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UTEN Feasibility Study

NATIONAL FUEL GAS DISTRIBUTION CORPORATION

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DEFINITIONS & ACRONYMS

Definitions

Baseload Operations	Baseload typically refers to the constant minimum load that the electric system must satisfy. Due to the bi-directional nature of thermal energy networks, the concept of a constant minimum load is less relevant. For purposes of the UTEN pilot projects, baseload operation will represent the majority of the annual load served by the UTEN.
Customer Distribution Network	A closed-loop system of pipes, which contains a fluid and transports energy between the primary distribution network and end-use equipment.
Customer Equipment	Piping, mechanical systems, and other equipment located on the customer side of the demarcation point.
Demarcation Point	Separation point between utility and customer distribution network.
Energy Center	Infrastructure that performs functions for the thermal energy network such as pumping the heat transfer medium, controlling fluid chemistry and temperature, and providing makeup fluid.
Energy Transfer Station (ETS)	Metering equipment and all related pipes, fittings, and other equipment, which may or may not include a heat exchanger, which connects and controls the transfer of energy between the utility distribution system and the customer equipment or thermal energy resource.
ETS Heat Exchanger	A device that transfers thermal energy from the fluid in the primary distribution network to the fluid in the Customer Distribution Network.
Geothermal Borefield	A series of interconnected boreholes that transfer thermal energy between the ground and the primary distribution network.
Heat Transfer Medium	Non-combustible fluid or fluid solution that is used to transfer the thermal energy in a thermal energy network.
Makeup Fluid	Stored heat transfer medium used to maintain thermal energy network operation and system volume.
Peak Load	The maximum thermal load that the thermal energy network will accommodate over a specified period of time (e.g.: in MMBtu/h or MW/h).
Primary Distribution Main Valve	Sectionalizing valve on the primary distribution network.
Primary Distribution Network	A network of pipes that contain a fluid that transports thermal energy among the energy center, any sources or sinks of thermal energy, and customer distribution systems, which is hydronically isolated by ETS heat exchangers.
Primary Distribution Network Main	Horizontal pipeline that carries thermal energy from the Energy Center to a customer's Service Lines.
Pumping Station	Pumping equipment and controls which circulate the fluid in the UTEN primary distribution network.
Service Lines	Piping containing a heat transfer medium between the utility distribution system main(s) and the customer energy transfer station.
Thermal Energy	Piped non-combustible fluids used for transferring heat into and out of buildings for the purpose of eliminating any resultant on-site greenhouse gas emissions of all types of heating and cooling processes, including, but not limited to, comfort heating and cooling, domestic hot water, and refrigeration.

Thermal Energy Network[1]	All real estate, fixtures and personal property operated, owned, used or to be used for or in connection with or to facilitate a utility-scale distribution infrastructure project that supplies thermal energy.
Thermal Energy Resource	An asset or facility that the thermal energy network can use to either extract thermal energy from (source) or reject thermal energy to (sink).
Utility Distribution System	A closed loop system of pipes that contains a fluid that transports thermal energy connecting the energy center(s), thermal energy resource(s), service line(s), and energy transfer station(s).
Utility Distribution System Main(s)	A closed-loop system of horizontal pipe(s) which contains a non-combustible heat transfer medium that transports thermal energy among the energy center(s) and service line(s).
Utility Thermal Energy Network	All real estate, fixtures and personal property owned and operated by a utility, used or to be used for or in connection with or to facilitate thermal energy network distribution infrastructure projects that supply thermal energy. It may also include thermal energy resource(s) owned by the utility.
Waste Heat	Heat energy transferred into the primary distribution network via heat exchanger, which has been recovered from a process that would have otherwise expelled it to the ambient environment.

[1] (New York Consolidated Laws, Public Service Law, 2023)

Commonly Used Acronyms & Abbreviations

ASHP	Air Source Heat Pump
ATL	Ambient Temperature Loop
BMS	Building Management System
BTU	British Thermal Unit
CBECS	Commercial Building Energy Consumption Survey
CLCPA	Climate Leadership and Community Protection Act
COP	Coefficient of Performance
CO_2	Carbon Dioxide
CWA	Clean Water Act
DAC	Disadvantaged Community
DER	Distributed Energy Resource
DPS	Department of Public Service
EC	Energy Community
EER	Energy Efficiency Ratio
GHX	Ground Heat Exchanger
GPM	Gallons Per Minute
GSHP	Ground Source Heat Pump
HVAC	Heating, Ventilation, and Air Conditioning
kW	kilo-Watt (1,000 W)
kWh	Kilo-Watt hours
LPP	Leak Prone Pipe
MBH	Thousand Btu Per Hour
MM	Million, (i.e. $15 MM = $15,000,000)
MT	Metric Tons
NFG	National Fuel Gas Company
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research & Development Authority
O&M	Operation & Maintenance
PON	Program Opportunity Notice
PSC	Public Service Commission
PV	Photovoltaic
PVT	Solar Thermal
SDWA	Safe Drinking Water Act
SF	Square Foot
SPDES	State Pollutant Discharge Elimination System Permit
UTEN	Utility Thermal Energy Network
UTENJA	Utility Thermal Energy Network & Jobs Act
WETS	Waste Energy Transfer Systems
WSHP	Water Source Heat Pump

EXECUTIVE SUMMARY

National Fuel Gas Distribution Corporation has engaged LaBella Associates to conduct a feasibility study for a potential Utility Thermal Energy Network (hereinafter 'UTEN') pilot project located in its New York State service territory. The site is inclusive of a city block of low-income housing development and an existing district heating system serving several municipal buildings in downtown Buffalo, NY. The project was deemed suitable for a district geothermal system, leveraging thermal resources such as vertical boreholes and wastewater heat recovery to meet the thermal loads of the buildings.

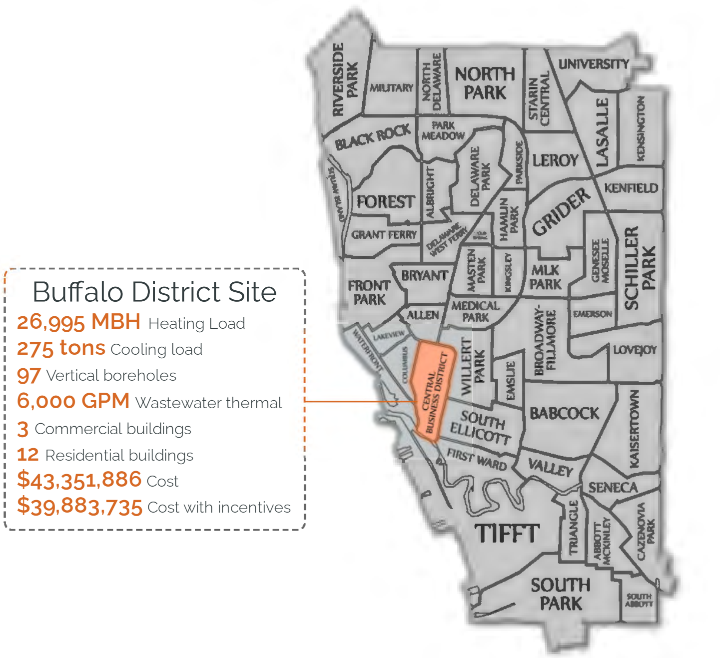

Figure 1: Site Location within City of Buffalo Boundary

The purpose of the study is to evaluate the feasibility of pursuing a UTEN pilot project at the site while ensuring that the system characteristics are in alignment with orders from the New York Department of Public Service (DPS). This was accomplished by developing preliminary schematic design documents, estimating project cost, and assessing the energy and emissions impact for the project. An overview of the methodology applied to the project is included below.

In order to properly assess thermal loads for all proposed UTEN buildings, natural gas consumption was provided to LaBella Associates by National Fuel. This consumption, in conjunction with building type specific load profiles from the NREL ComStock and ResStock database, was used to develop thermal load profiles for each site. From there, an assessment of available thermal resources and characteristics of geology was conducted. By modeling the projected load profiles with the proposed thermal resources, the estimated impact the system would have on ground temperature was determined to ensure that the system was thermally balanced. A pipe configuration analysis was conducted which compared the qualitative and quantitative benefits of each possible system type. This analysis was applied to each site to ensure that the most appropriate piping configuration was selected. Finally, an energy and economic impact analysis was conducted to model the impact that the project would have from the framework of carbon emissions reductions and overall cost.

In addition to the preliminary design of the systems, an assessment of permitting and regulatory requirements was conducted. Through the analysis, (12) Authorities Having Jurisdiction were identified with varying requirements, permits, and timelines.

Buffalo District Heating

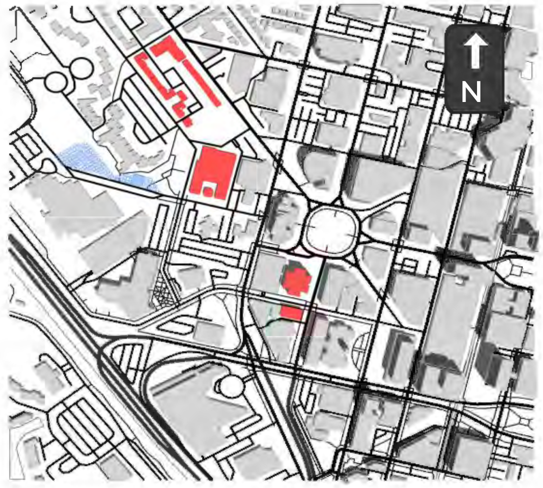

Figure 2: Buffalo District Site

For the Buffalo District site, flow data from a 96-inch sewer main yielded an estimated heating capacity of 26,995 MBH. The majority of the wastewater thermal capacity would be used to preheat the return water from (2) existing natural gas hydronic boilers in an existing district system which currently serves (3) municipal buildings. This effectively baseloads the system and reduces natural gas usage. Approximately 1,000 MBH of the wastewater thermal capacity would work in conjunction with (97) boreholes drilled down to (500) feet to meet the heating loads of the residential housing included at the site. The boreholes would be used to base load the residential buildings while the wastewater would be used to meet peak loads. The boreholes would also be used to meet the cooling load of the residential buildings. A four-pipe configuration was selected for this system's design to simplify tie-in to the existing hot water district system. Additionally, the thermal resources are centrally located which favors a two-pipe or four-pipe system. After inclusion of the IRA's investment tax credit, the net total cost for this project was estimated to be $39,883,735.

TECHNOLOGY OVERVIEW

The following sections will outline all technologies assessed in the study including HVAC equipment, thermal resources, and piping configurations. The information included below will serve as groundwork to establish the terms and techniques later used in the sections of the report specific to the proposed UTEN pilot project.

OVERVIEW OF GEOTHERMAL SYSTEMS

Geothermal energy broadly refers to thermal energy beneath the earth's surface that can be brought to the surface for use for heating, cooling, or to generate electricity. In a geothermal (or ground source) heat pump system. The earth's relatively constant temperature is used as an exchange medium instead of outside air.

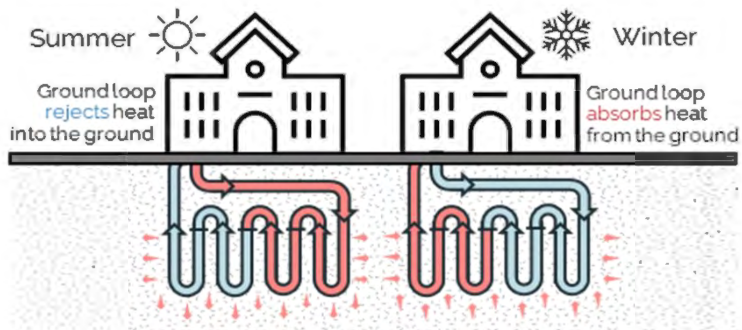

Figure 3: Geothermal Heating & Cooling Conceptual Diagram

In a traditional closed-loop system, fluid is pumped down into the earth through a series of buried pipes which acts as a heat exchanger to heat or cool the fluid before being pumped to a heat pump to condition spaces or heat water (Figure 3). By leveraging the temperature of the earth, building systems are able to operate more efficiently for both heating and cooling purposes when compared to technologies such as an air-source heat pump.

The most common end use of geothermal heat pump systems is space heating and cooling, along with water heating applications. Traditional applications involve a single closed loop ground heat exchanger(s) that are piped into a single building serving its heating and cooling loads. With recent legislation discouraging the use of natural gas, the concept of utility thermal energy network applications has become more popular; linking together several different buildings within a single network, all served by a common set of ground heat exchangers. This approach allows buildings to offset thermal loads using their inherent load diversity and creates an economy of scale that makes this approach more cost effective in most circumstances.

The most common types of ground heat exchangers involve vertical boreholes drilled straight down into the earth; however, this is not the only type of feasible system. Due to geological constraints, available land area, surrounding infrastructure, and other site considerations, a variety of other thermal sources/sinks can be used instead of or in addition to traditional vertical boreholes. Additional thermal sources include, but are not limited to horizontal borefields, perched aquifers, geothermal piles, sewer main lines, complimentary building loads, and surface water resources.

DISTRICT ENERGY SYSTEMS

The primary concept behind a utility thermal energy network system is to provide a shared loop between multiple buildings in order to allow for the exchange of thermal energy between buildings that have diverse thermal load profiles. The sharing of these loads allows the system to have a more balanced loop and therefore reduces the need for boreholes in the ground to act as the sole energy source in the networked system. The loop is pumped by a series of circulation pumps and feed water-source heat pumps in the connected buildings.

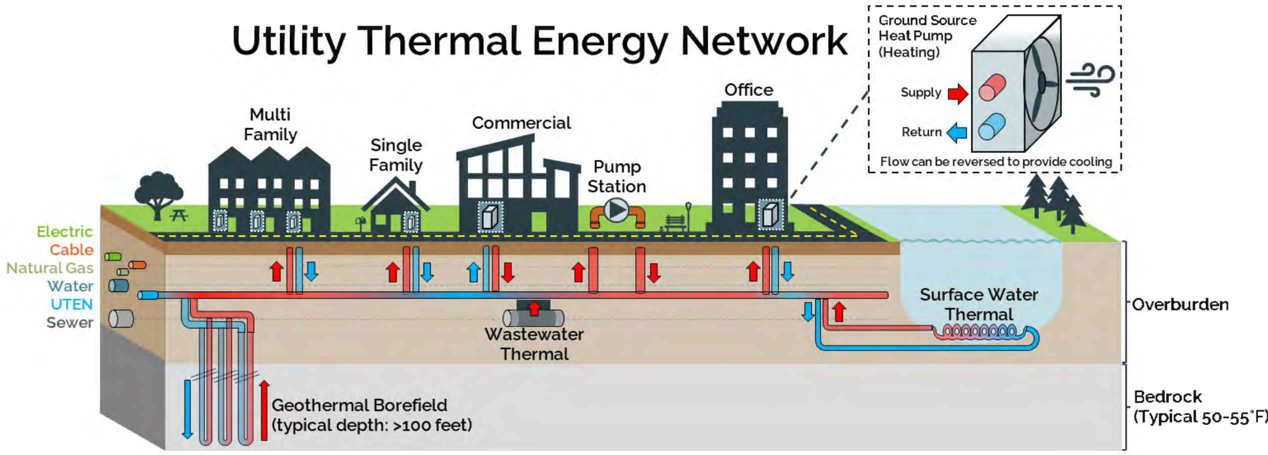

Figure 4: Utility Thermal Energy Network Example Conceptual Graphic

In the above example, the system uses vertical boreholes, surface water, and wastewater thermal as thermal resources. The system also benefits from the cooling dominant commercial building which helps to balance the heating dominant residential and office buildings. From a performance perspective, the greater the number of buildings that are connected to a common loop, particularly with a diverse set of heating and cooling load profiles, the greater the potential economic advantage is to the system. This economic advantage will be realized in a lower installation cost and more efficient heat pump operations, lowering the connected buildings operating costs long term.

There are several types of ground source heating systems, commonly categorized as generations. The different generations of loop technology demonstrate advances made in system design over the course of the last 20 years.

4G Systems

A 4G utility thermal energy network system features a central plant distribution network with a 4-pipe configuration. Separate hot and cold distribution pipes are used, each with a separate supply and return. The separate hot and cold distribution network pipes require water setpoints for heating that are much higher than needed for the heating discharge air and water setpoints for cooling that are much lower than needed for cooling discharge air, resulting in lower overall system-wide efficiency. Benefits of a 4-pipe system include less variance in the temperatures supplied to buildings throughout the loop.

