will require 21 bores which the parking lot can accommodate. The TD value used during analysis was conservative to account for any changes in thermal properties as the bore holes will be 400 feet deeper than the test well. It was ultimately not recommended due to the extrapolation in the available resource from the thermal conductivity report for the depth of the wells required, experienced drillers to install a system this depth, and the anticipated performance of the system.
3. Concentric 5"x3" Piping System - 1,610 foot depth: This option was analyzed as it would require only 11 bores. It was ultimately not recommended due to the extrapolation in the available resource from the thermal conductivity report for the depth of the wells required, experienced drillers to install a system this depth, and the anticipated performance of the system.
4. Concentric 7"x4" Piping System - 2,270 foot depth: This option was analyzed as it would require only 6 bores. It was ultimately not recommended due to the extrapolation in the available resource from the thermal conductivity report for the depth of the wells required, experienced drillers to install a system this depth, and the anticipated performance of the system.

There are four main types of geothermal configurations utilized for thermal heat transfer for the heating and cooling of commercial buildings, they are:

1. Vertical, closed loop system – vertical bore holes at varying depths utilizing u-bend piping in the bore hole connected by horizontal manifolds placed in horizontal trenches to connect the bore hole vertical piping system to the indoor mechanical systems. Since depth can be increased to accommodate additional load, less surface area is required for the bore field than other system types.
2. Horizontal, closed-loop system – horizontal piping which lays in shallow trenches connected by horizontal manifolds placed in the trenches to connect the bore field piping system to the indoor mechanical systems. As shallow trenches are cheaper than drilling vertical bore holes, a horizontal loop requires significantly more land area than is available at the Office Building.

3. Pond/lake, closed-loop system – thermal piping is submersed in a nearby body of water which is used as a thermal source and sink instead of the ground like Options 1 and 2. This is cheaper than the other options but was not considered for application at the Office Building due to the lack of access to a nearby body of water.
4. Open-loop system – instead of utilizing thermal piping to maintain a barrier between thermal sources and sinks like with the closed-loop systems, this system circulates the heat exchange fluid (typically water) that is already contained in the source. Expensive thermal piping is not required which saves on the initial capital cost for these project types and additional savings can be achieved using a surface body of water. This option was not considered at the Office Building as it requires the use of well or surface body water as the heat exchange fluid which is not available nearby the Office Building.

GEOTHERMAL DESIGN PARAMETERS

Due to the low amount of domestic hot water consumed on site the geothermal system will only be used to provide space conditioning for the building. The following table outlines the annual energy requirements of the building organized by heating and cooling. The system was sized using a combination of building demand and energy requirements so that the bore field would not be greatly oversized which would substantially increase the project cost and area required.

Table 16: Annual Building Energy Requirements

	Building Annual Cooling Requirement	Building Annual Heating Requirement
Space Conditioning Energy (kBtu)	1,129,481	2,498,473
Hot Water Generation Energy (kBtu)	---	0
Total Energy (kBtu)	1,129,481	2,498,473

Since the building is in a heating dominate climate, the ground energy will become unbalanced over time as more heat will be extracted from the ground then what is put back in. Due to this imbalance and cost of adding additional bores to only handle peak loads, a hybrid heat pump system is the most cost-effective arrangement to supplement peak loads and maintain bore field health. Due to the dominance of the heating season the hybrid arrangement will consist of two supplemental condensing hot water boilers which are sized to handle 20 percent of the load. The cooling season is not at risk for overheating the bore field as the cooling season is much shorter than the heating season, but during large cooling demands the bore field may have difficulty keeping up with peak cooling demand heat rejection capacity. As a result, it is proposed to use a cooling tower as a supplement for heat rejection during the cooling season which will work in conjunction with the bore field in the hybrid arrangement. Additional details about the operation of these systems during heating, cooling, and shoulder seasons are provided later in this report. The following table describes how the annual energy use requirements of the Office Building are distributed between the GSHP, boilers, and cooling tower. The net ground energy is negative as the amount of heat extracted from the ground during the heating season is greater than the amount deposited during the cooling season.

Based on the calculated loads for heating and cooling, and to maintain bore field health the geothermal heat exchange grid will be installed to maintain an average spacing between bores of 20.0 feet on-center (OC). It is proposed that boreholes be drilled to approximately 499 feet deep to maintain the design inlet water temperatures described above. Upon further review with GRTI, the estimated TD is conservative and will potentially decrease (improve) as depth is increased.

The system geometry consists of 12 rows, with 5 bores per row, totalling in 60 bores for the field. The average column to column spacing is 20.0 feet for a single u-bend configuration. The bores will have a total one way length of 29,940 feet. The bores will be 5 inches in diameter with and the high TC HDPE piping will have a nominal diameter of 1.25 inches.

Due to land availability at the Office Building the only location for the bore field is the asphalt parking lot. The parking lot's total footprint is approximately 20,000 square feet which most will be utilized for the 60 bores. Due to the layout of the parking lot, a symmetrical grid will be difficult to achieve but the 20-foot spacing will be maintained. Using the same method prior to drilling the test well, the proposed conceptual heat exchange grid layout is predicated on the existing location of underground utilities. The is a small tolerance for bore locations that can be adjusted within a few feet to accommodate interferences. An overflow area was identified if underground utilities or other restrictions require boreholes to be relocated outside of the tolerance area. A conceptual layout of the proposed geothermal heat exchange grid with 60 bores is shown in Figure *18*.

Figure 18: Heat Exchanger grid layout

The geothermal heat exchanger system selected was the single HDPE 1-1/4" U-Bend with 499-foot bores due to its cost, larger selection of available drillers, and simplicity of the system. To ensure that the geothermal heat exchanger design does not become too unbalanced, conservative spacing in the bore field was maintained based on industry standards. The system was designed based on the results of the thermal conductivity test and calculated heating and cooling loads which were estimated using a combination of eQuest building energy modelling software and spreadsheet calculations. Geothermal delivery supply water temperatures required for proper equipment operation and what the system design was predicated on are:

1. 40.0 degrees F minimum from the bore field to the heat recovery chillers in heating mode, and;
2. 80.0 degrees F maximum from the bore field to the heat recovery chillers in cooling mode.

The system design day was calculated first to compare the existing and proposed systems. It is the aggregated load for heating and cooling seasons including all constituent zones and hot water elements in the building. This is the loading profile for which the entire system is sized and is based on the worst-case season (heating or cooling) to ensure a conservative system design. The total capacity of the system is listed in the table below. Note that the existing heating capacity is for two boilers which are oversized and only at part load during peak conditions.

Table 17: Comparison of Existing and Proposed Systems

	Existing Cooling	Proposed Cooling	Existing Heating	Proposed Heating
Total Capacity (kBtuh)	3,600.0	2,050.4	7,114.0	1,745.0
Efficiency	0.582 IPLV (est.)	18.9 EER	80% (est.)	2.7 COP
Demand (kW)	180.1	108.2	<10	175.4

The circulating fluid for the loop would be 25 percent propylene glycol which gives the mixture a freezing temperature of approximately 14 degrees F. The system controls will ensure that the loop is kept above the freezing temperature. After system models were completed, final operating temperatures and flowrates for the system were established. Since the interior building loop is separated from the exterior loop, flows can be different based on demand within the building which can also save pump energy. Over a 5-year analysis period the long term soil temperatures will reach equilibrium temperature of 54.7 degrees F between the heating and cooling seasons. Temperature penalty describes the change in the deep earth temperature immediately surrounding the installed bore field after extended periods of system operation.

Table 18: Design Day Ground Loop Temperatures

Cooling Mode	Heating Mode
Unit Inlet 80.8 °F	Unit Inlet 41.6 °F
Unit Outlet 90.2 °F	Unit Outlet 36.6 °F

Calculations for peak flow were based on a block flow of 3 gpm per ton. The total bore field flow was calculated using the flow per path for 60 bores, with one path entering the bore field and one path leaving, for a total of 120 paths. Using the velocity and pipe characteristics, the head loss of the bore field was calculated to appropriately size the geoexchange source/sink pump located on the supply side loop. Operational system pressures in the heat exchanger loop will be between 20 and 30 psi and utilize a heat exchanger fluid with a mixture of 25 percent propylene glycol and 75 percent deionized or distilled water.

CONSIDERATIONS FOR MECHANICAL EQUIPMENT

Multiple layout options for new mechanical equipment were evaluated to be in either the existing mechanical space or in a new dedicated mechanical space located on the ground level outside. After evaluation, it was concluded that the new mechanical equipment will fit in the existing mechanical space in the basement. The proposed magnetic bearing chiller will be installed in the existing chiller vault. Since the existing chiller vault is located under the front lawn, it will be excavated so it can be easily removed in one piece. Once all the large equipment is removed through the opening, all new mechanical equipment will be lowered into the basement including the new chiller and other large equipment.

BUILDING SYSTEM DESCRIPTION

The exterior heat exchange loops from the bore field will enter the building on the southwest side of the building into the existing chiller vault. The manifold will tie together the multiple loops and will be constructed for a low head design to reduce pump energy. The manifold will consist of digital temperature sensors, flow meters to assist in system balancing, and shut off valves. Specific manifold will be detailed during the 60 percent design. The existing HW and CHW piping systems serving the AC units and boilers will be re-piped as required to accommodate the new piping configuration for the heat pump system and will be sized to minimize system head loss The new piping system will connect to the HW and CHW piping systems that leaves the mechanical room to serve the building will be maintained to reduce project cost.

The existing 300-ton chiller will be removed from the vault as it is being replaced with a new magnetic bearing (mag) chiller with heat recovery as a part of the new heat pump system. The associated chilled water pumps will be replaced from the adjacent space as well. In order to add supplemental heat rejection to the system, the current open evaporative cooling tower (the cooling tower is not adequate for this service) will be replaced with a closed-circuit cooling tower. This will provide a closed loop and not allow the condenser water loop to be exposed to the atmosphere. The intent is to utilize the associated condenser water pumps as a part of the hybrid system configuration.

Through preliminary sizing based on dimensions known at this stage, the vault will be able to house the equipment listed below.

Table 19: Chiller Vault New Equipment List

Type	Quantity	Make	Size
GSHP Manifold	1	TBD	TBD
Centrifugal Mag Bearing Chiller	1	TBD	200-tons

The remainder of the large equipment as noted below will be installed in the basement of the building after the existing 3,350 MBH boilers are removed. For the purposes of this 30 percent design, the proposed equipment will not require an expansion of the existing electric service as new equipment size is comparable.

Table 20: Remaining Basement Mechanical Room Equipment

Type	Quantity	Make	Size
Heat Pump Scroll Chiller	1	TBD	40-tons
Chiller Pumps	4	TBD	Varies
Pumps	4	TBD	Varies
Condensing Boilers	2	Camus	800 MBH
Boiler Pumps	2	TBD	TBD

Table 21: Design Chiller Heat Pump Inlet Load Temperatures

Cooling Mode (WB)	Heating Mode (DB)
Water to Air 67 °F	Water to Air 70 °F
Water to Water 55 °F	Water to Water 100 °F

The existing fan coil units (FCUs) and perimeter fin tube radiation (FTR) throughout the building are designed to utilize 180 degree F water to maintain temperature during a design heating day. As a result, these units will be maintained and will be on a 180 degree F hot water loop supplied by the supplemental condensing gas boilers during the heating season. The geothermal system itself is only capable of producing a maximum of 130-degree F water. The existing AC Units heating coils are designed to utilize 180 degree F hot water during the heating season and the cooling coils are designed to utilize 45-50 degree F chilled water during the cooling season to temper the AHU supply air to the spaces. Therefore, the heating coils do not have enough heating capacity at the lower heat pump loop temperature of 135 degree F. As a result, and to minimise system capital cost, the cooling coils will be re-piped for changeover duty so they can be used during the heating season for the low temperature hot water. This will expand the heat coil capacity and will work in conjunction with the existing hot water coils in the AHUs. Then during the cooling season, the cooling coils will be used for cooling service. As there was limited data available for the existing AC Units, airflows were estimated using coil temperature rise, and terminal unit airflow data.

SEASONAL OPERATION

OVERVIEW

The outdoor air temperature and the heating or cooling requirement of the building will determine if the GSHP system is either in the heating mode, cooling mode or simultaneous (heating and cooling) mode. The HVAC water side systems sequence of operation (SOO) will include a revised SOO for the core heating and cooling infrastructure which includes operation of the new GSHP system and integration into the existing hot water boiler and chilled water systems. The detailed SOO will need to be further developed and will be included as part of the 60 percent design documents.

The current water side operation of the buildings end terminal devices such as FTR, FCUs and Zone Cooling Coils will not change and will continue to be controlled as is by the existing controls and thermostats.
The HVAC's air side systems distribution and control will remain the same as is currently controlled. All outside air dampers on the AC units will be maintained under current sequencing based on building occupancy schedule. There may be minor adjustments in the control strategy as a result of the integration of the new GSHP system into the existing HVAC system.

HEATING SEASON

Based on an outdoor air temperature (OAT) of 50 degF +/- the GSHP will in a predominantly heating mode, where the new gas fired condensing boilers will be energized developing HW to serve the buildings FTR and FCU system on each floor. Based on the internal building temperature, the AC Units will be supplying 90 degree F +/- supply air to each floor. The GSHP will be in full heat mode, where heat will be extracted from the ground at a temperature of 36.6 degree F and distributed to the chiller heat recovery unit where the heat pump supply water temperature will be increased to the optimal temperature (max of 135 degree F) and distributed to each AC Unit coils. In this mode the AC Units heating and cooling coils will be used for heating the return air to the desired temperature based on the building requirements. energized and the heating or cooling requirement of the building. As the OAT drops to below 15 degree F +/- the heating requirements of the building will increase to the point where the new condensing boiler will not only provide 180 degree F HW for the FTR, etc, but also will supplement the heat pump loop to maintain a loop temperature of around 135 degree F to the AHU's as the bore field will not be able to maintain the required loop temperature required for heating. The 180 degree F heating loop will be on a temperature reset schedule, where the loop temp will be set on a sliding scale proportional to a corresponding OAT.

TRANSITIONAL OPERATION (HEATING & COOLING) – SHOULDER SEASON

As the season changes from Winter to Summer, the OAT rises and/or the buildings internal heat load increases there will be a need to provide both heating and cooling at the same time. In this scenario, there will be a small chiller that will be energized that provides chilled water to the cooling loop while the heat pump loop is still in the heating mode along with the 180 degree F loop which will allow for both heating and cooling to occur at the same time.

As the season changes from Summer to Winter, the OAT decreases and/or the buildings internal heat load decreases there will be a need to provide both heating and cooling at the same time. In this scenario, the main chiller will be deenergized and the small chiller will be energized to provide chilled water to the cooling loop which will allow for both heating and cooling to occur at the same time. The heat pump loop will operate in heating mode along with the 180 degree F loop for FTR operation.

COOLING SEASON

As the OAT rises above 65 degree F +/- and becomes a cooling only operation, the heating boilers are deenergized and the chiller generates chilled water a distributes to the AC Units cooling coil and interior zone cooling coils to maintain zone cooling setpoints. The heat from the chiller condenser is rejected to the GSHP loop which is maintained at 90.2 degree F and rejected to the ground through the bore field. In this mode, the control strategy is more in-line with a traditional chilled water system, except heat is rejected to the ground as opposed to the evaporative cooling tower. The one caveat to this is that we have incorporated a closed-circuit cooler (replaces the open cooling tower), where this will be used for heat rejection during peak cooling design periods working in parallel with the GSHP heat rejection system. This strategy will reduce the bore field heat saturation over the course of the cooling season.

DETAILED COST ESTIMATE

Material costs were estimated to +/- 20% based on vendor quotes and 2020 RS Means and labor costs were estimated as a percentage of the material cost. Separate cost estimates were provided for the GSHP system's source-side and supply-side. On the source-side cost estimates were provided for drilling 60 boreholes to 499-feet deep, casing for each borehole, all associated HDPE looping, grouting for each borehole, and tie-in of all boreholes together and tie-in to the mechanical equipment. Additional costs were estimated for excavation and trenching as well as pumps to pump the heat exchange fluid.

On the supply-side cost estimates were provided for the installation of two new high temp heat pump units with a heat pump coil for the chilled water or hot water operation as well as pumps to circulate the chilled water or hot water between the AHUs and the heat pumps. Based on existing loads and capacity of the GSHP loop, preliminary estimates determined that the installation of one 200-ton magnetic bearing multi-stack chiller, one 40-ton multi-stack scroll heat pump chiller, and a closed circuit cooling tower would meet the cooling loads of the Building. Additionally, two 800 MBH condensing boilers would meet the heating loads of the Building. An adder for a new mechanical space to house new equipment was included in the implementation cost, but based on the existing mechanical room layout, it appears use of the existing mechanical could be viable (see Mechanical Room Plan).

Including all required work for the GSHP measure (ECM 8b), the final cost per well for 60 wells is $47,886. Costs were estimated using a combination of driller and vendor estimates as well as RS Means.