In 4G systems, distributed multi-source thermal energy resources (geothermal, solar thermal, surface water, wastewater) must be integrated into the central plant. In addition, waste heat from cooling-dominant loads cannot be recycled throughout the loop in this scenario.

5G systems

A 5G ambient temperature loop system features a network of interconnected single-pipe loops. Ambient temperature water is typically circulated and maintained between 30°F to 95°F. Multiple sources of thermal energy resources can be connected to the loop including ground source, solar thermal, surface water, and wastewater heat recovery.

Waste heat from connected buildings can be recycled in this configuration, which allows the loop to leverage the building load diversities to limit the amount of supplemental energy resources that are needed to connect to the system –allowing it to operate more efficiently.

Using this concept of recycling heat within the loop requires the loop to include balanced heating and cooling loads- whereas the cumulative heating and cooling loads over the course of a year must be relatively balanced in order to avoid thermally saturating the ground – which leads to a decrease in system performance.

One method of combating that imbalance is to install auxiliary heating or cooling technologies to balance the thermal loads throughout the year. Another approach is to incorporate cooling-dominant buildings into the clean thermal network such as grocery stores, ice rinks, data centers, or refrigerated warehouses in order to inject thermal energy into the network loop. Temperature and pressure monitoring throughout the system will enable the control system to ensure thermal balance over the system's lifespan as well as monitor for leaks.

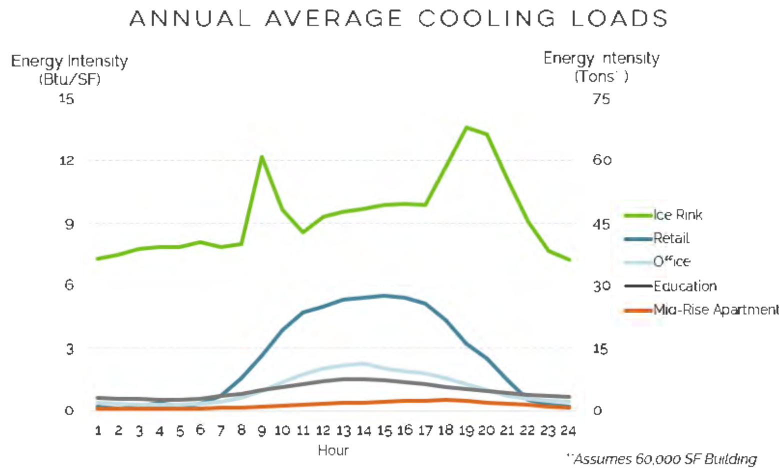

Figure 5: Example of Load Diversity Over 24 hr. Period

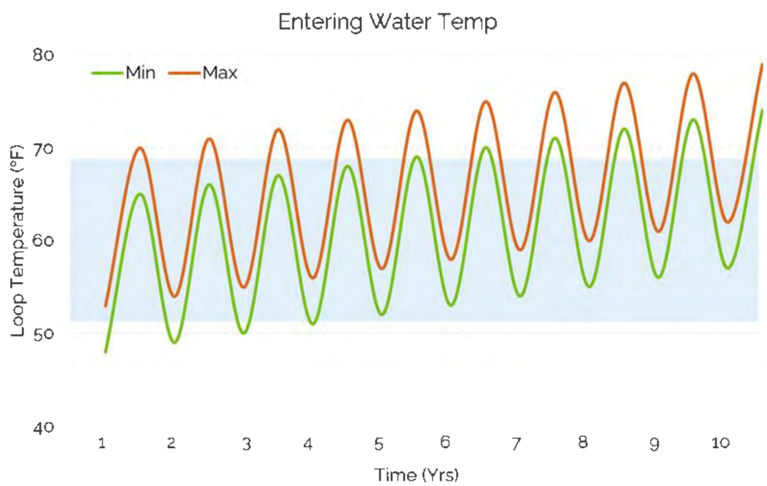

Figure 6: Example Saturated Loop Entering Water Temperatures over System Lifespan

Due to its nature of design, ambient temperature loops can be implemented as stand-alone loops or interconnected with adjacent loops forming an integrated ambient temperature thermal network or grid. The system can expand when a loop that connects a block of buildings is connected to an adjacent loop serving another group of buildings by way of bi-directional transfer laterals.

Ambient temperature loops can also be implemented in a variety of sizes, ranging from small neighborhoods to large cities with tens of thousands of tons worth of connected load. Since there is no centralized energy resource, the systems are easily expandable and can be tailored to fit specific street layouts, building systems, and accommodate for future buildouts and interconnections.

System Resiliency

The piping for these systems is placed underground generally using high density polyethylene piping that is resistant to earthquakes and other tectonic forces.[2] This type of piping is also resistant to water freezing and has heat-fused joints that are stronger than the pipe itself.

Coexistence with existing gas infrastructure will enable the utility thermal energy network system to relieve pressure on the distribution network during a peak event. Standby generation in the event of power outages can also be integrated in order to maintain operation of the circulation pumps.

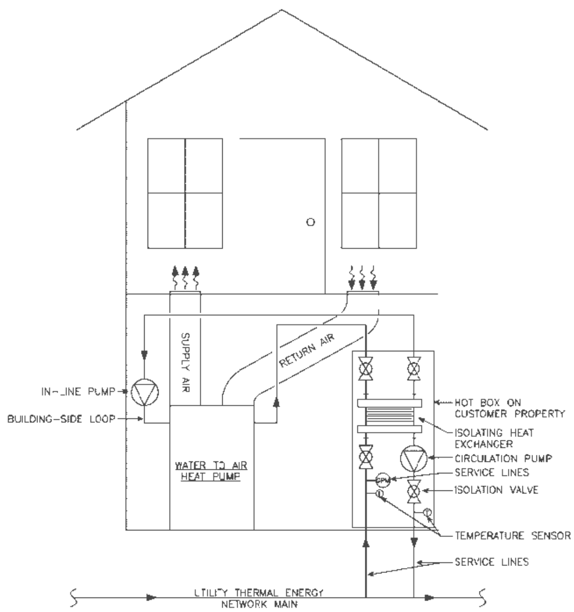

Figure 7: Conceptual System Interconnection

Repair and replacement of parts will involve servicing mechanical rooms and vaults – which are standard to all mechanical systems. Underground piping contains strategically placed isolation valves and crossover piping that typically protect the system and allow for repairs to the system without needing to shut down the entire loop.

Interconnection

A typical layout of the system is a primary-secondary system, which is demonstrated conceptually in Figure 7 with a heat exchanger to hydronically separate the loops. The primary loop refers to the UTEN main lines whereas the secondary loop refers to the building-side loop distributing fluid throughout the buildings. A typical building-side system includes circulation pumps, valves, sensors, and other appurtenances to operate and monitor the system.

A common line of demarcation that has been proposed in these projects is at the point in which the piping connects to the customer's HVAC equipment.

[2] (Ballantyne & LLC Ballantyne Consulting)

Thermal Resources

Several different thermal resources can be integrated into utility thermal energy network systems. Depending on geology at the site, availability of wastewater mains, and proximity to rivers, lakes, and ponds all can play a role in providing heat to the loop.

Ground Source Heat Exchangers

Ground source systems are among the most popular types of systems seen in the marketplace today (Figure 8). Traditional vertical boreholes are closed loop systems in which a vertical borehole is drilled deep into the ground (typically up to 500 feet in depth) and pipes are routed down into the wells in a U-shaped form and filled with grout. These systems are typically spaced in grids with approximately 15 to 25 feet of spacing between boreholes in order to maximize long-term thermal performance between the loop and the ground.

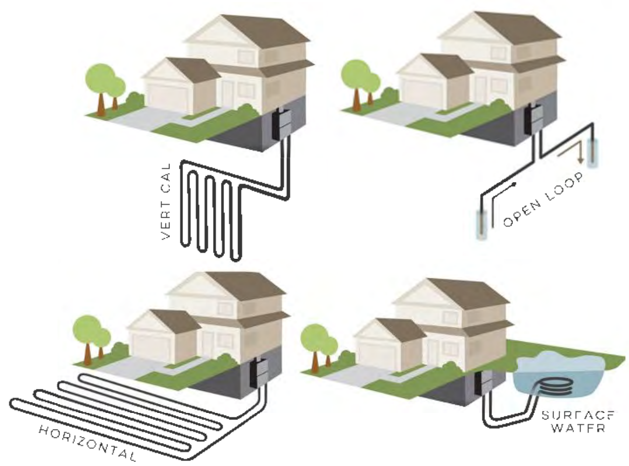

Figure 8: Example GHX Configurations

Horizontal ground source systems are another variation on the loop and are typically installed in trenches at least four (4) feet deep and two (2) feet wide. As shown in the image to the right, this option requires less drilling, but also requires significantly more surface area to trench in the piping at the site.

Wastewater Heat Exchangers

Waste Energy Transfer Systems (WETS) leverage municipal and building wastewater streams which are often in the range of 55 to 75˚F throughout the year. These systems generally fall into two (2) categories:

1. Building-level WETS.
2. District energy-level WETS

Building-level WETS are applied when a facility has sufficient wastewater volume and related hot water demand. Typically, these applications include multi-family buildings (>75 units), hospitals, breweries, commercial laundries, and mixed-use developments.

These systems tend to run in a "batch" mode; on a demand for hot water, a solids-handling pump moves effluent from a holding tank into a tank surrounded by a heat exchanger. The refrigeration cycle is energized and heat is moved from the effluent to the hot water. When either the effluent reaches a temperature setpoint or the hot water has reached its setpoint, the refrigeration is stopped, and the effluent tank is emptied into the wastewater pipe leaving the building. The cycle repeats as needed. In some applications, a secondary heat recovery circuit is used to access heat from the building's HVAC systems or an ambient temperature loop.

Figure 9 to the right illustrates the concept of a building-level WETS. It should be noted that the wastewater never comes into direct contact with the geothermal fluids. District Energy-Level WETS shift from a batch mode of operation to a continuous mode of energy transfer. The energy transfer can remove heat from or add heat to the thermal network depending upon the water temperature and the wastewater temperature.

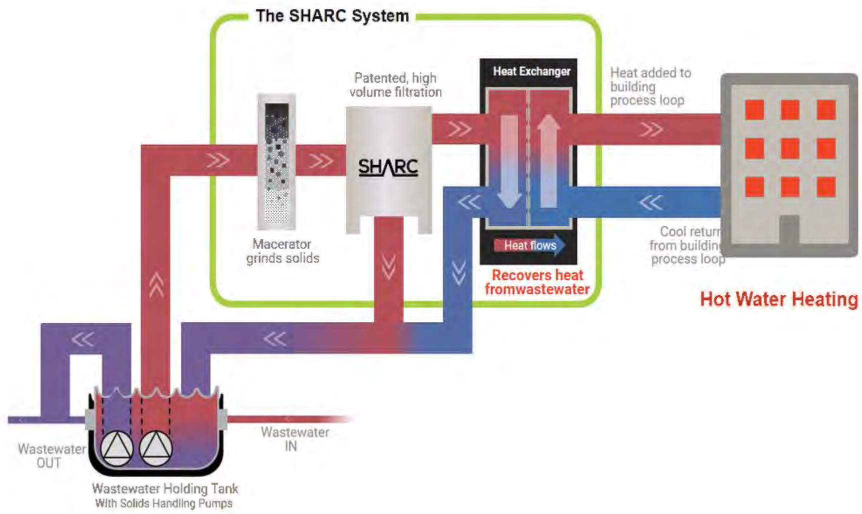

Figure 9: Building-Level WETS using wastewater as a heat source

Maintenance is typically performed on these systems once or twice per year and entails opening the solids separator to inspect for any material accumulation. There are current applications of this technology out in the marketplace including a 1,000-ton system in Vancouver, British Columbia.

One of the most important design elements to WETS is the wastewater storage tank. This equipment has two main purposes: to settle/remove solids and to store thermal energy. Shown below is a diagram depicting the main elements of a wastewater storage tank.[3] The sludge pump removes solids while the wastewater pumps feed the heat exchangers.

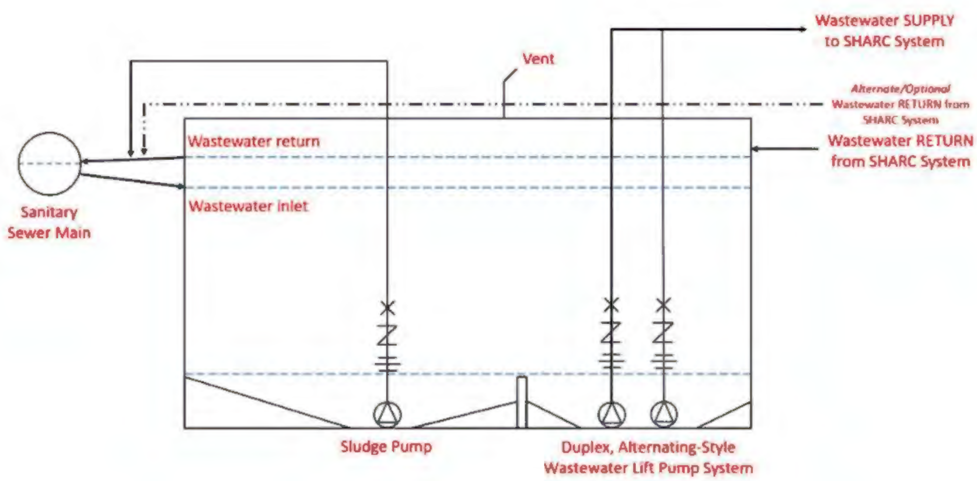

Figure 10: WETS thermal storage container

It is important to note that an application that combines storm and sanitary sewers would require an analysis on the impact of winter events on the effluent temperature, such as snow or freezing rain. Some municipalities have placed a lower limit on the effluent discharged from a WETS in order to limit it to the temperature of the entering city water.

[3] (SHARC Energy, 2024)

Solar Thermal

Solar Thermal (PVT) systems include the attachment of a hydronic heat transfer panel to the backside of each solar PV collector, then connecting these panels via tubing to a pump and heat exchanger. The solar thermal panels then are able to provide thermal energy as opposed to electrical energy for a typical photovoltaic panel. Shown below is a simplified diagram depicting solar thermal operation.

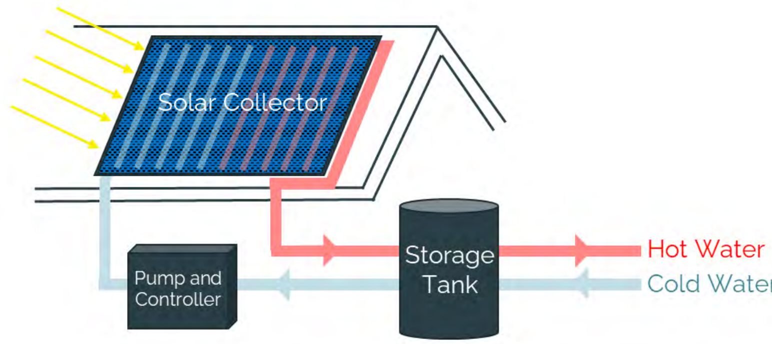

Figure 11: Solar Thermal Operation source

In the heating mode, the hydronic panel absorbs heat from the backside of the solar PV panel while at night or when the air temperatures are favorable, these hydronic panels can also provide heat rejection (nominally 1 ton per 10 square meter). While solar panels that provide both electrical energy and thermal energy exist, they have not yet reached mainstream adoption to make them cost effective.

Solar PVT systems would be connected to an ambient temperature loop with a heat exchanger to allow an antifreeze solution to be used in the hydronic panels. A pump would circulate the PVT fluid through one side of the heat exchanger when the hydronic panels provided a beneficial heat transfer either in the heating or cooling mode. A second pump would move the thermal energy from the heat exchanger to the ATL.

Geothermal Energy Piles

New construction projects can be designed to incorporate energy piles in the building's foundation. Pile foundations are long, column elements in a foundation installed during construction. By outfitting these piles with geothermal piping and ground heat exchangers, they can act as shallow vertical boreholes and provide a thermal resource for the building (Figure 12).[4] In areas where land availability is constrained such as within dense city centers, geothermal energy piles are an attractive option. Note that this thermal resource is not able to be retrofitted in existing buildings. Helical piles are an example of a foundation technique that can be used as a thermal energy resource as a geothermal energy pile.