Table 22: ECM8b - GSHP Summary

Summary of Estimated System Costs	
Source-Side	$ 820,000
Supply-Side	$ 813,144
Demolition	$ 95,000
Total	$ 1,728,144
% Markup	10%
Project Cost	$ 1,900,958
Net Project Cost*	**$ 2,873,187**
Cost/Well	**$ 47,886**

*Note: Net Project Cost includes all NYPA CPC costs, before financing

LIFE CYCLE COST ANALYSIS

A 20-year life-cycle cost analysis (LCCA) was completed by NYPA and is included here for reference. The LCCA compared the base case ECMs 8.a.1 – Boilers and 8.a.2 – Chillers to the alternative ECM 8.b. – GSHP. This analysis assumed that the boilers in ECM 8.a.1 were replaced immediately at Year 0, and the chillers would be replaced at Year 10 (assumes 10 years of useful life remaining). ECM 8.b.1 was assumed to be fully installed at Year 0 and there would no major component replacements over the 20-year analysis period. The energy cost was escalated at based on the Energy Information Administration's (EIA) energy price projects for NYS over the 20-year period. The BLCC analysis uses a 2.5% discount rate provided by the Federal Energy Management Program (FEMP) to account for inflation for renewable energy projects. The analysis also uses a variable energy escalation rate provided by the Department of Energy (DOE). There were no operation and maintenance (O&M) savings credited in the analysis, assuming that comparable O&M is required in the base case and alternate scenarios. Due to the substantially higher initial capital cost of the GSHP and low cost of natural gas, the total present value life-cycle cost was negative $242,176.

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs Paid By Agency:			
Capital Requirements as of Base Date	$985,795	$3,456,022	-$2,470,227
Future Costs:			
Recurring and Non-Recurring Contract Costs	$0	$0	$0
Energy Consumption Costs	$1,392,236	$1,155,660	$236,576
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	-$77,529	-$2,069,004	$1,991,475
	------------	------------	------------
Subtotal (for Future Cost Items)	$1,314,707	-$913,344	$2,228,051
	------------	------------	------------
Total PV Life-Cycle Cost	$2,300,503	$2,542,678	-$242,176

Figure 19: Life Cycle Comparison of Present-Value Costs

ECM 9: CONTROLS OPTIMIZATION

Original commissioning documentation could not be obtained, and it is uncertain if commissioning was originally completed for the Office Building. If the hybrid GSHP system is installed, the entire system will be commissioned to ensure that is functioning according to the design intent. If it is decided to not proceed with the hybrid GSHP system, it is still recommended to optimize the existing controls and retro-commission the existing building systems for the following reasons:

- Energy savings
- Restoring equipment function to original operation
- Reduction of occupant complaints
- Increased equipment life
- Improved indoor air quality
- Updated O&M requirements

This will also result in an updated baseline for the Office Building's operation that can be utilized for ongoing commissioning as well as future energy audit and design projects. Energy savings and cost estimates for this measure were based on studies completed by ASHRAE, PNNL, and Energy Star using a dollar per square foot metric.

ECM 10: BUILDING ENVELOPE UPGRADE

Due to the Building's curtain wall construction, maintaining comfort within the building around the perimeter is difficult due to the high conductive heat losses and gains due to thermal bridging through the aluminum framing and high infiltration rates. The windows are single pane with insulated glazing and have not been upgraded since the original construction. It is proposed to install a curtainwall retrofit window system that will reduce convective and conductive heat transfer from the windows. This type of system was selected due to its simplicity to install and lower capital cost compared to completely overhauling the existing envelope. The system can be installed during normal operating hours with minimal disruption to daily activities and does not change the exterior appearance of the building as it is installed from the inside. Although this will not solve all the comfort issues reported by staff, it will reduce them along with reducing the heating and cooling loads served by mechanical equipment.

Section 6
Next Steps

REVIEWED BUT NOT RECOMMENDED CAPITAL IMPROVEMENTS

A number of potential ECMs were not currently recommended due to high cost, low savings, or installation difficulty.

IMP 1: BUILDING LIGHTING CONTROL RETROFIT

The common area hallway lighting for each floor is integrated into the building's security system. The security system is deactivated at 6AM turning the lights on and deactivated at midnight turning all of the lights off. If the system is deactivated at any point after midnight, it forces all of the common area lighting back on in the building no matter what floor the individual is accessing. It is proposed to install an occupancy sensor control at the light panel relay of each floor so that the fixtures are energized only when an occupant is present. The length of time that the fixtures stay active during occupied periods can be adjusted so they do not turn off prematurely. This will also allow the light schedule to be adjusted to an earlier time as there is infrequent occupancy on most floors after typical business hours. However, due to the high cost of replacement and a recent LED fixture retrofit, this measure is not recommended for implementation.

IMP 2: STAIRWELL LIGHT SENSOR RETROFIT

There are two linear LED fixtures per floor, one at the floor entrance and the other at the landing between floors. To comply with lighting code, these fixtures are energized 24/7 for emergency egress purposes. A minimum level of illumination can be maintained with once fixture energized at a time during unoccupied periods of time. It is proposed to install an occupancy sensor on the landing fixtures to deenergize them when the building is unoccupied. The fixtures at the floor level will remain unchanged. However, due to the high cost of replacement and a recent LED fixture retrofit, this measure is not recommended for implementation.

IMP 3: FRONT ENTRANCE VESTIBULE MODIFICATIONS

The front entrance experiences a high volume of foot traffic as it is the main entrance for the DMV. There are two sets of double swinging doors to enter the vestibule and an additional two sets to enter the lobby. It was reported by facility staff that the outermost doors are frequently damaged due to wind and have difficulties closing, allowing more air into the vestibule. Additionally, the three supply air diffusers from AC-2 are located on the floor of the vestibule in between the doors and the four return air registers are located toward the ceiling on the opposite side. It is proposed to reconfigure the supply air diffusers so that they are above the doors to act as an air curtain to keep unconditioned air from entering the vestibule. The existing diffusers will have to be replaced for an option that will increase the velocity and direct the supply air appropriately.

Due to the cost of this measure it was not recommended for implementation. Any modifications to these areas should be completed to satisfy occupant comfort and O&M purposes. Other modifications such as revolving doors were investigated but are not recommended due to the expense as well.

IMP 4: REAR ENTRANCE AIR CURTAIN

The rear entrance has a small vestibule with double automatic sliding doors on each end. Since they are timed to close, they are often both open at the same time as the vestibule is short. This allows outside air to enter the building. Outside air infiltrates at a faster rate when the front doors are open at the same time. To counteract this, air curtains should be installed above the sliding doors to reduce the amount of infiltration.

Like the front vestibule, this measure is cost and savings prohibitive. Other modifications such as revolving doors were investigated but are not recommended due to the expense as well.

IMP 5: INSTALL VFD ON CHILLED WATER PUMP

All AC units are served by the chiller via a chilled water loop and three-way valves. It is proposed to replace the three-way valves at each unit with a two-way valve and install a VFD on the CHWP that serves the loop. The VFD will allow the pump to respond to unit demand based on system pressure. The chiller manufacturer was contacted in order to assess the required pressure and flows in the evaporator of the unit. There was only a small amount of room to reduce the flow and the chiller already has VSD capability. Due to these reasons, the pump turn down using a VFD would be minimal thus the savings would be minimal.

BEST PRACTICE OPPORTUNITIES

REPLACE AC-4 STEAM GENERATORS WITH ULTRASONIC TECHNOLOGY

The existing electric steam generators on AC-4 are not active as there are issues with over humidifying the vault spaces. Instead, the humidity can float during the winter as less humidity is preferred compared to too much. It is proposed that the existing steam generators be removed and that ultrasonic humidifiers be installed in each floor of the vault. It is recommended that these units be supplied with deionized water to reduce future O&M cost but at a higher initial cost. These units will allow for humidity to be controlled independently within each space which can differ based on occupancy and stratification at the common stairwell. Since the steam generators are not currently in operation, there will be no energy savings for this measure, and it is considered a best practice.

Manufacturers report that ultrasonic humidifiers use as little as 1/10th the energy of comparable steam generators.

AC UNIT SCHEDULE REVISIONS

The AC units have an occupied schedule from 6AM to midnight during weekdays and it was reported that county staff sometimes occupy the facility during the evening hours. It is recommended to take a work hour survey of all employees to judge if schedule revisions can be implemented. Since this is a no cost ECM, any revisions to the building schedules will result in immediate energy savings.

ROOF REPLACEMENT

Funding has also been secured to replace the roof which is original to the building. It is recommended to consider any upgrading the roof type at this stage as it will be cost prohibitive to retrofit before the next future replacement. All components of the roof should be inspected, and insulation should potentially be replaced.

COMPRESSED AIR

The existing air compressor serving the pneumatic controls is past the end of its useful life and should be replace as a part of a future capital cost project. The associated air dryer was replaced recently. Additionally, staff should use ultrasonic leak detection equipment to tag the location of compressed air leaks. Regularly checking for and repairing leaks located within the compressed air system can provide electricity savings and reduce operation of the air compressors. Lower compressor operation also results in lower maintenance costs.

TURN OFF COMPUTER EQUIPMENT OVERNIGHT

If computers are left on overnight, they will continue to draw power. The Office Building can utilize the built-in Task Scheduler program on Microsoft Windows computers to set up a daily repeating task of shutting down the computer overnight. This will reduce the overnight phantom load as well as reduce the run time of the computer, resulting in less wear-and-tear on computer components.

MAINTAIN CLEAN AIR FILTERS AND INTAKES

Regularly cleaning the intake screen and providing clean filters to each AC unit could reduce the overall system pressure drop and decrease the load on the supply fans.

Section 7
Measurement and Verification Procedure

MEASUREMENT AND VERIFICIATION PROCEDURE

Measurement and verification for GSHP systems is recommend to use Option D—Calibrated Computer Simulation in the "M&V Guidelines: Measurement and Verification for Performance-Based Contracts". Option D recommends the use of computer simulation software to establish baseline energy consumption of the existing facility's operation by calibrating model outputs with monthly utility data. A separate simulation with the GSHP retrofit measure can be completed to establish energy savings compared to the existing baseline. The GSHP simulation should be calibrated with spot measurements of equipment during the performance period to ensure that actual operating parameters conform to the original design operating parameters. If the actual operation differs from the design operation, the GSHP simulation should be adjusted to reflect actual operation. Example of spot measurements to be logged during the performance period attempt to ascertain equipment efficiency, system performance, and bore field performance and might include:

1. Water temperatures entering and leaving the heat pump
2. Ambient outdoor temperature
3. Supply and return load water temperatures for water-to-water GSHP systems
4. Heat pump unit input kW

Section 8
Energy Analysis Methodology

ENERGY ANALYSIS METHODOLOGY

The basic methodology behind the energy analysis in this report follows the following steps.

1. Annual bills were reviewed and aggregated into a final number. This number was compared with similar building types to understand the relative efficiency of the building. The monthly use was plotted for the two years to understand annual trends. As there were no major anomalies identified, the utility bills were an accurate means of annual energy consumption for the Office Building.
2. Electric and natural gas utility bills were disaggregated through equipment runtime estimation. Lighting counts and runtime were used to establish lighting use. Hot water heating consumption was determined as the sole source of natural gas consumption onsite. Office equipment was counted and noted for utilization during the energy audit to develop use estimates.
3. ECMs savings were then developed through Microsoft Excel® Bin Analysis, percentage-based estimates, and equipment literature. ECM savings were then vetted by comparing them to disaggregated energy use by system and adjusted if necessary, to provide a reliable result.

Appendix A

Project #:	30040573					
Project Name:	Ulster County Office Building					
Engineer:	Arcadis Consulting					
Measure:	Proposed Chiller Design to Alternate Chiller Design					
Alternate Design:						
Location:	**Description:**	**Qty:**	**Material:**	**Labor:**	**Unit Price:**	**Ext. Price:**
Supply-Side	200-ton Mag Bearing Multi-Stack Chiller	1	$264,000.00	$ 79,200.00	$343,200.00	$343,200.00
Supply-Side	40-ton Multi-Stack VME Scroll Heat Pump Chiller	1	$106,500.00	$ 31,950.00	$138,450.00	$138,450.00
					Total Cost:	$481,650.00
					Mark-Up 10%	$ 48,165.00
					Project Cost:	$529,815.00

Ground Loop Design

Borehole Design Project Report - 7/2/2020

Project Name:	**Ulster County Office Bldg**		
Designer Name:	Brian Urlaub		
Date:	7/1/2020	**Project Start Date:**	7/1/2020
Client Name:	**Arcadis**		
Address Line 1:			
Address Line 2:			
City:		**Phone:**	
State:		**Fax:**	
Zip:		**Email:**	

Calculation Results

Design Method: *Design Day*	**COOLING**	**HEATING**
Total Bore Length (ft):	**29940.0**	**29940.0**
Borehole Number:	**60**	**60**
Borehole Length (ft):	**499.0**	**499.0**
Ground Temperature Change (°F):	**-0.3**	**-0.3**
Unit Inlet (°F):	**80.8**	**41.6**
Unit Outlet (°F):	**90.2**	**36.6**
Total Unit Capacity (kBtu/Hr):	**2050.4**	**1745.0**
Peak Load (kBtu/Hr):	**2050.4**	**1643.2**
Peak Demand (kW):	**108.2**	**175.4**
Heat Pump EER/COP:	**18.9**	**2.7**
System EER/COP:	**18.9**	**2.7**
System Flow Rate (gpm):	**512.6**	**410.8**

Input Parameters

Fluid		**Soil**	
Flow Rate	3.0 gpm/ton	Ground Temperature:	55.0 °F
Fluid:	25.0% Propylene Glycol	Thermal Conductivity:	1.49 Btu/(h*ft*°F)
Specific Heat (Cp):	1.01 Btu/(°F*lbm)	Thermal Diffusivity:	1.16 ft^2/day
Density (rho):	62.4 lb/ft^3		

Piping	
Pipe Type:	1 1/4 in. (32 mm)
Flow Type:	Turbulent - SDR11
Pipe Resistance:	0.104 h*ft*°F/Btu
U-Tube Configuration:	Single
Radial Pipe Placement:	Average
Borehole Diameter:	5.00 in
Grout Thermal Conductivity:	1.20 Btu/(h*ft*°F)
Borehole Thermal Resistance:	0.198 h*ft*°F/Btu

Input Parameters (Cont.)

Pattern

Vertical Grid Arrangement:	12 x 5
Borehole Number:	60
Borehole Separation:	20.0 ft
Bores Per Circuit	1
Fixed Length Mode	On
Grid File	None

Modeling Time Period

Prediction Time: 5.0 years

Long Term Soil Temperatures:

Cooling: 54.7 °F

Heating: 54.7 °F

Default Heat Pumps

Manufacturer: Chillit Chillers LLC
C6H-40T Series

Design Heat Pump Inlet Load Temperatures:

	Cooling (WB)	*Heating (DB)*
Water to Air:	67 °F	70 °F
Water to Water:	55 °F	100 °F

Optional Hybrid Loads

	Cooling	Heating
Geo Peak (%)	80%	79%
Geo Total (%)	80%	79%
Hybrid Peak (%)	20%	21%
Hybrid Total (%)	20%	21%

Extra kW

Pump Power	0.0 kW
Cooling Tower Pump:	0.0 kW
Cooling Tower Fan:	0.0 kW
Additional Power	0.0 kW

Loads File

Ulster Co Load Profile 7.1.20.zon

Loads

Design Day Loads

Time of Day	*Heat Gains (kBtu/Hr)*	*Heat Losses (kBtu/Hr)*
8 a.m. - Noon	27.7	1643.2
Noon - 4 p.m.	2050.4	691.7
4 p.m. - 8 p.m.	27.7	691.7
8 p.m. - 8 a.m.	27.7	691.7