Figure 12: Geothermal Energy Piles

[4] (Solar Impulse Foundation, 2023)

Surface Water

Surface waters (rivers, ponds, lakes, subterranean stormwater holding systems, etc.) can be an effective heat source or sink. If the body of water is classified as "navigable", permitting may be required by the Corps of Engineers. Additionally, the NYSDEC would need to be engaged for any significant ground water discharges that may be a part of a clean thermal network.

The "connection" to surface water typically takes one (1) of two (2) forms; place a closed-loop heat exchanger in the body of water or pump the water to a heat exchanger where the energy is transferred.

Surface water heat exchangers generally take two (2) forms:

1. Plate-type heat exchangers
2. Coiled-pipe heat exchangers

Plate-type heat exchangers are typically comprised of multiple flat-plate heat exchangers where the heat transfer fluid flows through the closed-loop flat plates to provide either heat rejection or absorption. Plate construction is typically stainless steel or titanium depending on the water chemistry (fresh versus seawater). These systems are relatively compact for their capacity and are shipped factory-assembled for field piping and placement.

Coiled-pipe heat exchangers may be configured as a flat arrangement or as individual coil bundles. If the primary loop has any non-potable water chemicals or antifreeze, it is recommended that the surface water heat exchanger be separated from the primary loop with a separate heat exchanger in case of a leak in the surface water heat exchanger.

In general, if surface water is pumped from the source to a heat exchanger, the intake structure should be placed in a location to minimize the potential for thermal cross-contamination. In a flowing body of water (river), this means the intake should be upstream and ideally out in the area of higher flow instead of at the riverbank. The return should be located downstream of the intake. Care should be exercised if the intake/discharge structures are located in an area where boats may anchor.

Piping configuration is typically supply and return connections to the primary loop with a dedicated circulating pump. If metering of the quantity of thermal contribution is desired, this can be achieved via a flow meter and two (2) temperature sensors, or a smart pump variable frequency drive (which calculates flow ± 3-5% accuracy) with two (2) temperature sensors.

Mechanical Heat Recovery

In most conventional systems, excess heat is generated as a byproduct of mechanical processes such as mechanical cooling, air compression systems, or electricity generation. Typically, this excess heat is rejected into the environment as waste heat. It is possible, and becoming more common in the HVAC industry, to recover this heat through the use of heat exchangers to temper incoming air or water in order to increase the net energy efficiency of the system. This heat can also be moved to a geothermal loop and stored for future use.

A common example and proof of concept of this is combined heat and power (CHP) electric generation plants – where the net efficiency of the system can be increased from approximately 30% to over 75% efficient.

HVAC System Integration

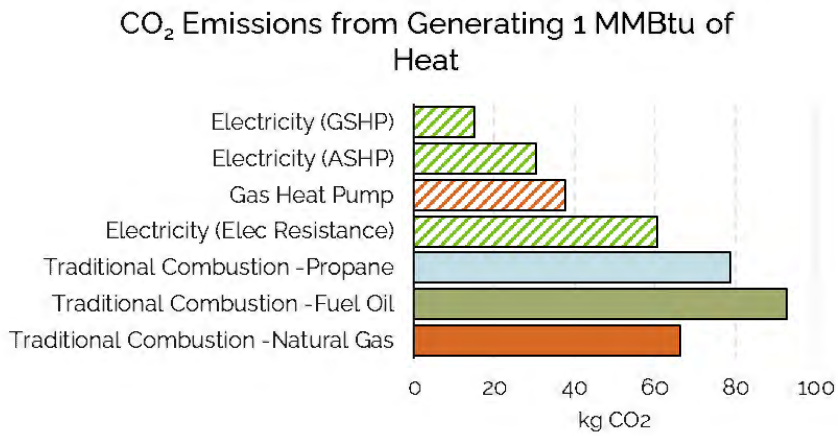

Figure 13: Typical Emissions from HVAC Heat Sources

The primary driver behind most conversions to electric HVAC systems is its ability to displace natural gas equipment with electric equipment. Taking into consideration New York State's 2040 goal of providing 100% carbon-free electricity, this approach allows the systems to eventually achieve carbon-neutrality, which would provide a significant reduction in carbon emissions throughout the state. This is indicated Figure 13 to the right, where green hashes indicate current emissions associated with generating one (1) MMBtu of heat that will eventually become emission free with 100% carbon-free electricity. The emissions from natural gas are indicative of typical combustion equipment seen in commercial buildings.

Current electric heating and cooling technologies in the marketplace today include water source heat pumps (WSHP), GSHPs, air source heat pumps (ASHP), multi-source heat pumps, and ductless mini split systems. Taking into consideration overall system efficiency and the expected increase in electric consumption from a widescale conversion to electric heating, a highly efficient network of WSHPs or GSHPs provides an opportunity to leverage existing thermal resources in order to mitigate the increase in peak electric load.

Air Source Heat Pumps

Air source heat pumps (without some modification) cannot be integrated into ambient temperature loops; however dual, multi, and poly-modal heat pumps can be integrated. These systems comprise of a refrigeration system with a compressor and copper or aluminum coils with fins to aide with heat transfer. In heating mode, liquid refrigerant on the outside coil removes heat from the air and evaporates into gas – releasing heat from the refrigerant as it condenses back into a liquid. Equipped with a reversing valve, the direction of flow can be changed to reverse the cycle and alternate between heating and cooling modes.

Typical air source heat pumps have a seasonal coefficient of performance between 1.5 and 2.5 in cold climates which exceeds electric resistance heating, but is not as efficient as ground source heat pumps. In addition, air source heat pumps do not operate efficiently at lower temperatures and rely on supplemental heating, often electric resistance, to meet the heating needs of the spaces it is serving. Typical lifespans for air source heat pumps are listed at 15 years in the NYS Technical Resource Manual (TRM).[5]

[5] (New York State Joint Utilities, 2022)

Mini Split Systems

Mini split heat pump systems are typically good approaches to use for houses with "non-ducted" heating systems such as radiant panels and wood/kerosene space heaters. These systems are more easily implemented where installing additional ductwork is not feasible.

Like standard air-source heat pumps, these systems consist of an outdoor compressor/condenser and an indoor heating unit. There are versions of this technology with water-source compressor units, that can connect to a ground source network. Ducted systems safely move conditioned air where ductless systems move refrigerants via copper tubing to the space to condition either air or a hydronic fluid. These systems can contain a significantly higher volume of refrigerants as compared to packaged GSHP and WSHP systems.

Water Source Heat Pumps

Water source heat pumps (WSHP) connect to the ambient temperature loop for the heat source and sink. For the purposes of this study, WSHPs are unitary devices (i.e., a single packaged unit that both heats and cools) in the building, controlled by the building, not by the ambient temperature loop.

As previously mentioned, these heat pumps are connected to a hydronic system, whether it is an ambient temperature loop, or a loop served by mechanical equipment in a boiler/cooling tower arrangement for instance. The water that the unit receives is pre-conditioned, allowing the heat pumps to operate much more efficiently than an air source heat pump - often exceeding a COP of 5. This increase in efficiency reduces energy consumption, which has a significant impact on seasonal electric usage and electric loads during peak hours.

GSHPs do not need supplemental systems if sized properly for their application due to the ATL operating in a more favorable temperature range than even individual building ground heat exchangers. This ensures that water/ground source heat pumps will be at their highest efficiencies and highest capacities most of the time. In contrast, air source heat pumps lose a good portion of their efficiency at the extreme air temperatures to which they are exposed. The effective useful life (EUL) for ground source heat pumps is listed as 25 years in the NYS TRM.[6]

[6] (New York State Joint Utilities, 2022)

SYSTEM CONFIGURATION ANALYSIS

System configuration plays a vital role in the design of a district system. Factors such as underground footprint, pumping energy, piping costs, and associated mechanical equipment costs play a critical role in the selection and design of these types of systems. Three main piping configurations exist that are viable for utility thermal energy networks: single-pipe systems, two-pipe systems, and four-pipe systems. Each of these systems have inherent advantages and disadvantages with respect to the system's long-term viability. The forthcoming analysis seeks to address these both qualitatively and quantitatively using a fictitious system that is representative of a typical utility thermal energy network.

One-pipe systems are decentralized and involve an ambient temperature utility distribution system main which connects to heat pumps located in each building. Due to the lower temperature water used in this configuration, insulation is not needed. The water temperature in the main pipe fluctuates throughout the system based on the loads of each building as they extract and reject heat into the system. It is common for the supply temperatures for these systems to fluctuate up to a designed limit of 5 degrees between buildings.

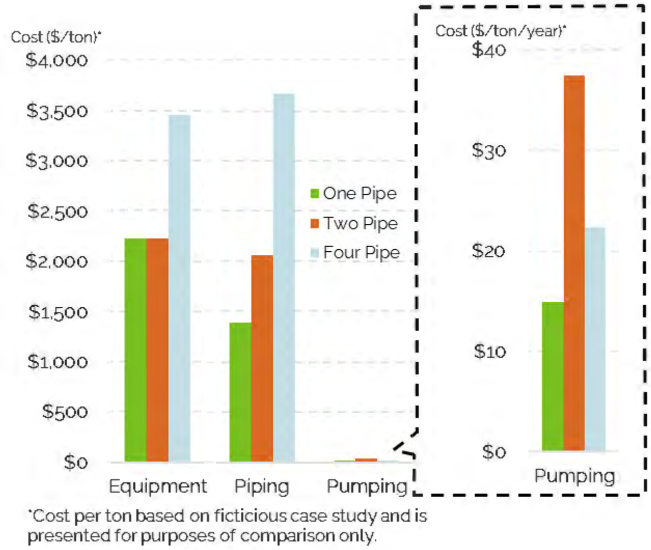

Figure 14: Pipe Configuration Costs

Two-pipe systems are centralized and involve an ambient temperature supply and return pipe which connects to heat pumps located in each building. Similar to the one-pipe system, a two-pipe system does not require insulation. The water temperature in the main supply pipe remains constant, which is a benefit compared with the one-pipe system. Conversely, this system configuration requires higher pumping energy, larger flow requirements, and larger pipe sizes to accommodate this.

Four-pipe systems are centralized and involve four centralized, insulated pipes: chilled water supply (CHWS), chilled water return (CHWR), hot water supply (HWS), and hot water return (HWR). The water is conditioned by a centralized heat pump located within an energy center. This configuration often requires the lowest flow rates and subsequently the smallest pipe sizes of the (3) configurations. However, the underground footprint and upfront cost is the largest with this configuration due to the mechanical equipment required and increased piping & insulation costs.

Table 1: Pipe Configuration Summary

System Attribute	One Pipe System	Two Pipe System	Four Pipe System
Capital Cost	▲	▬	▼
Subsurface Area	▲	▬	▼
O&M Cost	▲	▬	▼
Control Complexity	▼	▲	▲
Equitable Billing	▼	▲	▲
Expandability	▲	▼	▼

The table to the left summarizes some of the benefits and drawbacks for each system configuration to be later discussed in the report. The importance placed on each attribute varies for different organizations and is typically evaluated on a project-by-project basis dependent on site conditions.

One-pipe System

A one-pipe system, also referred to as an ambient temperature loop, is a decentralized system consisting of a singular pipe which provides both heating and cooling for the buildings connected to the system. The temperature in the pipe fluctuates based on the thermal loads required by the building and is typically designed to stay within a temperature range of 35˚F to 90˚F. The temperature differential between buildings in single pipe systems varies and is typically designed to stay within 5 degrees of the temperature setpoint. A common practice is to locate additional thermal resources throughout the system to “recharge” the system as necessary.

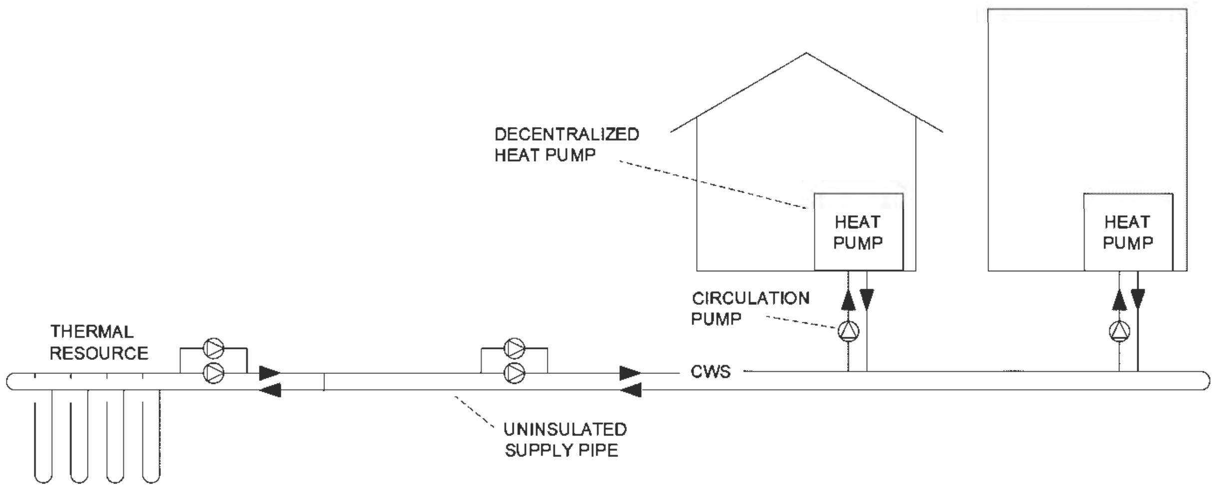

Figure 15: One-Pipe System Schematic

Customer HVAC Equipment

Each building connected to a single pipe system has its own heat pump. These heat pumps convert the ambient temperature water from the main loop into usable heating and cooling for the respective buildings using the refrigeration cycle. Residential buildings typically have a small water to air packaged unit while commercial buildings typically have one or multiple large water to air rooftop units. Depending on the existing systems in place, water-to-water heat pumps are a viable option to connect to a UTEN system in place of an existing hydronic system within a building. Each building connected to the loop would also have its own circulation pump, which would be sized based on the respective pressure drop of the building and can vary in speed based on building demand.

Utility Equipment

There is no central HVAC equipment as part of this configuration. The main loop has its own pump to maintain flow throughout the system. The main loop pump does not need to overcome pressure drops in any buildings connected to the loop and therefore is typically a smaller sized pump when compared to the main loop pump in a two or four-pipe configuration. This reduction in pump size leads to a decrease in overall pumping energy required for this configuration. While there is additional pumping energy required for the circulation pumps, these pumps are typically smaller and do not run constantly as the main pump does. Therefore, the system as a whole will consume less pumping energy than a two-pipe or four-pipe alternatives. In addition to the main pumps, the utility will own the thermal resource which will be used by the loop. The potential thermal resources are dependent on-site configuration and may include vertical boreholes, horizontal boreholes, wastewater heat exchangers, surface water heat exchangers, heat recovery, and solar thermal.

Piping Configuration

The system has one main pipe which acts as both the supply and return for the system. Each building has (2) service connections with a supply and return. Because this is an ambient temperature system, insulation is not required on any piping. Due to the lower temperature differential utilized by heat pumps when compared with traditional hot/chilled water conditioning, the system typically requires a higher GPM and subsequently a larger pipe size compared to a four-pipe system.

Energy Monitoring and Metering

The inherent nature of single pipe systems results in fluctuation in supply temperatures between buildings, which is dictated by the thermal loads throughout the system. While it is possible to limit the temperature drift throughout the system, it is certain that buildings will experience some degree of temperature fluctuation throughout the system. Buildings furthest from the thermal resources in the system will receive a "diluted" water temperature (i.e. slightly lower temperature in heating conditions) and therefore result in slight decreases in HVAC equipment efficiency.

As a result of this, some may argue that an additional layer of complexity as it relates to metering and billing may be introduced. Due to the impact on HVAC equipment efficiencies from building-to-building, standard billing on a BTU basis may not be seen as equitable by all stakeholders and building owners. As there is no current standard in place for metering in these systems, there is uncertainty with respect to what is considered an acceptable metering and billing approach.

The accuracy of a BTU meter is currently dependent on the accuracy of temperature sensors. Because heat pump systems operate at a lower temperature differential than traditional hot/chilled water systems, sometimes with temperature drops of less than 3 degrees Fahrenheit, the importance of the accuracy of the temperature sensor is magnified. Thus, more accurate (and subsequently more expensive) temperature sensors will be required for an accurate BTU meter.