Annual Equivalent Full-Load Hours

COOLING 551 *HEATING* 1520

Days Occupied per Week: 5.0

Monthly Loads on Next Page

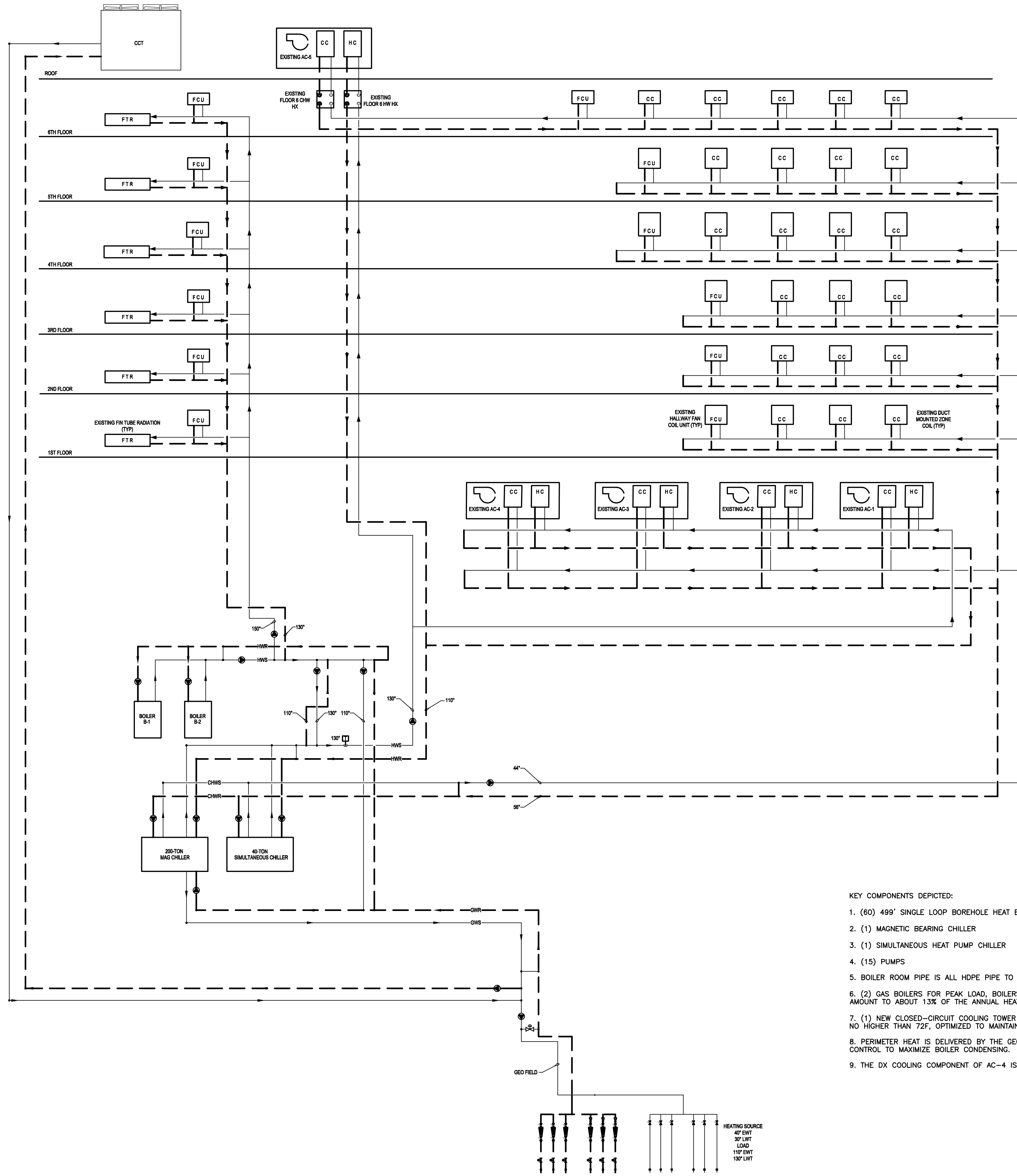
Monthly Loads Data				
	Cooling		Heating	
	Total (kBtu)	**Peak** (kBtu/hr)	**Total** (kBtu)	**Peak** (kBtu/hr)
January	0	0	542533	1643
February	0	0	451165	1643
March	0	0	379697	1292
April	0	0	245760	989
May	106334	1874	43839	628
June	259331	2050	0	0
July	282596	2050	0	0
August	317724	2050	0	0
September	128110	1992	0	0
October	35386	1936	90547	1283
November	0	0	304595	1125
December	0	0	440337	1643
Total	**1129481**		**2498473**	
Hours at Peak		**3.0**		**3.0**

Hourly Loads Data

Included: None

Filename: None

PRELIMINARY DESIGN - SUBJECT TO CHANGE



KEY COMPONENTS DEPICTED:

1. (60) 499' SINGLE LOOP BOREHOLE HEAT EXCHANGERS
2. (1) MAGNETIC BEARING CHILLER
3. (1) SIMULTANEOUS HEAT PUMP CHILLER
4. (15) PUMPS
5. BOILER ROOM PIPE IS ALL HDPE PIPE TO ALLOW LARGER PIPE SIZES WITH LOWER PUMP HEAD LOSS. LONG LIFE LOW MAINTENANCE PIPING.
6. (2) GAS BOILERS FOR PEAK LOAD, BOILERS ARE INTENDED TO REMOVE ABOUT 20% OF THE PEAK MBH HEATING REQUIREMENT, BUT OPERATION SHOULD ONLY AMOUNT TO ABOUT 13% OF THE ANNUAL HEATING ENERGY DUE TO THE LOW BIN HOURS OF OPERATION.
7. (1) NEW CLOSED–CIRCUIT COOLING TOWER IS EMPLOYED IN A HYBRID CONFIGURATION TO KEEP GROUND WATER MAXIMUM HEAT TO AN EWT AT THE CHILLERS NO HIGHER THAN 72F, OPTIMIZED TO MAINTAIN 65F EWT UNDER MOST CONDITIONS.
8. PERIMETER HEAT IS DELIVERED BY THE GEOEXCHANGE SYSTEM DOWN TO ABOUT 29F OUTSIDE THEN SWITCHED OF TO BOILERS WITH AN OUTDOOR RESET CONTROL TO MAXIMIZE BOILER CONDENSING.
9. THE DX COOLING COMPONENT OF AC–4 IS A REDUNDANT BACK UP COOLING SYSTEM AND SHALL BE MAINTAINED.

ARCADIS

LEGAL ENTITY:
ARCADIS U.S., INC.

CONSULTANTS

SEALS

**30% SUBMITTAL
DO NOT USE FOR
CONSTRUCTION**

KINGSTON, NY
ULSTER COUNTY

GEOTHERMAL CLEAN ENERGY CHALLENGE STAGE 3 REPORT FOR ULSTER COUNTY OFFICE BUILDING

ARCADIS PROJ. NO. 30040573

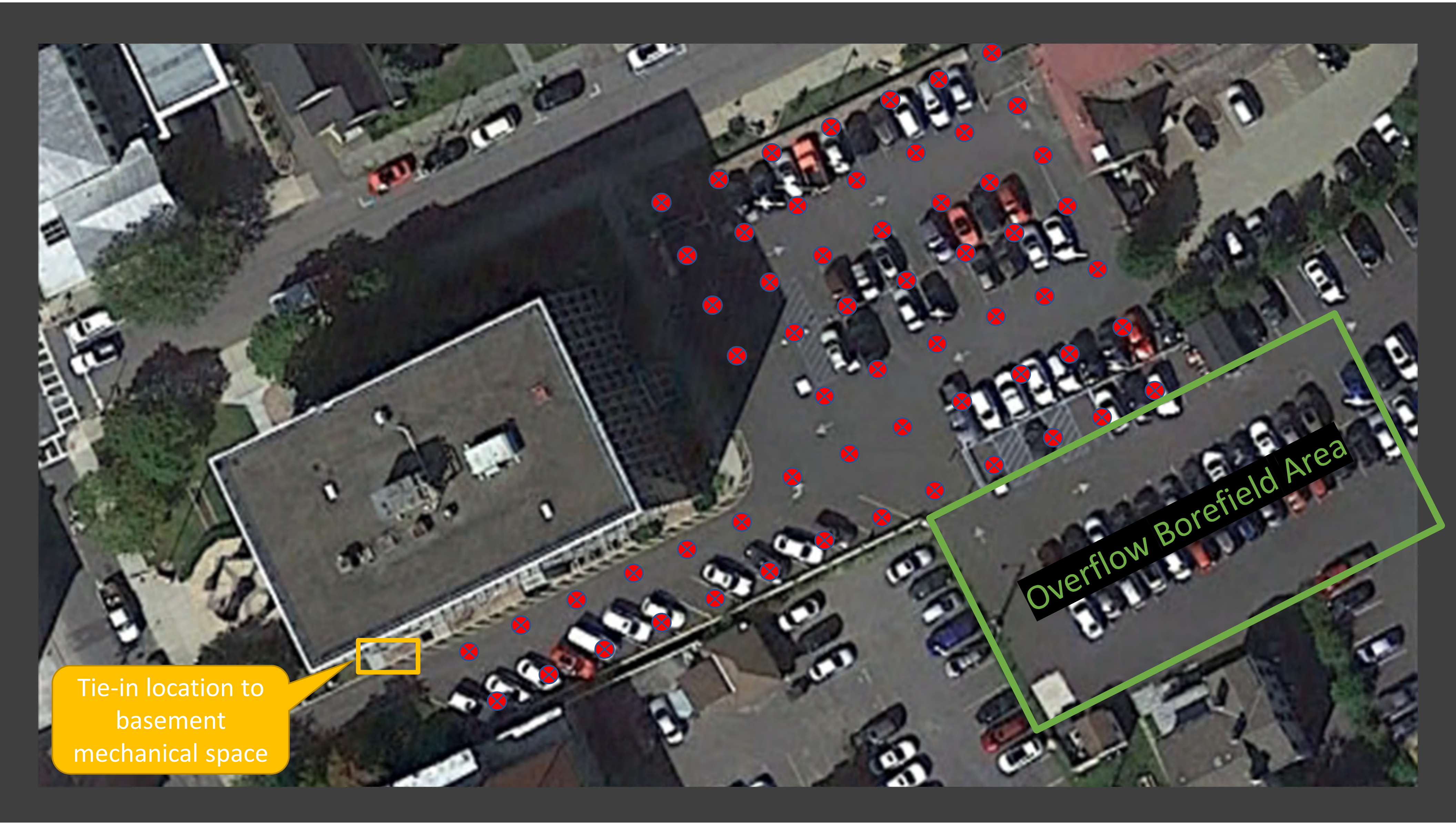
NO.	DATE	ISSUED FOR	BY

DATE: JULY 2020
PROJECT NO.: 30040573
FILE NAME: ULSTER GSHP ONE–LINE
DESIGNED BY:
DRAWN BY:
CHECKED BY:

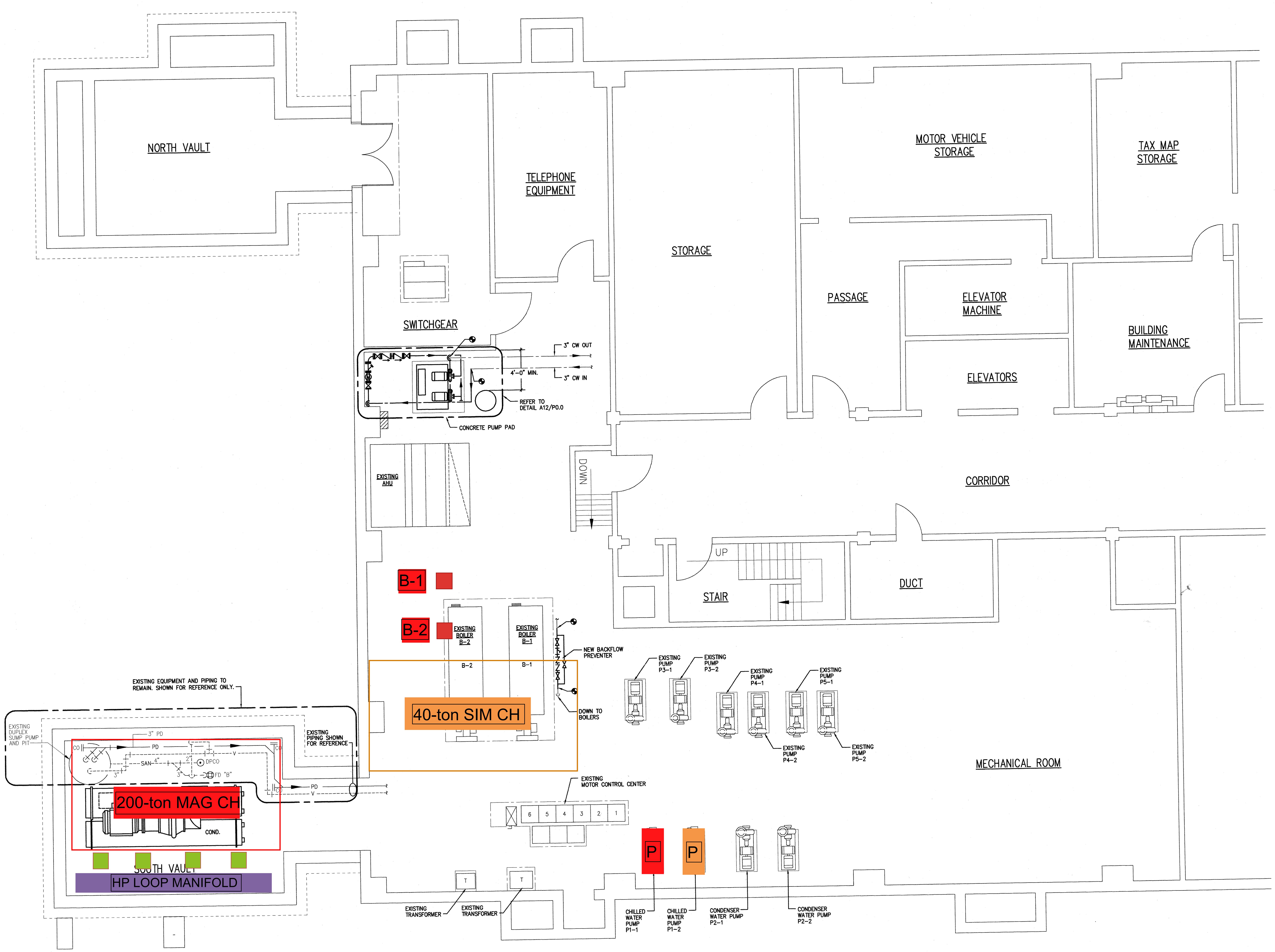
SHEET TITLE

SCALE:
NO SCALE

SHEET ______ OF XXX


Tie-in location to basement mechanical space
Overflow Borefield Area

TENTATIVE MECHANICAL ROOM EQUIPMENT LAYOUT



A1/P1.0 *PLUMBING PIPING BASEMENT PLAN*

SCALE: 1/4"=1'-0"

IT IS A VIOLATION OF THE LAW FOR ANY PERSON, UNLESS HE IS ACTING UNDER THE DIRECTION OF A LICENSED PROFESSIONAL ENGINEER, TO ALTER THIS DRAWING IN ANY WAY. ALTERATIONS MUST HAVE THE SEAL AFFIXED ALONG WITH A DESCRIPTION OF THE ALTERATION, THE SIGNATURE AND DATE.

CONTRACTOR SHALL VERIFY ALL DIMENSIONS AT SITE. UNAUTHORIZED ALTERATIONS OR ADDITIONS TO THIS DOCUMENT IS A VIOLATION OF THE NEW YORK STATE EDUCATION LAW.

No.	REVISIONS/SUBMISSIONS	Date

0 1" 2" 3"

ULSTER COUNTY OFFICE BUILDING
CHILLER REPLACEMENT
244 FAIR STREET
KINGSTON, NEW YORK

RICHARD R. STEPHENS
CONSULTING ENGINEER, P.C.
621 COLUMBIA STREET EXTENSION
COHOES, NEW YORK 12047
PHONE (518) 786-6466 FAX (518) 786-6366

KENNETH HEWES BARRICKLO ARCHITECT, P.C.
173 GREEN STREET
KINGSTON, NEW YORK 12401
PHONE (845) 339-0058 FAX (845) 339-7380

Drawing Title

PLUMBING PIPING BASEMENT PLAN

Seal		
	Designed RRS	Project No. 2315
	Drawn MEH	CAD File No. M:\DWG\2003\2315\2315P\2315PP\2315P1.0
	Checked RRS	Drawing No. **P1.0**
	Scale 1/4"=1'-0"	
	Date SEPTEMBER 19, 2003	3 OF 3

Appendix B

ARCADIS | Design & Consultancy for natural and built assets

Project #: 30040573
Project Name: Ulster County Geothermal
Engineer: Chris Muller
Measure: ECM 18a and 18b

ECM 8a. - Baseline

Location	Item	Qty	Material	Labor	Unit Price	Cost
Supply-Side	Condensing Boilers	2	$ 70,000	$ 46,000	$ 116,000	$ 232,000
	Variable Speed Chiller	1	$ 175,000	$ 66,000	$ 241,000	$ 241,000
					Total	**$ 473,000**
					% Markup	10%
					Project Cost	**$ 520,300**
					Boiler Only	$ 255,200

ECM 8b. Proposed

Location	Description	Qty	Material	Labor	Unit Price	Ext. Price
Source-Side Opt #1	HDPE 1-1/4" UBend500 FT	0			$ 1,017,775	$ -
Source-Side Opt #2	GeoperformX Double 1-1/2" U-Bend 900 FT	0			$ 759,107	$ -
Source-Side Opt #3	Concentric 5"x3"GeoperformX, 1610FT	0			$ 673,682	$ -
Source-Side Opt #4	Concentric 7"x4"GeoperformX, 2270FT	0			$ 651,829	$ -
Source-Side Opt #5	500' Drilled bores, 80' casing, looping, grouting, bore tie-in	1			$ 700,000	$ 700,000
	Excavation	1			$ 100,000	$ 100,000
	Source Side Pumps	1			$ 20,000	$ 20,000
Supply-Side	200-ton Mag Bearing Multi-Stack Chiller	1	$ 264,000	$ 79,200	$ 343,200	$ 343,200
	40-ton Multi-Stack VME Scroll Heat Pump Chiller	1	$ 106,500	$ 31,950	$ 138,450	$ 138,450
	Closed-Circuit Cooling Tower	1	$ 160,000	$ 20,000	$ 180,000	$ 180,000
	Supply Side Pumps/Piping	1	$ 20,200	$ 5,700	$ 25,900	$ 25,900
	800MBH Gas Boilers	2	$ 16,732	$ 5,020	$ 21,752	$ 43,503
	Camus Boiler Pumps	2	$ 804	$ 241	$ 1,045	$ 2,090
	Mechanical Room Adder	1	$ 40,000	$ 20,000	$ 60,000	$ 60,000
Cx	Commissioning	1	$ -	$ 20,000	$ 20,000	$ 20,000
Demo	Boilers	2	$ -	$ 20,000	$ 20,000	$ 40,000
	Chiller	1	$ -	$ 30,000	$ 30,000	$ 30,000
	Cooling Tower	1	$ -	$ 25,000	$ 25,000	$ 25,000
	Chiller Salvage	1	$ -	$ -	$ -	$ -
					Total	$ 1,728,144
					% Markup	10%
					Project Cost	**$ 1,900,958**
					Cost/Well	**$ 31,683**