An additional consideration for single pipe/ambient temperature systems in comparison to four-pipe systems is the value of the thermal energy produced. Since single pipe systems rely on distributed heat pumps, the value of the conditioned water is inherently less than a traditional district hot water/chilled water system that is conditioned in a centralized location. Providing partially conditioned ambient temperature water as opposed to conditioned water limits the billing potential of the resource and places the burden of higher electric usage on the customer.

System Configuration and Scalability

A one-pipe system is typically controlled based on secondary circulation pumps equipped with variable speed drives serving each building within its service connection. The circulation pumps control flow to the building from the main loop based on the building's thermal load. The main loop pump operates continuously, circulating the flow within the main loop to match the maximum flow requirement of any individual building. During periods where there is no load called for by any of the buildings, the main loop will continue to operate at a lower speed to ensure the utility is consistently available for the customers.

Because the one-pipe system is decentralized, it can be expanded upon relatively easily when compared with the centralized two-pipe and four-pipe systems. Because the main loop pumps are sized for the maximum flow within any given building on the loop, pumping upgrades would not be required if additional buildings are added to the loop as long as none of the added buildings have a higher flow than any of the buildings that are currently on the loop. Additional thermal resources and buildings can be added to the main loop so long as the resultant impact on thermal balance is considered.

Two-Pipe System

A two-pipe ambient temperature loop is similar to a one-pipe system, however it includes supply and return piping. Where the temperature provided to each individual building varies in a one-pipe system, a two-pipe system provides constant supply temperatures to each building, ideally maintained between 35˚F to 90˚F. The supply pipe can provide both heating and cooling to a building. This approach does not require the system to be "recharged" at certain segments of the piping as the entering water temperature for each building will remain relatively constant. This lends well towards systems with a large centralized thermal resource.

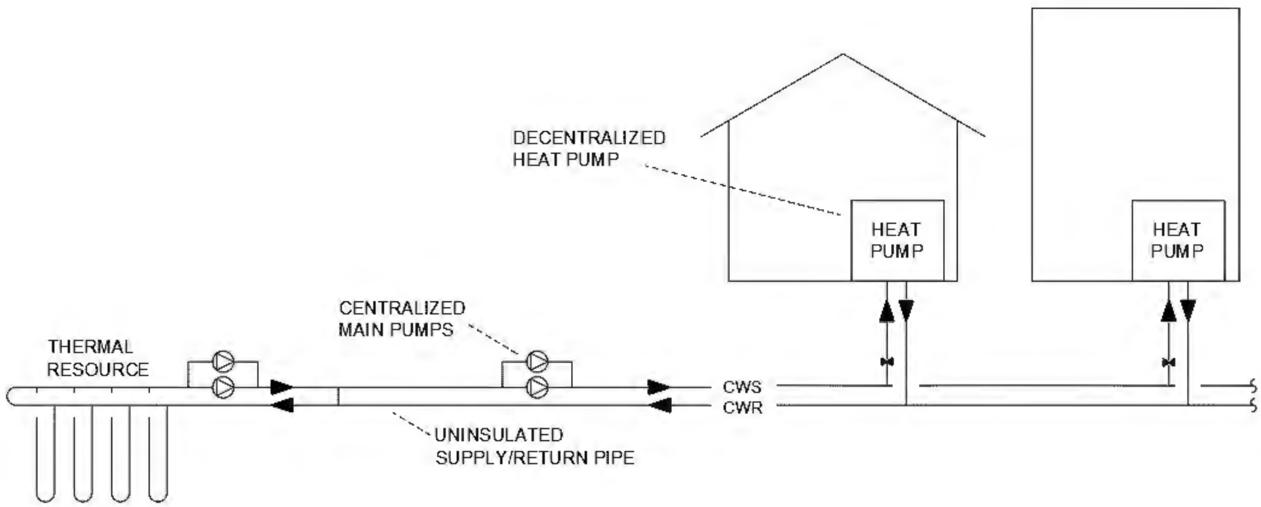

Figure 16: Two-Pipe System Schematic

Customer HVAC Equipment

Each building connected to the loop has its own heat pump. These heat pumps convert the ambient temperature water from the main loop into usable heating and cooling for the respective buildings using the refrigeration cycle. Similar to the one-pipe system, residential buildings would typically have a small water to air packaged unit while commercial buildings would typically have one or multiple large water to air rooftop units. Water to water heat pumps could also be used should the existing equipment lend well to that approach. The buildings do not have their own circulation pumps in this model. Instead, the flow is controlled by a series of modulating valves.

Utility Equipment

This system does not have circulation pumps for each building. Instead, the entire system is pumped by the main circulation pumps. This causes additional complexity to the system as each heat pump will need to be balanced to ensure it receives sufficient flow. The main supply pump will need to be sized based on the required peak flow of the system along with pressure drops leading up to and including the last building on the loop. These additional design considerations lead to a larger main pump size when compared with a one-pipe system. In addition to the main pumps, the utility will own the thermal resource which will be used by the loop.

Piping Configuration

The system has two main pipes which act as the supply and return for the system. Similar to a one-pipe system, each building has 2 service connections (supply/return). Because this is an ambient temperature system, insulation is not required on any piping. Due to the lower temperature differential utilized by heat pumps when compared with traditional hot/chilled water conditioning, the system typically requires a higher flow rate and subsequently a larger pipe size compared to a four-pipe system.

Energy Monitoring and Metering

Unlike a single pipe system, a two-pipe system provides constant supply temperatures and therefore does not have significant complexity relating to billing structures. While no metering standards currently exist, the typical method of metering for this type of system entails the use of a BTU meter or temperature sensors on the supply and return piping coupled with a flow sensor. Energy consumption from a customer can be calculated as a result of the temperature differential between the supply and return and the flow rate.

An additional consideration applicable to all ambient temperature systems in comparison to four-pipe systems is the value of the thermal energy produced. Since single pipe systems rely on distributed heat pumps, the value of the conditioned water is inherently less than a traditional district hot water or chilled water system that is conditioned in a centralized location. Providing partially conditioned ambient temperature water as opposed to conditioned water limits the billing potential of such a resource and places the burden of higher electric usage on the customer.

System Configuration and Scalability

A two-pipe system is typically controlled based on modulating valves for each building along with a differential pressure sensor in the main loop. The control valves direct water into the building based on the building's thermal load. The pressure loss across these control valves would be monitored by a differential pressure sensor placed at the end of the supply and return runs. The main supply pump would then modulate based on the readings of the differential pressure sensor. A minimum flow rate for periods of low/no demand would be established to ensure the utility is consistently available for the customers.

Because a two-pipe system has centralized components, scaling the system for expansion would likely entail replacement of components of the central infrastructure. Additional pumping would be required to serve the additional pressure drop required by the system as a result of the system expansion.

Unlike a single-pipe system that can locate thermal resources throughout the system, a two-pipe system requires the resources to be centralized. In areas with land constraints or limited thermal capacity this may be a limiting factor in the feasibility of this type of system. A more practical method for expansion of two-pipe systems is to create a separate hydronic system as opposed to modifying the existing system.

Four-Pipe System

A four-pipe system provides hot or chilled water to the buildings within the district with a dedicated supply and return line for each. The temperature ranges for this type of configuration are typically lower for chilled water (40°F to 50°F) and higher for hot water (120°F and 180°F). In order to serve these temperatures, centralized mechanical equipment is required to condition the water from the thermal resource to these higher and lower temperatures. This system configuration is commonly used in commercial building applications and often is compatible with existing hydronic HVAC systems in buildings when applied in a district system.

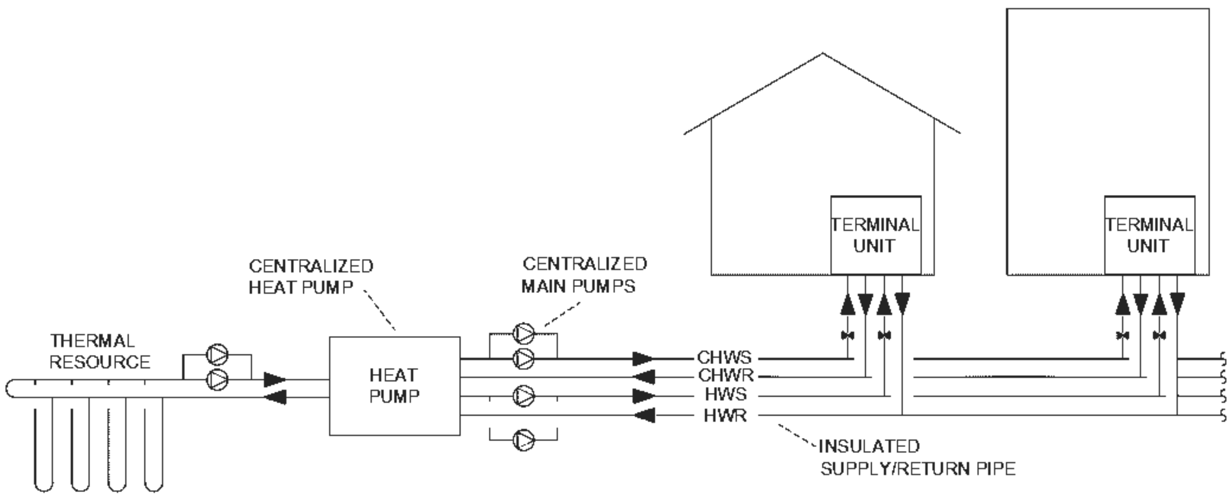

Figure 17: Four-Pipe System Schematic

Customer HVAC Equipment

The terminal units located in each building would not be heat pumps and would use the preconditioned hot/chilled water to provide space conditioning to the building. Residential buildings would typically have a small fan coil unit while commercial buildings would typically have one or multiple large rooftop units outfitted with hot and chilled water coils. This system is typically more compatible with existing hydronic HVAC systems and may serve to reduce HVAC conversion costs, depending on each individual building's operating parameters. In this configuration the buildings do not have their own circulation pumps on the service connection. Instead, the flow to each building is controlled by a series of modulating valves.

Utility Equipment

While each building has their own heat pump in the one-pipe and two-pipe configurations, a four-pipe system uses a centralized heat pump located at an energy center, commonly referred to as a central plant. This heat pump conditions the chilled water and hot water supply using the energy from the thermal resource to operate more efficiently than a typical boiler or chiller. Due to the addition of large, centralized equipment and associated appurtenances, this system typically has higher capital costs and maintenance costs for the centralized infrastructure.

Similar to a two-pipe system, the main pumps in a four-pipe system need to be sized based on the required peak flow of the system along with pressure drops leading up to and including the last building on the loop for both heating and cooling, respectively. Since a four-pipe system has two different supply runs, there will need to be at least two main sets of pumps that will inherently have a reduced runtime over the course of the year due to the increased (hot water) and decreased (chilled water) system temperatures.

Piping Configuration

A four-pipe system has four main pipe segments: hot water supply, hot water return, chilled water supply, and chilled water return. Each associated service connection consists of the same four-pipes. Due to the water temperatures in this system, it is necessary to insulate the pipes to limit heat loss throughout the system. Additionally, the pipe sizes for this system are typically smaller in comparison to an ambient temperature system.

Energy Monitoring and Metering

Similar to a two-pipe system, a four-pipe system provides constant supply temperatures and therefore does not have significant complexity relating to billing structures. While no metering standards currently exist, the typical method of metering for this type of system entails the use of a BTU meter or temperature sensors on the supply and return piping coupled with a flow sensor. Energy consumption from a customer can be calculated as a result of the temperature differential between the supply and return and the flow rate.

An additional consideration applicable to all ambient temperature systems in comparison to four-pipe systems is the value of the thermal energy produced. Since single pipe systems rely on distributed heat pumps, the value of the conditioned water is inherently less than a traditional district hot water or chilled water system that is conditioned in a centralized location. Providing partially conditioned ambient temperature water as opposed to conditioned water limits the billing potential of such a resource and places the burden of higher electric usage on the customer.

System Configuration and Scalability

A four-pipe system is controlled by modulating valves at each building along with a differential pressure sensor in the main loop. The control valves direct modulate the flow of water into the building based on the building's load. The pressure loss across these control valves would be monitored by a differential pressure sensor placed at the end of the supply and return runs. The main supply pump typically modulates to account for the system's total pressure drop. A minimum flow rate for periods of low/no demand would be established to ensure the utility is consistently available for the customers. This control approach applies to both the hot and chilled water piping.

A four-pipe system has additional centralized equipment compared to other system configurations and subsequently has additional complications with system expansion. Additional pumping is required to serve the additional pressure drop required by the system expansion.

Unlike a single-pipe system that can locate thermal resources throughout the system, a four-pipe system requires the resources to be centralized. In areas with land constraints or limited thermal capacity in the energy center, this may be a limiting factor in the feasibility of this type of system. A more practical method for expansion of four-pipe systems is to create a separate hydronic system as opposed to modifying the existing system.

CASE STUDY

The three system configurations (one-pipe, two-pipe, and four-pipe) were applied in a fictitious case study for the purpose of comparing system parameters as it relates to pipe sizes, associated equipment costs, and utility infrastructure costs.

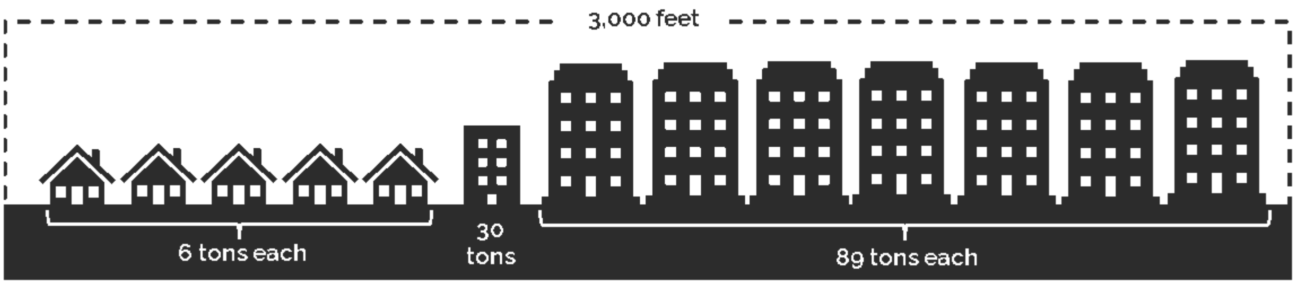

Figure 18: Representative Case Study

The system comprises of (5) residential houses and (8) commercial buildings with peak loads indicated in the figure above. It was assumed for the purpose of this exercise that the load profiles for each building align with the loads from the NREL ComStock and ResStock database. The system size is intended to model the system sizes currently present in the New York State UTEN pilot projects.

Preliminary equipment selections were determined based on the peak loads for each building. The equipment selections were then used to determine required flow rates and head loss across the equipment. Pipe sizes were determined to ensure that friction losses were less than 1 foot per 100 feet of piping and fluid velocity did not exceed 3 feet per second. The required flow along with pressure losses from the equipment and piping were then used to size preliminary pumps.

Insulation thicknesses (where applicable) were determined based on ASHRAE Table 6.8.3-1 and Table 6.8.3-2. This methodology is summarized in the figure to the right and was applied to each pipe configuration. From there, the pipe configurations were compared based on equipment cost, piping cost, and pumping energy. Additionally, estimated subsurface space requirements were determined based on methodology as outlined in the pipe spacing section to exemplify the disparities in required space that exist for each configuration.

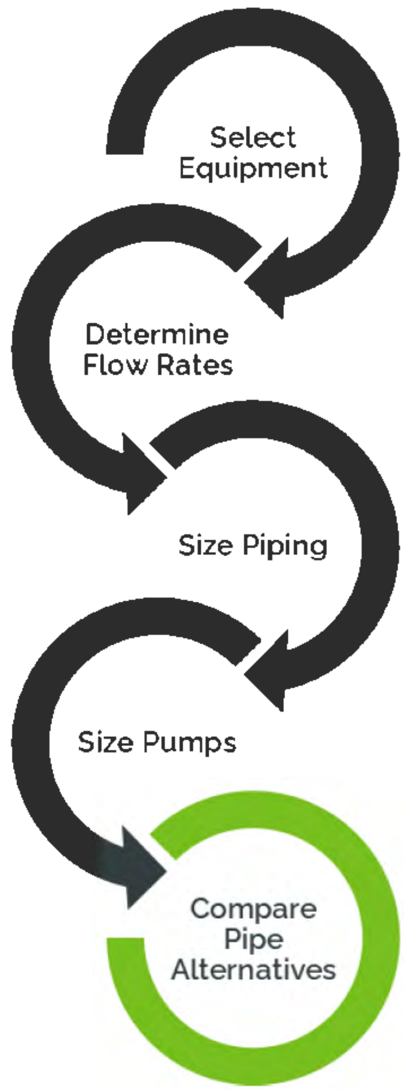

Figure 19: Case Study Process Flow

Subsurface Space Requirements

As shown in the figures below, underground footprint for the different pipe configurations varies based on pipe size, insulation thickness, and spacing between piping. The four-pipe configuration takes up the largest underground footprint when compared with a one-pipe and a two-pipe system. Because of this, the availability of space in the right of ways may influence the system selection in dense urban environments. The methodology behind spacing between piping is outlined in the following section with a more detailed analysis included in Appendix E.

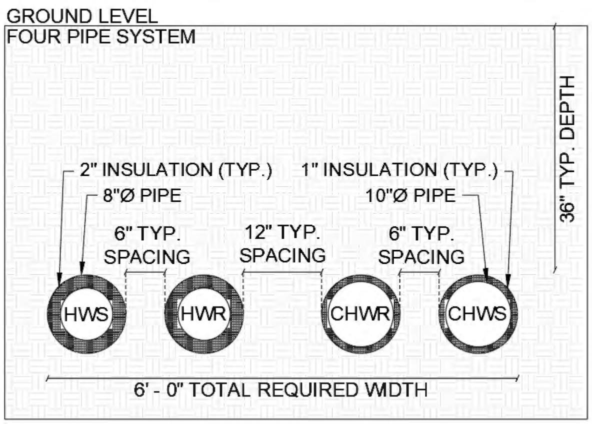

Figure 20: Four-Pipe Subsurface Footprint

In standard direct buried applications for a four-pipe system, the supply and return piping for hot and chilled water should be placed as close together as possible while maintaining sufficient spacing for servicing. For the purposes of this example, a 6 inch maintenance clearance was kept between the piping. While the inclusion of insulation limits the potential for heat transfer between the piping, the spacing between the hot water return and the chilled water return should be maximized to the largest extent practical to minimize any potential heat transfer between these two pipes.

In standard direct buried applications for a two-pipe ambient system, the supply and return piping should be placed at a minimum 6 inches apart. This distance, as explained in the pipe spacing section, is critical to ensuring that no thermal bridging occurs between the supply and return piping. To maximize heat transfer with the ground, the spacing between the supply and return piping should be maximized to the largest extent practical. For the purposes of this example, 12 inch spacing was selected to increase thermal transfer with the ground while maintaining a relatively small underground footprint.

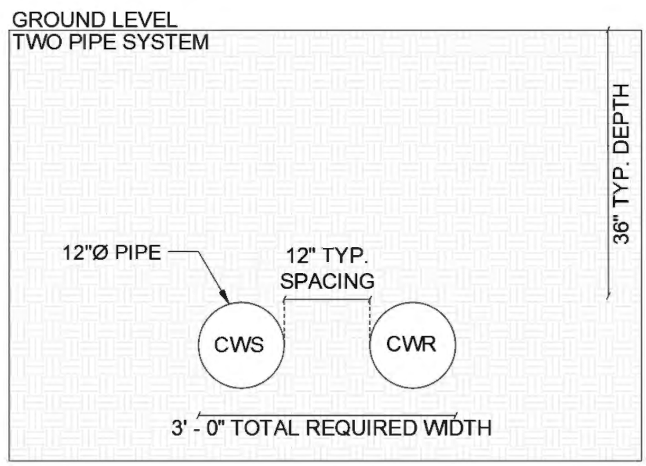

Figure 21: Two-Pipe Subsurface Footprint

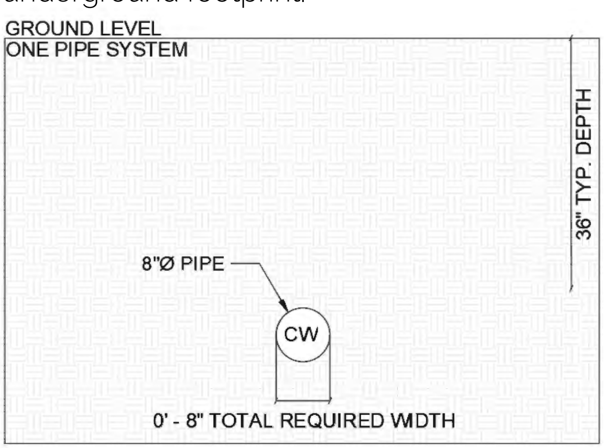

Figure 22: One-Pipe Subsurface Footprint

The pipe spacing for a one-pipe system is straightforward as there are no additional pipes (and subseqent heat transfer) to account for. Similar to other underground utilities, a minumum depth of 3 feet was selected. The depth of the pipe will be based on the location of other underground utilities, along with the area's frost line.

Comparative System Costs

In order to quantify cost disparities between the three system configurations, unit cost estimates were determined for costs associated with centralized equipment, pumping energy, and piping. Costs per linear foot of piping were applied based on the utility's contracted rate for gas piping, which is directly applicable to a direct buried pipe system. The cost breakdown for a one-pipe, two-pipe, and four-pipe system utilizing 12-inch pipe in a level trench is shown below using existing contract rates with additional piping material costs for systems with multiple pipes.

Table 2: 12-inch Pipe (Level Trench) Cost Breakdown

12" Pipe	Level Trench (Base Cost, $/LF)					
	Assumed Trench Width (in.)	Trench Cost	Pipe Material	2" Pipe Insulation (M&L)	Pipe Labor ($/LF)	Total $/LF
One-pipe	24	$ 49.76	$ 20.62	$ -	$ 15.47	$ 85.84
Two-Pipe	48	$ 99.51	$ 41.24	$ -	$ 30.93	$ 171.68
Four-Pipe	84	$ 174.15	$ 82.48	$ 45.00	$ 61.86	$ 363.49

The same cost breakdown was applied to varying pipe sizes ranging from 1 inch to 12 inches. For each pipe size, additional cost based on site conditions was included as well. For the 12-inch pipe example, the following table outlines cost adders for different site conditions.

Table 3: 12-inch Pipe Site Restoration Cost Adders

12" Pipe	Site Restoration Cost Adder ($/LF)			
	Asphalt (non-street)	Concrete	Grass	Street
One-pipe	$ 52.20	$ 78.19	$ 19.42	$ 122.33
Two-Pipe	$ 104.40	$ 156.38	$38.84	$244.66
Four-Pipe	$ 261.00	$390.95	$ 97.10	$ 611.64

For the purposes of the case study, it was assumed that restoration of the street would be required for the main piping and restoration of grass would be required for the service piping. By comparing the cost across the three configurations as shown in the figure below, it is apparent that the four-pipe system would require the largest upfront cost due to the additional pipes as well as the centralized mechanical equipment .

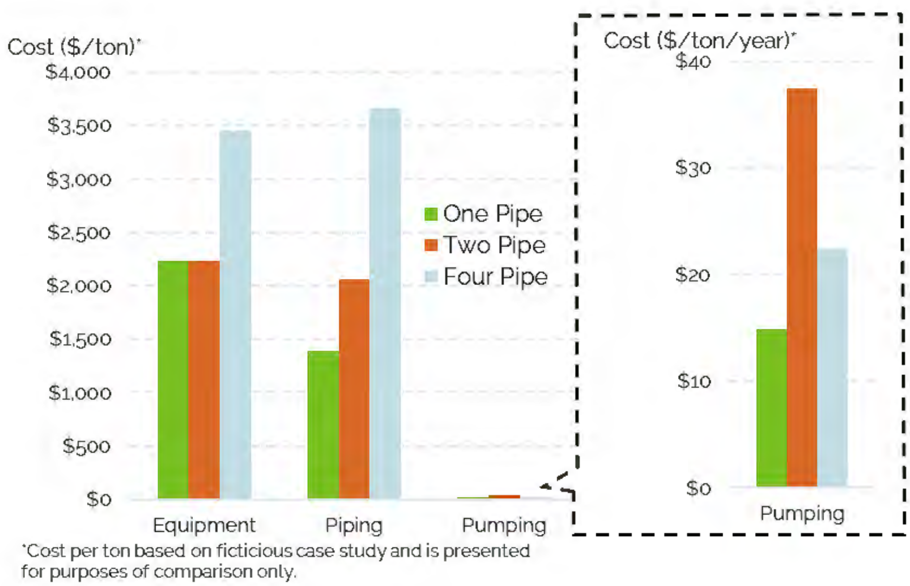

Figure 23: System Alternatives Pipe Cost Estimate

The two-pipe system requires the largest flowrate and subsequently has the largest pumping energy of the three pipe configurations. When compared with a two-pipe system, a four-pipe system operates at a higher temperature differential and therefore requires less flowrate, and subsequently less pumping energy to transfer the same amount of heat. The one-pipe system operates at a lower temperature differential; however, it is sized based on the peak individual building flow rate as opposed to the sum of all building flowrates. Therefore, the flowrate in the main pipe is relatively low which results in the lowest pumping energy of the three system configurations.

BUFFALO DISTRICT HEATING

SITE CHARACTERIZATION

The proposed Utility Thermal Energy Network Pilot Project is inclusive of a city block of low-income housing development and an existing district heating system serving (3) municipal buildings in downtown Buffalo, NY. The existing district heating system is housed in the facility adjacent to the Buffalo Fire Headquarters. The proposed project includes the construction of a geothermal borefield and wastewater heat exchange facility to serve the thermal demands of the residential buildings (both heating and cooling) and to baseload the existing district system in an effort to displace gas consumption from the central plant boilers.

Figure 24: Buffalo District Project Boundary

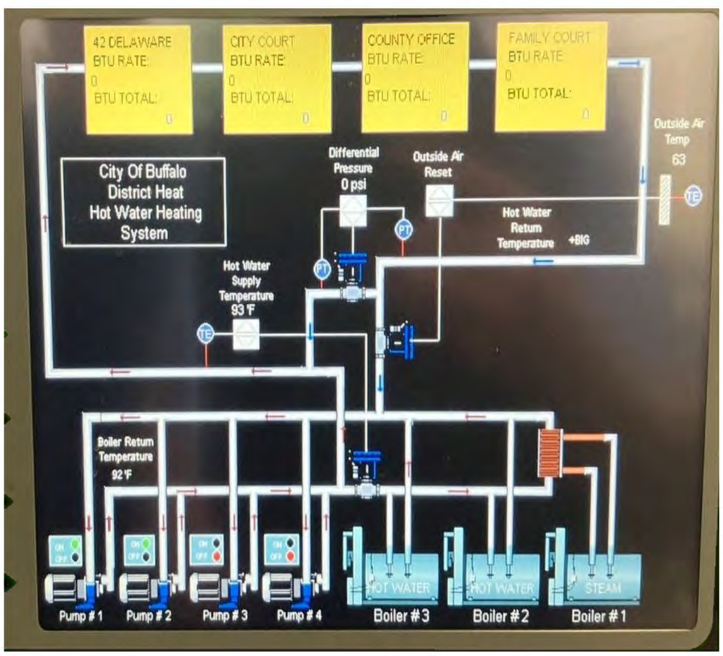

Figure 25: Buffalo District Existing Controls Diagram

The Buffalo District Heating System is located in downtown Buffalo next to the fire headquarters and contains (2) 26,779 MBH gas-fired boilers that feed into a hydronic loop providing hot water supply and return for (2) municipal buildings. A separate steam system uses (1) 16,738 MBH gas-fired boiler to provide steam to Buffalo City Hall. This steam system is also used to base load the hydronic system via a steam to hot water heat exchanger and feed hydronic equipment at the Fire Headquarters via a separate steam to hot water heat exchanger. The flow diagram as captured from the district plant controls menu is shown to the left. Note that the County Office and Family Court buildings are no longer on the district system; the controls interface has not been updated to reflect this.

Several buildings previously served by the hydronic district system have since divorced from the system. Because these buildings likely still operate on hydronic systems, the potential remains to bring them back on to the existing district system in the future.

The current planned approach includes leveraging the 96-inch diameter combined storm/sanitary sewer main as a thermal resource to raise the inlet temperatures to the existing gas boilers – thus reducing the amount of energy to supply water at the specified setpoints. This will enable the system to operate with 100% redundancy and will mitigate downtime during construction.

In addition to the wastewater heat recovery system, a closed-loop vertical borefield will be installed across the street from the central district system on city-owned property. This borefield will feed into water-to-water heat pumps to supply hot water and chilled water to the residential buildings. In an effort to reduce borefield costs, part of the heat recovered from the wastewater heat exchanger will be used on peak days to supplement the heating capacity from the borefield. The conceptual operation of this system is shown below.

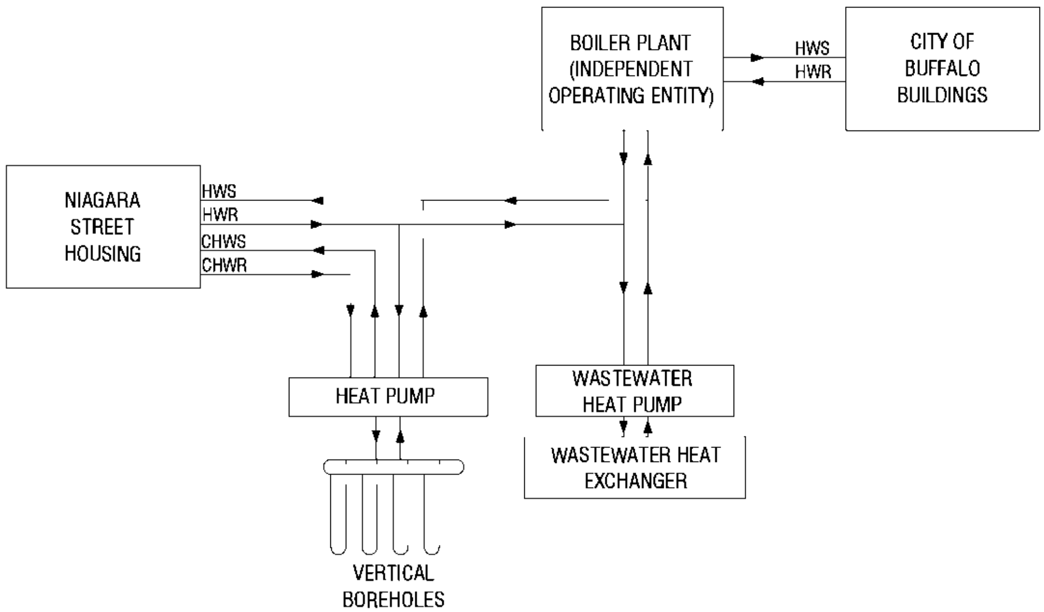

Figure 26: Buffalo District Conceptual Flow Diagram

Note that the existing boiler plant will remain an independent operating entity. The UTEN will tie in to the existing hydronic systems within the boiler plant to reduce the load met by the existing natural gas boilers. HVAC conversions inside the residential buildings will likely be required to be made compatible with the hydronic UTEN system. Due to the nature of the system's integration into the existing district system, no additional HVAC conversions will be required in the buildings served by the district heating system. Shown below is a table which outlines all proposed potential UTEN customers at this site.

Table 4: Buffalo District Building List

Address	Square Feet	Classification
175 Court Street, Buffalo, NY (City of Buffalo FD HQ)	66,863	Warehouse
50 Delaware Ave, Buffalo, NY (Buffalo City Court)	324,080	Office
42 Delaware Ave, Buffalo, NY (Old City Court)	63,248	Office
188-196 Niagara Street, Buffalo, NY	6,346	Apartment
198-204 Niagara Street, Buffalo, NY	5,462	Apartment
206-212 Niagara Street, Buffalo, NY	5,462	Apartment
214-222 Niagara Street, Buffalo, NY	6,346	Apartment
224 Niagara Street, Buffalo, NY	45,318	Apartment
121-113 Seventh Street, Buffalo, NY	7,190	Apartment
111-105 Seventh Street, Buffalo, NY	5,614	Apartment
103-97 Seventh Street, Buffalo, NY	5,614	Apartment
95-89 Seventh Street, Buffalo, NY	7,190	Apartment
87-83 Seventh Street, Buffalo, NY	4,172	Apartment
81-73 Seventh Street, Buffalo, NY	7,190	Apartment
71-69 Seventh Street, Buffalo, NY	4,126	Apartment

The graphic below outlines the locations of the commercial (red) and residential (blue) buildings included within the pilot. The red buildings are currently operating as part of the existing Buffalo District system. The hydronic equipment in the Fire Headquarters is served by a steam boiler via a steam to hot water heat exchanger while Buffalo City Court and Old City Court are served by the existing hydronic district system. City Hall, as shown in orange, is currently on a steam system. Note that geothermal systems operate at temperatures much lower than steam systems. For this reason, existing steam systems would not be compatible with a geothermal system. In order to be compatible, the existing steam equipment would need to be replaced with hydronic equipment. The buildings in green used to be on the district system but have since been divorced from the system and rely on their own individual systems.