ARCADIS | Design & Consultancy for natural and built assets

Project #: '30040573
Project Name: Ulster County Geothermal
Engineer: Chris Muller
Measure: ECM 8b - GSHP Compared to Baseline ECM8a

Savings Type	Peak Baseline	Peak Proposed	Savings
kW*	134.0	-69.2	$ 394.25
kWh	187,398	-145,625	$ 3,312.17
therms	23,272	-4,802	$ 17,247.09
		Total	**$ 20,953.51**

*kW cost savings calculated separetely as monthly savings vary

Load Reductions	
Cooling (MMBtu)	Heating (MMBtu)
143	1,847

Incremental Cost Analysis				
		Baseline[1]	Proposed[2]	Incremental Cost Difference
$	Implementation Cost	$ 520,300.00	$ 1,900,957.96	**$ 1,380,657.96**

Summary of Incremental Cost Savings	
Total Implementation Incremental Cost	$ 1,380,657.96
Annual Cost Savings	$ 19,793.94
Simple Payback Period	69.8

Notes:

1. The Baseline Implementation Cost assumes the replacement of both boilers and the chiller, including labor.
2. The Proposed Scenario Implementation Cost assumes the replacement removal of the existing boilers and chiller, as well as the installation of all GSHP components, including all costs associated with the loop as well as the mechanical equipment

Appendix C

FORMATION THERMAL CONDUCTIVITY
TEST & DATA ANALYSIS

TEST LOCATION	**Ulster County Office Building** **Kingston, NY**
TEST DATE	January 31 – February 3, 2020
ANALYSIS FOR	Wragg Well Drilling & Pump Service LLC 172 Baker Road Roxbury, CT 06783 Phone: (860) 354-1989
TEST PERFORMED BY	Wragg Well Drilling & Pump Service LLC

Executive Summary

A formation thermal conductivity test was performed on the geothermal bore at the Ulster County Office Building site at 244 Fair St. in Kingston, New York. The vertical bore was completed on January 20, 2020 by Wragg Well Drilling & Pump Service. Geothermal Resource Technologies' (GRTI) test unit was attached to the vertical bore on the afternoon of January 31, 2020.

This report provides an overview of the test procedures and analysis process, along with plots of the loop temperature and input heat rate data. The collected data was analyzed using the "line source" method and the following average formation thermal conductivity was determined.

Formation Thermal Conductivity = 1.49 Btu/hr-ft-°F

Due to the necessity of a thermal diffusivity value in the design calculation process, an estimate of the average thermal diffusivity was made for the encountered formation.

Formation Thermal Diffusivity ≈ 1.16 ft^2/day

The undisturbed formation temperature for the tested bore was established from the initial loop temperature data collected at startup.

Undisturbed Formation Temperature ≈ 54.3-55.5°F

The formation thermal properties determined by this test do not directly translate into a loop length requirement (i.e. feet of bore per ton). These parameters, along with many others, are inputs to commercially available loop-field design software to determine the required loop length. Additional questions concerning the use of these results are discussed in the frequently asked question (FAQ) section at www.grti.com.

TEST PROCEDURES

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) has published recommended procedures for performing formation thermal conductivity tests in the ASHRAE HVAC Applications Handbook, Geothermal Energy Chapter. The International Ground Source Heat Pump Association (IGSHPA) also lists test procedures in their Design and Installation Standards. GRTI's test procedures meet or exceed those recommended by ASHRAE and IGSHPA, with the specific procedures described below:

Grouting Procedure for Test Loops – To ensure against bridging and voids, it is recommended that the bore annulus is uniformly grouted from the bottom to the top via tremie pipe.

Time Between Loop Installation and Testing – A minimum delay of five days between loop installation and test startup is recommended for bores that are air drilled, and a minimum waiting period of two days for mud rotary drilling.

Undisturbed Formation Temperature Measurement – The undisturbed formation temperature should be determined by recording the loop temperature as the water returns from the u-bend at test startup.

Required Test Duration – A minimum test duration of 36 hours is recommended, with a preference toward 48 hours**.**

Data Acquisition Frequency - Test data is recorded at five minute intervals.

Equipment Calibration/Accuracy – Transducers and datalogger are calibrated per manufacturer recommendations. Manufacturer stated accuracy of power transducers is less than ±2%. Temperature sensor accuracy is periodically checked via ice water bath.

Power Quality – The standard deviation of the power should be less than or equal to 1.5% of the average power, with maximum power variation of less than or equal to 10% of the average power.

Input Heat Rate – The heat flux rate should be 51 Btu/hr (15 W) to 85 Btu/hr (25 W) per foot of installed bore depth to best simulate the expected peak loads on the u-bend.

Insulation – GRTI's equipment has 1 inch of foam insulation on the FTC unit and 1/2 inch of insulation on the hose kit connection. An additional 2 inches of insulation is provided for both the FTC unit and loop connections by insulating blankets.

Retesting in the Event of Failure – In the event that a test fails prematurely, a retest may not be performed until the bore temperature is within 0.5°F of the original undisturbed formation temperature or until a period of 14 days has elapsed.

Data Analysis

Geothermal Resource Technologies, Inc. (GRTI) uses the "line source" method of data analysis to determine the thermal conductivity of the formation. The line source method assumes an infinitely thin line source of heat in a continuous medium. A plot of the late-time temperature rise of the line source temperature versus the natural log of elapsed time will follow a linear trend. The linear slope is inversely proportional to the thermal conductivity of the medium. Applying the line source method to a u-bend grouted in a borehole, the test must be run long enough to allow the finite dimensions of the u-bend pipes and the grout to become insignificant. Experience has shown that approximately ten hours is required to allow the error of early test times and the effects of finite borehole dimensions to become insignificant.

In the analysis of the data from the formation thermal conductivity test, the average temperature of the water entering and exiting the u-bend heat exchanger was plotted versus the natural log of elapsed testing time. Using the Method of Least Squares, linear coefficients were calculated that produce a line that fit the data. This procedure was repeated for various time intervals to ensure that variations in the power or other effects did not produce inaccurate results.

The calculated results are based on test bore information submitted by the driller/testing agency. GRTI is not responsible for inaccuracies in the results due to erroneous bore information. All data analysis is performed by personnel that have an engineering degree from an accredited university with a background in heat transfer and experience with line source theory. The test results apply specifically to the tested bore. Additional bores at the site may have significantly different results depending upon variations in geology and hydrology.

Through the analysis process, the collected raw data is converted to spreadsheet format (Microsoft Excel®) for final analysis. If desired, please contact GRTI and a copy of the data will be made available in either a hard copy or electronic format.

Contact: Galen Streich
Regional Managing Engineer
Elkton, SD
Ph: 866-991-4784
gstreich@grti.com

Test Bore Details
(As Provided by Wragg Well Drilling & Pump Service LLC)

Site Name	Ulster County Office Building
Location	Kingston, NY
Driller	Wragg Well Drilling & Pump Service
Installed Date	January 20, 2020
Borehole Diameter	8 inches, 0-126 ft 6 inches, 126-499 ft
Casing	6 inch permanent steel casing to 126 ft
U-Bend Size	1 ¼ inch DR-11 HDPE
U-Bend Depth Below Grade	499 ft
Grout Type	GeoPro TG Lite/PowerTEC
Grout Mixture	100 lb TG Lite, 32 lb PowerTEC, 30 gal water
Grouted Portion	Entire bore

Drill Log

Formation Description	Depth (ft)
Sand	0'-110'
Gray shale	110'-499'

Note: Bore produced approx. 3 gpm water at 200 ft.