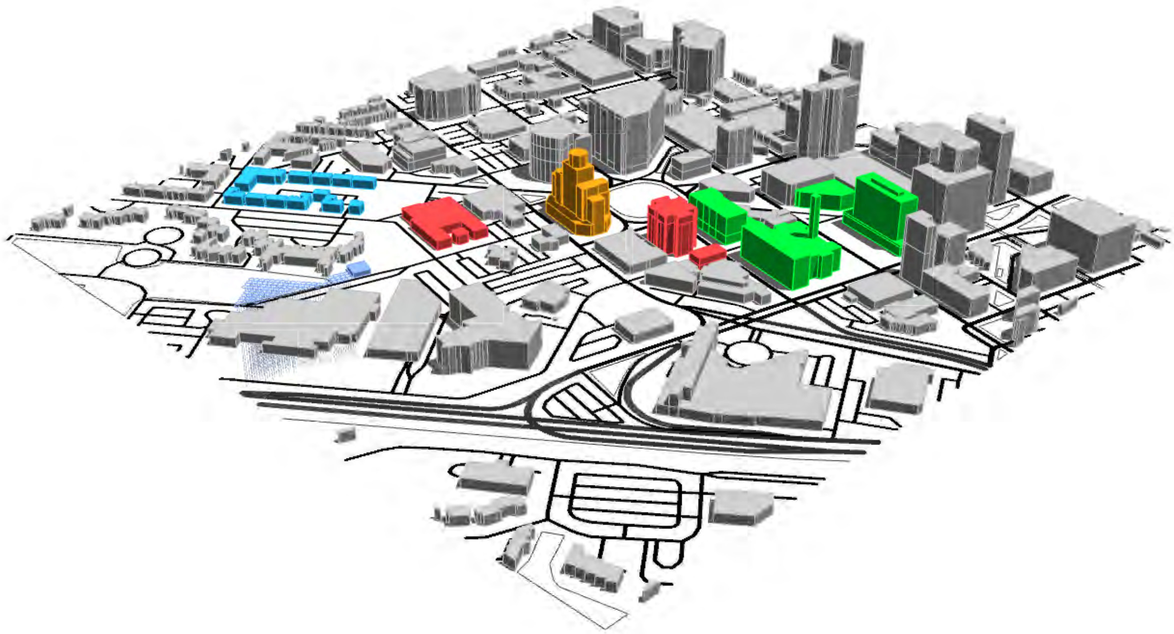

Figure 27: Buffalo District Buildings in Scope

Cost estimates for converting City Hall into a hydronic system and transitioning the divorced buildings back onto the district are provided below.

Table 5: Divorced Buffalo District Building Conversion Cost Estimate

Building	Address	Square Footage	Peak Heating (MBH)	Retrofit Cost Estimate
Buffalo City Hall	65 Niagara Square	500,000	10,000	$43,750,000
Buffalo Athletic Club	69 Delaware Ave	200,000	5,100	$4,080,000
Erie County Family Court	1 Niagara Street	157,689	4,021	$3,216,856
Erie County District Attorney	25 Delaware	285,732	7,286	$5,828,933
Supreme Court Building	77 West Eagle	29,000	740	$591,600
Rath Building	95 Franklin Street	550,000	14,025	$11,220,000

Cost estimate based on previous steam to hydronic government office conversion.

Given additional complexities with City Hall, costs could exceed preliminary estimates

Note that City Hall has several complications which led to its high estimated retrofit cost estimate. The building was built in 1930 and was previously listed on the National Register of Historic Places. Additionally, it houses a steam distribution system with piping and equipment that cannot be reused for a hydronic system. All steam radiators, coils, and piping would need to be replaced with hydronic compatible alternatives.

Figure 28: City Hall Hybrid Breakdown

While converting the entirety of Buffalo City Hall from a steam system to a hydronic system presents certain technical and financial challenges, there exists potential to convert a portion of the building for a reduced cost. Not only would a portion of the building become much more energy efficient, but there would be an added public relations benefit for including the high profile building within the UTEN pilot. The hydronic piping that serves the (2) office buildings runs through the basement of City Hall. The location of this piping is convenient and has the capacity to take on additional load due to the aforementioned divorced district buildings. As previously discussed, (1) 16,738 MBH gas-fired boiler provides steam to Buffalo City Hall. There is no backup space heating equipment within City Hall and therefore if the steam distribution piping were to leak, as it recently did in the winter of 2023, the building could lose heat. By utilizing the hydronic system to partially heat the building, some inherent resiliency would result for the floor(s) that are converted.

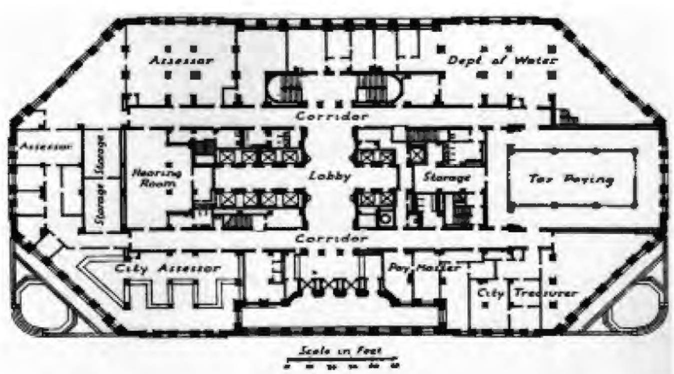

Figure 29: First Floor of City Hall

Shown to the left is a floor plan of the first floor at City Hall. It contains central corridor and lobby spaces with perimeter offices. Being directly above the basement, hydronic piping could be installed to serve each of these spaces without facing space constraints within the risers. This issue would be present if the system were to extend to higher floors. The second floor contains a similar floor plan and includes the mayor's office as well.

City of Buffalo has expressed interest in converting City Hall to a hydronic system based on discussions with City of Buffalo maintenance staff. Additionally, the existing steam system was noted to require high maintenance and is prone to leaks. Cost has been one of the main detractors towards converting the building to a hydronic system. However, as shown in the table below, a portion of the building can be converted to geothermal for a fraction of the cost of converting the entire building.

Table 6: Partial City Hall Conversion Cost Estimate

Building	Address	Square Footage	Peak Heating (MBH)	Retrofit Cost Estimate
Buffalo City Hall 1st Floor	65 Niagara Square	38,605	772	$3,884,628

Estimated

Should National Fuel elect to investigate this option further, an analysis on the existing equipment would need to be conducted to better refine the projected cost estimate. In terms of thermal capacity, the proposed wastewater heat exchange system as discussed in the system design section would have sufficient capacity to take on the additional heating load from the first floor at City Hall. Note that while there exists potential to convert a portion of City Hall to geothermal, all results presented in the report exclude City Hall from the proposed scope of work.

EXISTING ENERGY CONSUMPTION

In order to establish existing heating loads and develop a baseline for the energy impact analysis, the existing natural gas consumption for each building included in the pilot was investigated. The analyzed utility data occurred during the calendar year 2023 and is shown below. Note that 42 Delaware Ave did not have its own natural gas account.

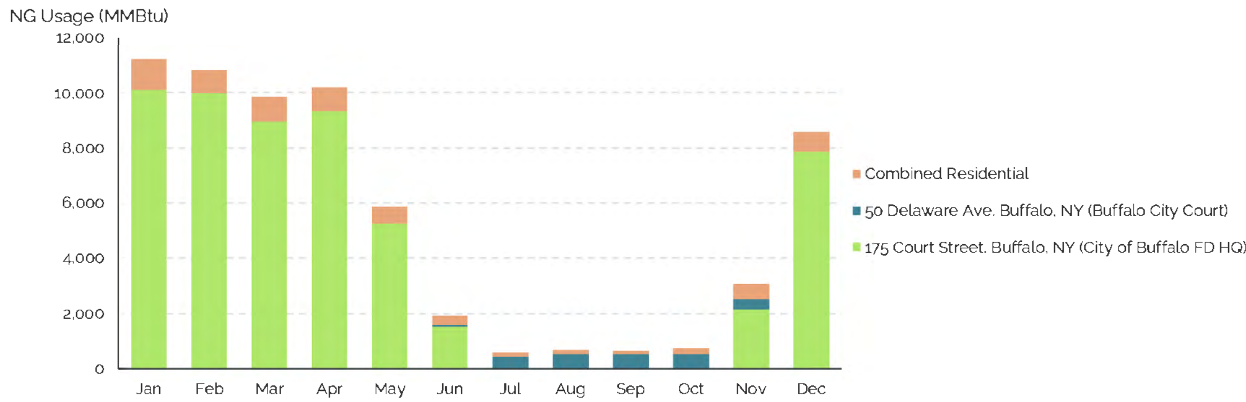

Figure 30: Buffalo District Existing Natural Gas Consumption

As apparent from the graph above, the majority of natural gas consumption can be attributed to heating in the winter months. Other uses of natural gas include domestic hot water and kitchen equipment. Note that the existing district system resides within 175 Court Street which accounts for the large gas consumption found at that address. In addition to the existing natural gas consumption for each account, daily trend data for the existing district system was made available for analysis. This data included water temperature and energy consumption which were used to quantify peak heating load served by the district heating system. Shown below is the trend data of Btu consumption for the district plant over the course of several years.

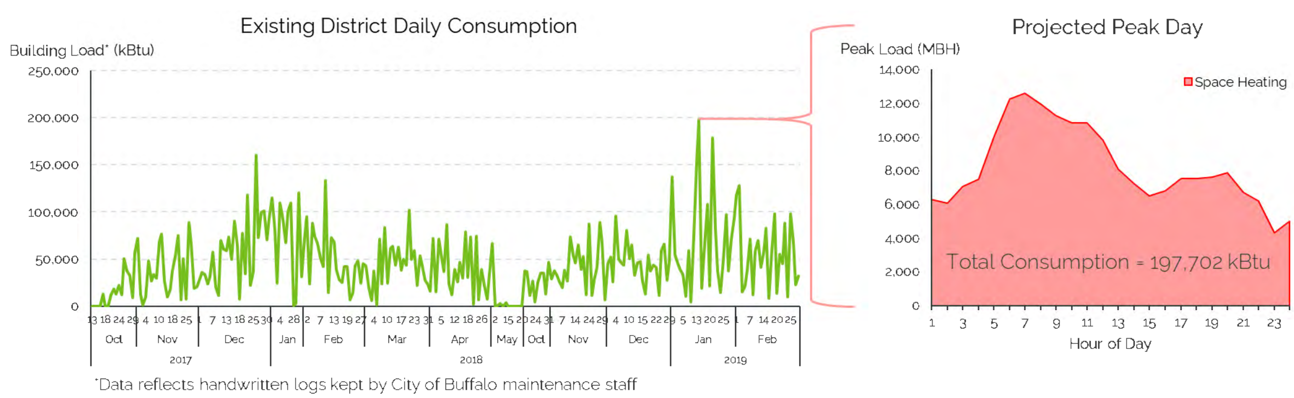

Figure 31: Buffalo District Existing Trend Data

While hourly data was not available, consumption over the course of a day was mapped to a peak hourly load profile for an office building in order to estimate peak heating load. As shown in the figure above, the consumption of 197,702 kBtu on January 14th was applied to the load profile which yielded a peak load of 12,590 MBH.

The utility data, trend data, and information relating to the existing equipment at each building were used to scale ComStock and ResStock load profiles in order to create an annual load estimate for each building, calibrated with utility data and typical energy intensities. ComStock and ResStock are analysis tools developed by the National Renewable Energy Laboratory with support from the U.S. Department of Energy to model end-use consumption for commercial and residential buildings, respectively. By developing annual load profiles at an hourly basis, the impact that the system would have on thermal resources such as wastewater and ground heat exchangers can be better quantified. Shown below are several graphs which outline the estimated heating (red) and cooling (blue) load profiles on an hourly basis. Each individual data point reflects the thermal load at an hour of the year.

The existing hydronic district system, which serves (2) office buildings, has a peak heating load of 12,590 MBH. This aligns with the (2) installed hydronic boilers, which each have a capacity of 26,779 MBH and are currently oversized due to the reduction in buildings served by the district system. The proposed design includes leveraging the wastewater heat exchanger to tie into the existing heating system and baseload the heating demands to reduce natural gas consumption.

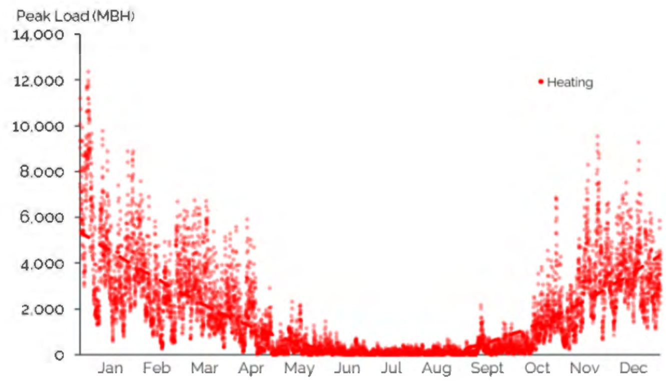

Figure 32: Existing District System Load Profile

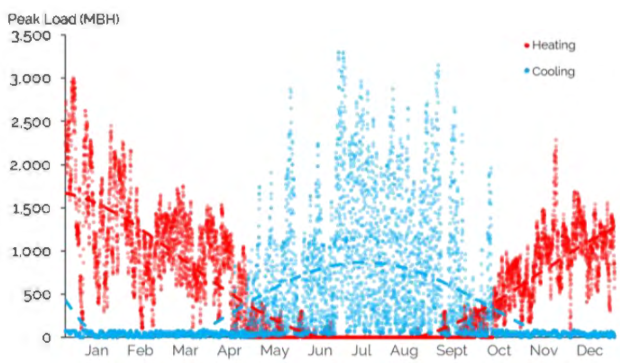

Figure 33: Existing Residential Load Profile

The existing residential housing have a peak heating load of 3,000 MBH and a peak cooling load of 275 tons. The proposed design includes sizing the borefield to meet the entirety of the residential cooling loads. Any additional heating load that the resultant borefield is not able to produce would be met by the wastewater heat exchanger.

By overlaying the load profile for the existing district heating system with that of the residential buildings, it is apparent that the residential loads represent a minute portion of the overall load. Any wastewater energy that is used to meet the thermal loads of the residences will be minimal when compared with the existing district system. For the existing district system, approximately 75% of peak load, or about 9,280 MBH, would be offset by the wastewater heat exchanger.

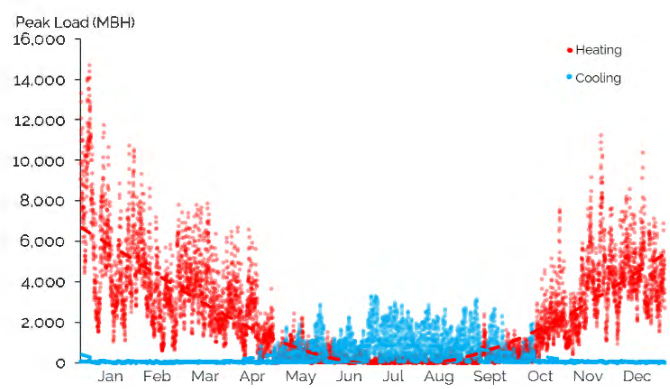

Figure 34: Existing Combined Load Profile

Geologic Assessment

The site geology plays a critical role in the design of a ground heat exchanger. National Fuel's Service territory contains a wide range of geological conditions that may impact the methods and depths of drilling and installing geothermal boreholes. Particular features can either benefit or detract from the cost effectiveness of a particular project. Based on the regional geothermal drilling capacity, ideal conditions would feature a few feet of unconsolidated material (i.e., overburden) followed by bedrock with high thermal conductivity and diffusivity for effective heat transfer. Generally undesirable deep overburden (>100 feet to bedrock) may encourage a series of shallower boreholes using a mud-rotary drilling method. Encountering shallow methane deposits will also reduce potential borehole depths and encourage the project to access other sources of thermal energy, such as nearby surface water or available wastewater resources to compensate. A narrative on site geology for Buffalo is laid out below, based on surveys from the US Geological Survey maps for surficial (surface) and bedrock geology and NYSDEC Water Well Logs. A PDF of all referenced NYSDEC Water Well Logs is included in Appendix B. Additionally, local drillers were consulted to provide information on the site geology. They were able to confirm the geology as outlined in the water well logs, provided a thermal conductivity to be used in the GLD modeling software, and recommended that the depth of boreholes not exceed 500 feet due to current regulations.

City of Buffalo

NYSDEC Water Well Information: A review of (2) NYSDEC well completion reports found that depths of 0 feet to 52 feet consisted of sand and gravel. At a depth of 52 feet to the depth limit of each of these wells (342 feet, 345 feet, respectively), dolomite rock was encountered with progressively higher flow rates of water. One of the wells was for a geothermal system and depth was capped at 342 feet.

Surficial Geology (City Hall District System): The site area has been mapped by the New York State Museum Geological Survey on the Surficial Geologic Map of New York Niagara Sheet as **Glacial Outwash**. This surficial geology includes coarse to fine gravel with sand in a proglacial fluvial deposition. The surficial geology is well-rounded and stratified, and generally has a finer texture away from the ice border. Thickness ranges from (2) to (20) meters (6.56 feet to 65.6 feet).

Subsurface Geology: The site area has been mapped by the New York State Museum Geological Survey on the Bedrock Geologic Map of New York Niagara Sheet as **Onondaga and Bois Blanc Limestones** that is up to (150) feet in thickness. Shown below is the second part of the description from USGS Lexicon website (ref. NY046) and reference NY017:

> Middle Devonian Onondaga of NY represents broad, carbonate platform facies deposited during early to middle Eifelian time. Carbonates are characterized by calcarenitic to cherty to argillaceous limestones and minor shales deposited in a shallow epicontinental sea. The Selinsgrove Limestone Member of the Needmore Formation of central PA is the direct equivalent of the Onondaga Limestone in NY. The Onondaga is generally subdivided into four members across NY: Edgecliff, Nedrow, Moorehouse, and Seneca. These four members are directly equivalent to those of the Buttermilk Falls Limestone of eastern PA. The Clarence Member has been recognized only in western NY and is here designated a local informal facies of the Edgecliff. The informal Jamesville Quarry facies of the Edgecliff is also named in this report for the chert-poor, crinoidal pack- and grainstone that occurs at the Edgecliff type locality. Several marker beds within the Nedrow Member are recognized and the upper boundary with the Moorehouse Member is redefined. The Moorehouse contains several fossil horizons and the Seneca contains several bentonite beds, including the Tioga B or Onondaga Indian Nation Bentonite, which defines its base. The Lower-Middle Devonian (Emsian-Eifelian) boundary, long placed at the base of the Onondaga in NY, could lie as high as the base of the Nedrow Member according to Kirchgasser and Oliver (1993), as there are no age diagnostic fossils in the Edgecliff (Brett and Ver Straeten, 1994). The Seneca Member of the Onondaga Formation as now defined is part of a general fining-upward trend that extends from the underlying upper part of the Moorehouse Member into the overlying Marcellus Formation at its type section. Deposition of member is more complex than previously thought as details reveal that it contains two cycles rather than one, indicating two deepening intervals. The upper contact of the Seneca as defined in this report is marked by a thin, apparently widespread lag bed with fish bone material. Member is thickest in the central Finger Lakes area. Thins eastward and is eventually cutout near Albany. Contains a relatively low diversity fauna. Chonetid and atrypid brachiopods are abundant and LEPTAENA, common; rugose corals are uncommon. Fine to medium-grained wacke- to packstones dominate the unit. In outcrop appears as thick-bedded to massive limestones separated by thin shaly to bentonitic partings. Light-weathering chert is present mainly in the western region. Thin dark shales increase in number toward the top. Base is marked by the Onondaga Indian Nation Ash (Tioga B of PA), which differs from boundary as defined by Conkin, who placed the base of the Seneca 0.47 to 1.25 m above the base of the bentonite. As many as eight Tioga Ash Beds may occur in the Seneca Member, including the Tioga B. At the Seneca Stone quarry, 8.5 km northwest of the type section, the member is 7.1 to 8.4 m thick, depending upon placement of the upper contact, and underlies the Bakoven Member of the Union Springs Shale [shown in chart as assigned to Marcellus subgroup]. Zone L, as the transitional 1.3-m-interval was labeled by Oliver (1954) was assigned by him to the Seneca. However, authors follow Conkin and Conkin (1979) in assigning interval to the overlying Union Springs. Age of the Seneca is Middle Devonian (Eifelian) (Brett and Ver Straeten, 1994). Authors informally propose two dominant, widespread facies of the Edgecliff Member of the Onondaga Limestone: the cherty, micritic Clarence facies, formerly known as the Clarence Member of western NY, and a coarse crinoidal, non- to sparsely cherty Jamesville Quarry facies. The Jamesville Quarry is present at the Edgecliff type locality near Syracuse, where it reaches a thickness of about 5.7 m. To the west the Edgecliff thins to a minimum of 2.5 m at Seneca Stone quarry. The only trace of Clarence-like lithology at this location is a distinctive 0.5 m-thick band of cherty calcisiltite 1.8 m above the base of the Edgecliff. Between Seneca Stone quarry and Phelps the Edgecliff thickens and is composed primarily of sparsely fossiliferous calcisiltites with abundant bands of dark gray to black chert, closely resembling the typical western NY Clarence facies. Total thickness of the Edgecliff reaches a maximum of 14 m. Unit underlies calcareous shale-dominated strata and laterally equivalent argillaceous limestones of the Nedrow Member. The Foxtown Member of the Buttermilk Falls Limestone of eastern PA is directly equivalent to the Edgecliff. The basal contact is conformable in parts of eastern NY, but westward becomes unconformable and overlies increasingly older Devonian to Silurian strata. In some parts of west-central to western NY, overlies upper Lower Devonian Tristates Group and elsewhere the Middle Devonian Hamilton Group. This basal unconformity is known as the Wallbridge Unconformity. The Lower-Middle Devonian (Emsian-Eifelian) boundary, long placed at the base of the Onondaga in NY, could lie as high as the base of the Nedrow Member according to Kirchgasser and Oliver (1993), as there are no age diagnostic fossils in the Edgecliff (Brett and Ver Straeten, 1994).

System Design

The load profiles in conjunction with the geologic attributes of the site were used to develop a preliminary system design, which is shown below. This design includes both vertical boreholes as well as a wastewater heat exchanger to meet the thermal loads of the UTEN.

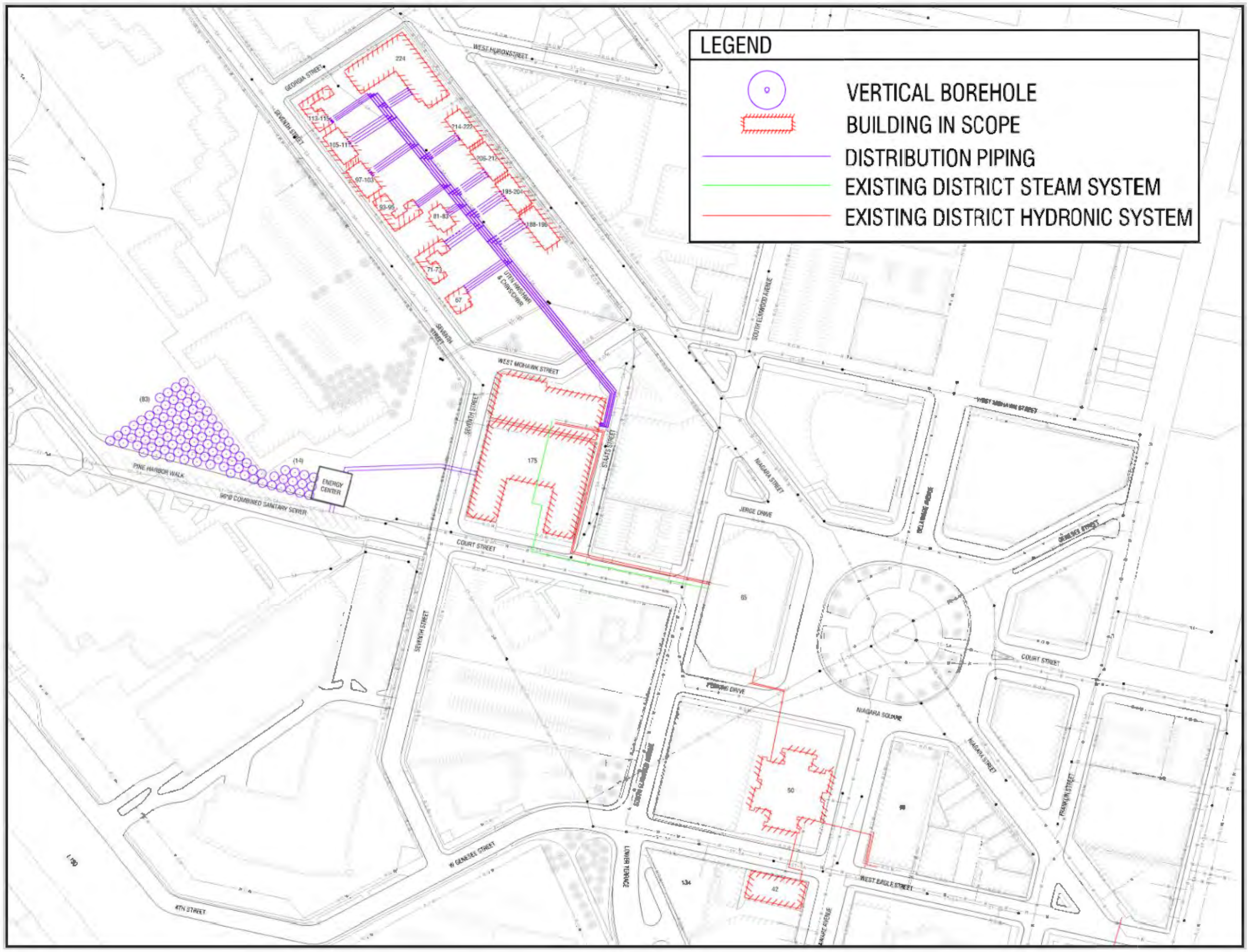

Figure 35: Buffalo District Site Conceptual Site Plan

The preliminary proposed loop configuration is a four-pipe temperature loop with hot water supply and return along with chilled water supply and return to the Buffalo housing. The existing district heating infrastructure would remain in place for the City of Buffalo buildings. The wastewater heat exchanger would tie into the existing boiler plant to base load the system. As previously discussed, figure 26 illustrates the conceptual flow diagram for the system. A more detailed one line diagram is included in Appendix A. An energy center is located adjacent to the vertical boreholes and will house circulation pumps, heat pumps, wastewater heat exchangers, and additional ancillary equipment. Note that the location of this energy center is proposed and can be changed.

Not included in this analysis is specific information on the existing HVAC systems at the buildings. It is assumed that the Buffalo housing buildings currently use traditional gas-fired heating systems and will need to be converted to water-source heat pump systems.

Through GLD modeling software, it was determined that for the cooling load of the residential buildings, (97) vertical boreholes drilled down to (500) feet would be required. The proposed vertical borefield would contribute 2,000 MBH, or 66%, of the peak heating load for the residential buildings. The remainder of the heating load would be met by the wastewater heat exchanger.

Trend data on the flow rate through the combined sanitary/sewer line was compiled and analyzed to determine the capacity of the thermal resource. The relatively consistent flow rate of 6,000 GPM, as shown in the figure below, has a thermal capacity of approximately 26,995 MBH. Of this total capacity, approximately 1,000 MBH would be used for residential heating and 9,280 MBH would be used to base load the existing district system. Additional thermal capacity exists if the system were to ever expand.

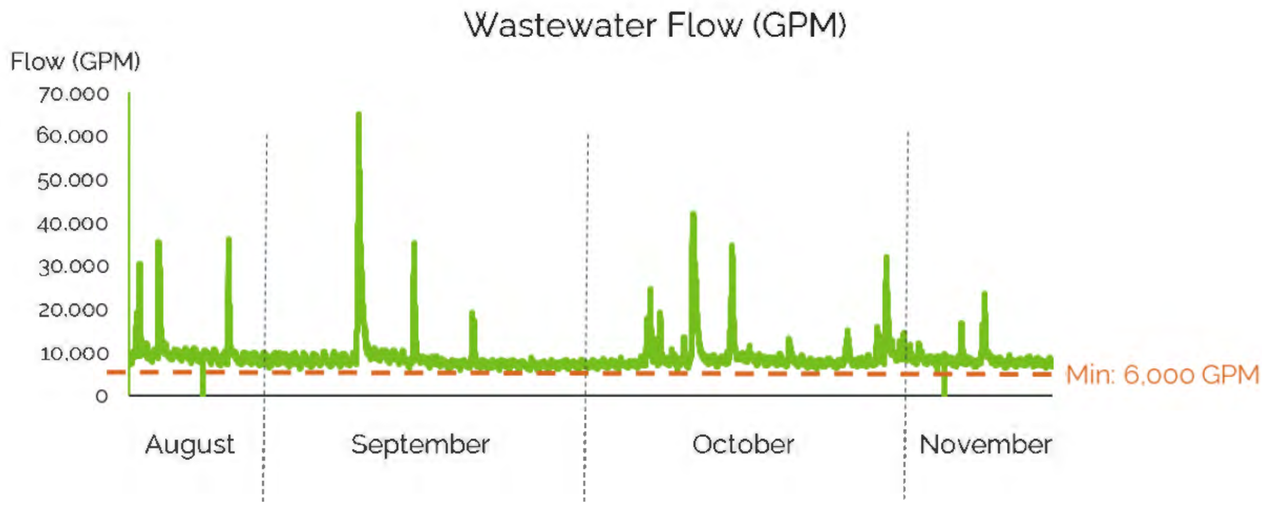

Figure 36: Combined Sewer/Sanitary Flow Data

Due to the use of the wastewater heat exchanger to thermally balance the normally heating dominant load profiles for the residential buildings, the ground heat exchangers experience minimal thermal shift over time. Shown below are estimated entering water temperatures for a (20) year period as modeled in GLD.

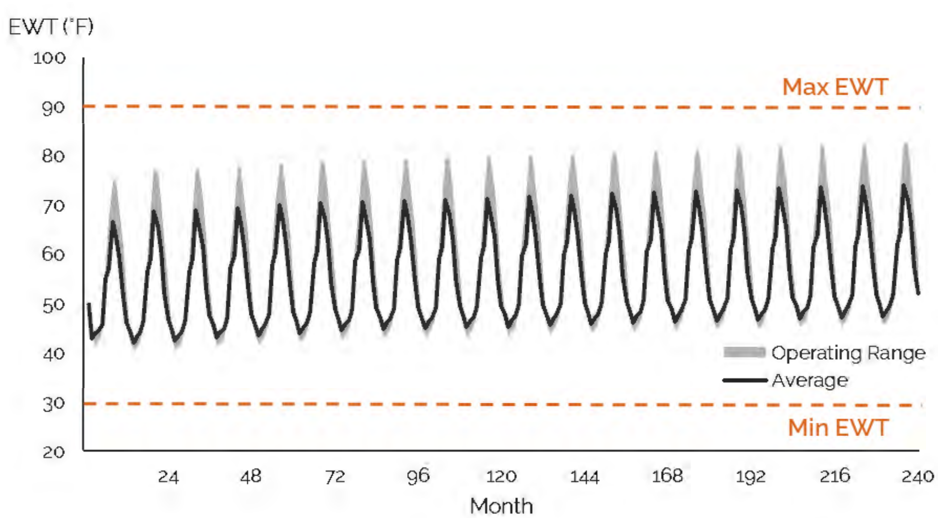

Figure 37: Entering Water Temperatures for Proposed Vertical Boreholes

A detailed output summary of the GLD model is included in Appendix F.

Shown below is a graphic which outlines the heating and cooling control strategies for the system on a peak day.