Thermal Conductivity Test Data

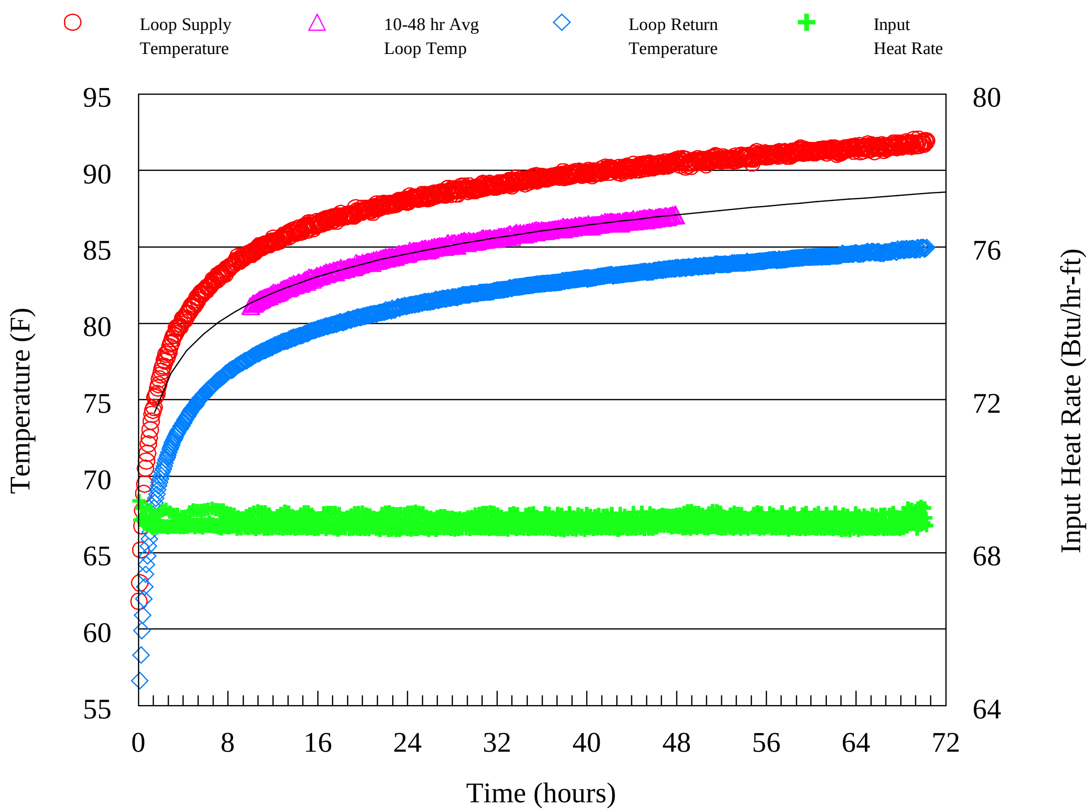


Fig. 1: Temperature & Heat Rate Data Vs Time

Figure 1 above shows the loop temperature and heat input rate data versus the elapsed time of the test. The temperature of the fluid supplied to and returning from the U-bend are plotted on the left axis, while the amount of heat supplied to the fluid is plotted on the right axis on a per foot of bore basis. In the test statistics below, calculations on the power data were performed over the analysis time period listed in the Line Source Data Analysis section.

Summary Test Statistics

Test Date	January 31 – February 3, 2020
Undisturbed Formation Temperature	Approx. 54.3-55.5°F
Duration	70.3 hr
Average Voltage	238.9 V
Average Heat Input Rate	34,316 Btu/hr (10,057 W)
Avg Heat Input Rate per Foot of Bore	68.8 Btu/hr-ft (20.1 W/ft)
Circulator Flow Rate	9.9 gpm
Standard Deviation of Power	0.22%
Maximum Variation in Power	0.47%

LINE SOURCE DATA ANALYSIS

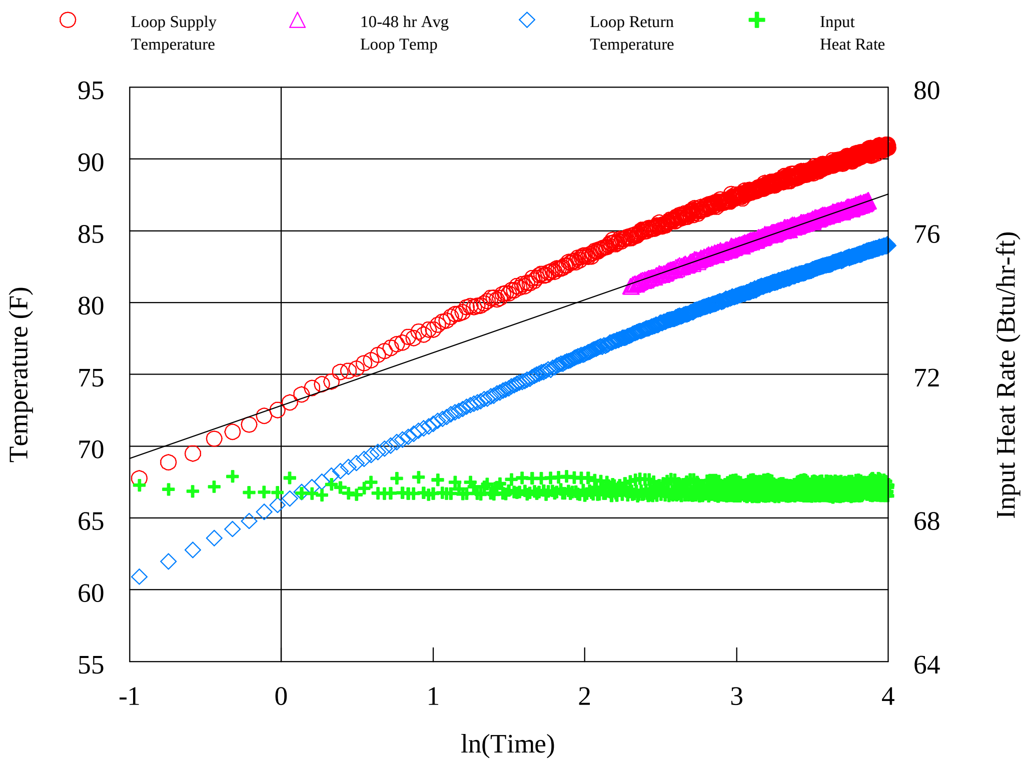


FIG. 2: TEMPERATURE & HEAT RATE VS NATURAL LOG OF TIME

The loop temperature and input heat rate data versus the natural log of elapsed time are shown above in Figure 2. The temperature versus time data was analyzed using the line source method (see page 3) in conformity with ASHRAE and IGSHPA guidelines. A linear curve fit was applied to the average of the supply and return loop temperature data between 10 and 48.0 hours. The slope of the curve fit was found to be 3.69. The resulting thermal conductivity was found to be **1.49 Btu/hr-ft-°F**.

THERMAL DIFFUSIVITY

The reported drilling log for this test borehole indicated that the formation consisted of sand and shale. A heat capacity value for shale was calculated from specific heat and density values listed by Kavanaugh and Rafferty[1]. A weighted average of heat capacity values based on the indicated formation was used to determine an average heat capacity of 30.8 Btu/ft^3-°F for the formation. A diffusivity value was then found using the calculated formation thermal conductivity and the estimated heat capacity. The thermal diffusivity for this formation was estimated to be **1.16 ft^2/day**.

[1]Stephen P. Kavanaugh and Kevin Rafferty, Geothermal Heating and Cooling: Design of Ground-Source Heat Pump Systems (Atlanta: ASHRAE, 2014), 75.

Certificate of Calibration

GRTI maintains calibration of the datalogger, current transducer and voltage transducer on a regular schedule. The components are calibrated by the manufacturer using recognized national or international measurement standards such as those maintained by the National Institute of Standards and Technology (NIST).

FTC Unit 207

DA Unit 60

Primary Equipment		
Component	Calibration Date	Calibration Due Date
Datalogger	7/14/2017	7/14/2020
Current Transducer	7/14/2017	7/14/2020
Voltage Transducer	7/14/2017	7/14/2020

GRTI periodically verifies the combined temperature sensor/datalogger accuracy via a water bath. Temperature readings are simultaneously taken with a digital thermometer that has been calibrated using instruments traceable to NIST.

Date	8/13/2019			
Thermocouple 1 (°F)	32.3 32.3 32.3			
Thermocouple 2 (°F)	32.2 32.2 32.2			
Thermocouple 3 (°F)	32.2 32.1 32.2			
Thermocouple 4 (°F)	32.2 32.1 32.2			
Digital Thermometer (°F)	32.3 32.3 32.3			