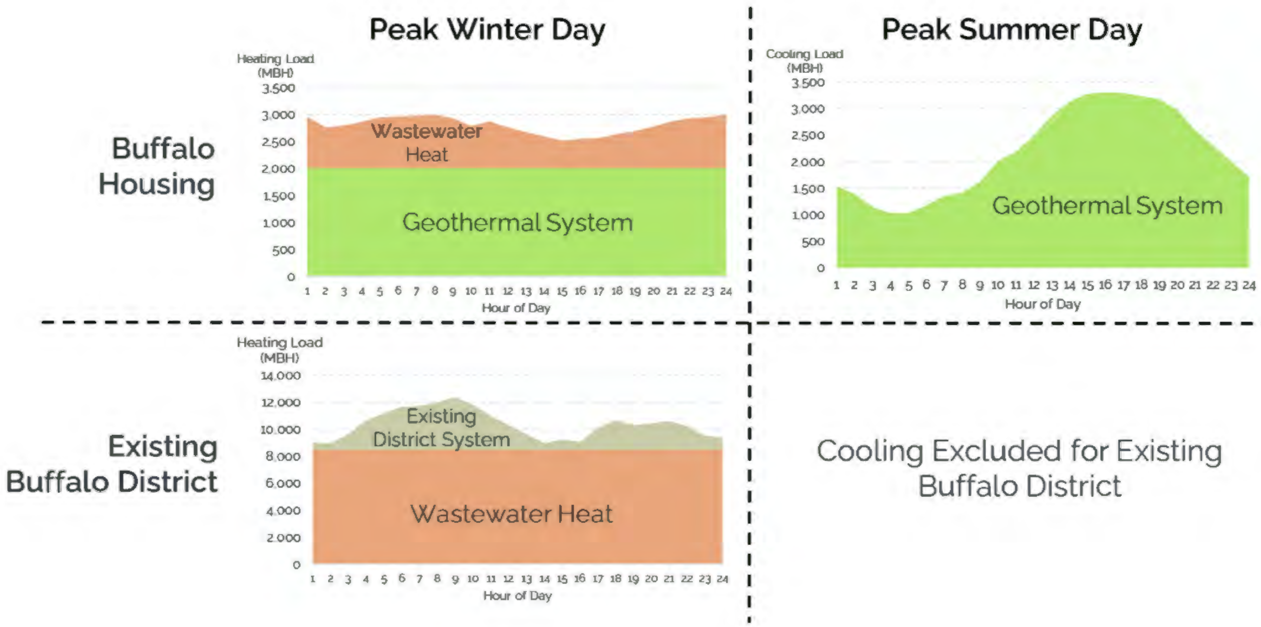

Figure 38: Buffalo District Site Conceptual Peak Day Load Distribution

By base loading the existing district system with a wastewater heat exchanger, the natural gas boilers will be used to a significantly lesser extent, primarily relying on the highly efficient wastewater heating system to meet building loads. The boilers will remain vital to the system for both peak heating days and for resiliency as they provide 100% redundancy to the existing district system. In order for the geothermal system to tie into the existing district system, the existing temperature range needs to be compatible with what a geothermal system can produce. Current geothermal heat pumps can provide hot water up to 180°F. By analyzing the entering and exist water temperatures of the existing plant as shown below, it is apparent that the geothermal system would be able to condition the return water and subsequently reduce the heating load for the boiler plant.

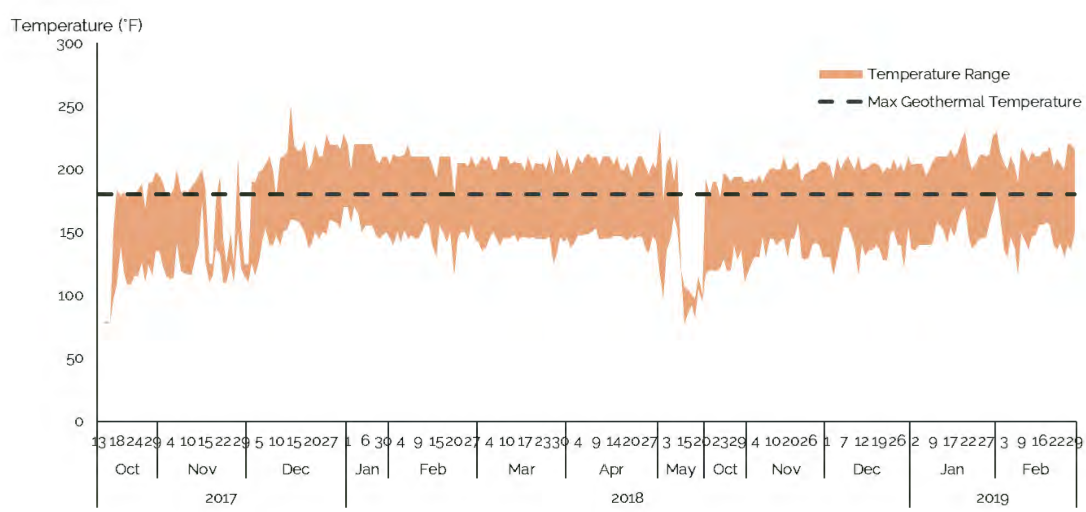

Figure 39: Buffalo District Existing Temperature Range

Energy and Emissions Impact

Based on the building loads, preliminary energy consumption of the district is shown in the graphs below. This clearly shows the increase in peak electric load from using electric heat pumps to base load the existing natural gas system. Electric consumption is reduced in the summer due to the more efficient cooling technology for the residential buildings.

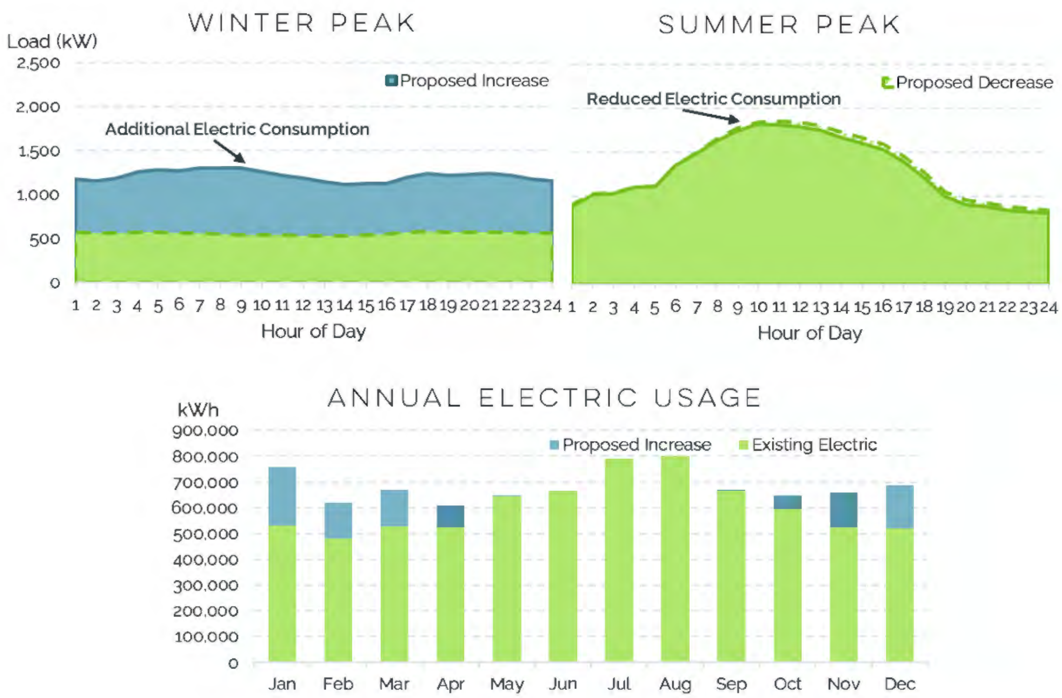

Figure 40: Estimated Electric Impacts at Buffalo District Site

When investigating the electric impact of the UTEN, it is important to note any major electric infrastructure upgrades required for the local utility. Shown below is the electric capacity of National Grid near the proposed energy center.

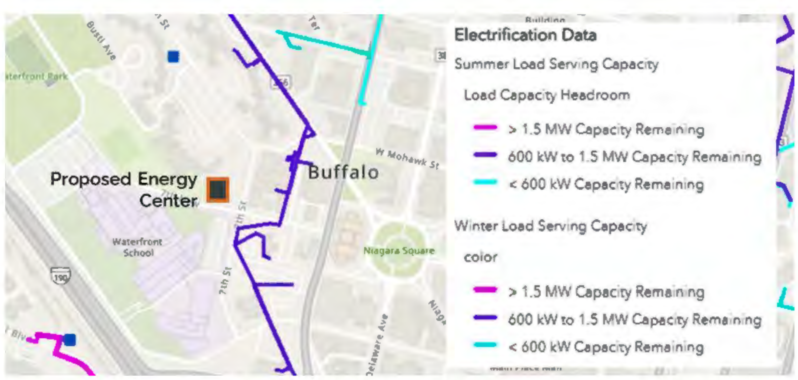

Figure 41: Electric Capacity at Buffalo District Site

As apparent from the figure above, between 600 kW and 1.5 MW of capacity is available adjacent to the proposed energy center. Based on the projected electric demand, it appears that no utility electric capacity upgrades would be required for the project. However, a new electric service would be required for the proposed energy center.

Shown below is the impact that the UTEN has on natural gas consumption for a peak summer and winter day. To reaffirm, this impact excludes City Hall from the proposed scope of work.

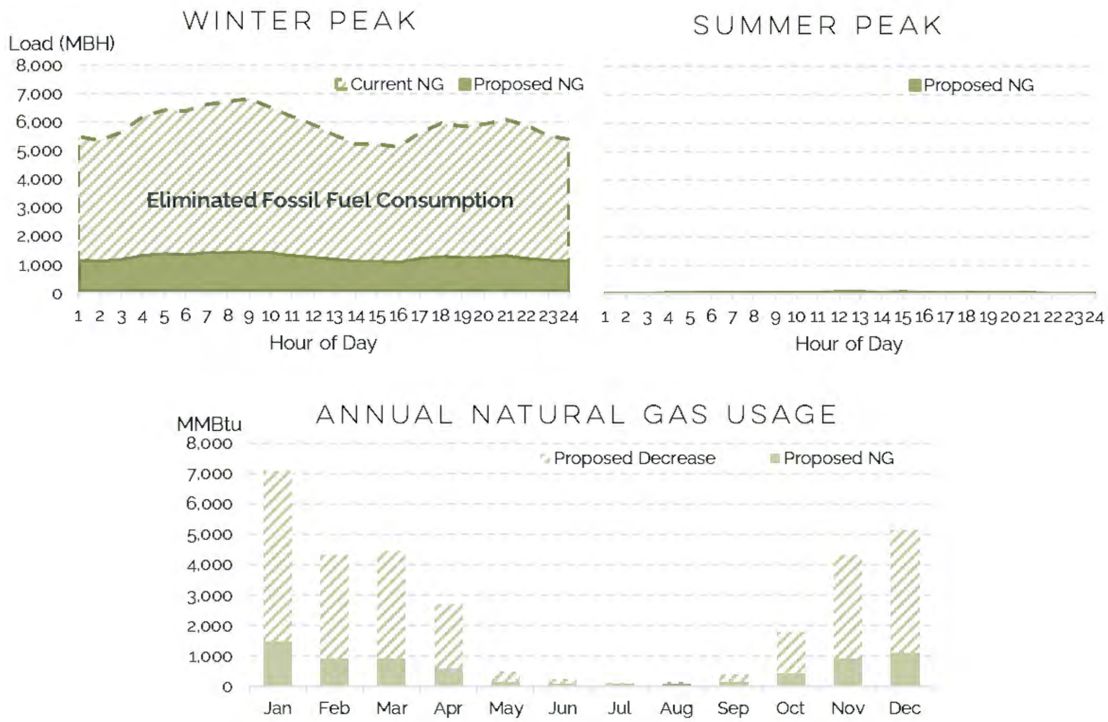

Figure 42: Estimated Natural Gas Impacts at Buffalo District Site

As evident in the figure above, the majority of natural gas savings occur during the heating season in the winter months. The base natural gas usage is due to the supplemental heating provided by the existing natural gas boiler plant.

Shown below is a table which outlines the consumption and demand along with carbon dioxide equivalent (CO_2e) for the potential system. The existing scenario is the sum of building energy consumption for all proposed pilot customers. Existing and proposed scenarios including the first floor of City Hall have been included as well for reference.

Table 7: Buffalo District System Annual Energy Comparison

Scenario	Electric Usage Less Pumping Energy (kWh)	Pumping Energy (kWh)	Electric Demand (kW)	Natural Gas Usage (MMBtu)	Carbon Emissions (MT)
Existing	7,137,481	132,615	1,926	31,181	2,423
Proposed Hybrid System	8,205,034	176,820	1,886	6,893	1,252
Existing (Incl. 1st Floor City Hall)	8,371,736	132,615	2,265	32,871	2,643
Proposed Hybrid System (Incl. 1st Floor City Hall)	9,480,186	187,872	2,222	7,586	1,425

Economic Analysis

The figure to the right illustrates the estimated installation cost for the proposed UTEN. The cost is broken down by major category with additional soft costs and design contingencies included as well. An incentive through the IRA Investment Tax Credit has been included with an assumed 8% reduction in overall cost. A general breakdown and calculation for this incentive is included in the Appendix D. Additionally, detailed cost estimates are provided in Appendix C. The two largest costs for the system are for the HVAC equipment, vertical boreholes, and wastewater heat exchange system. Because the majority of these assets would be owned by the utility in an at-scale model, the subsequent costs would be present regardless of the system being a pilot. This differs from an ambient temperature system (one-pipe or two-pipe) where the heat pumps would be located within the customer's building and therefore would be at their expense in an at-scale model.

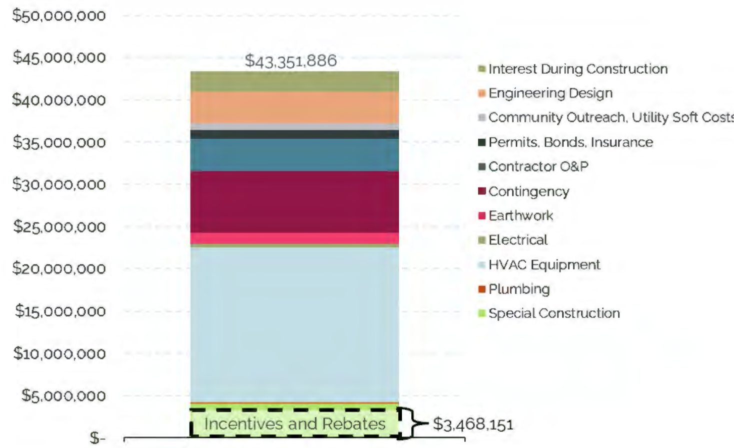

Figure 43: Buffalo District Site Estimated Capital Costs

The figure to the left includes the estimated annual costs for the proposed system. A full-time employee has been included to operate and maintain the proposed system. This cost represents the largest portion of the annual O&M costs. An additional maintenance cost has been included for the wastewater heat exchange units which would be handled by a 3rd party. The smallest portion of annual maintenance costs corresponds with pumping energy required by the system,

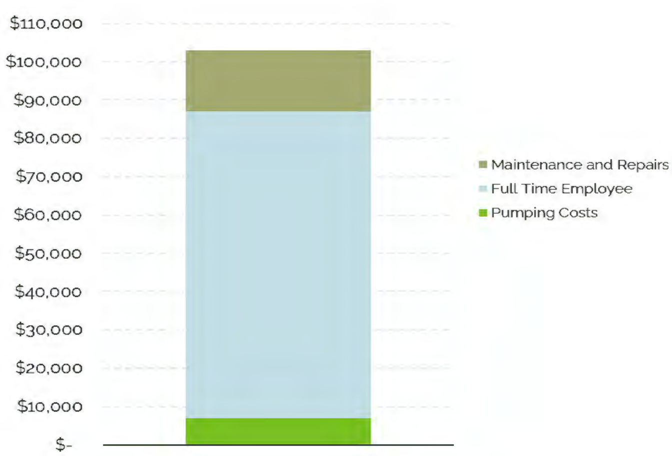

Figure 44: Buffalo District Site Estimated Annual Costs

The table below outlines upfront costs for each of the proposed solutions along with a ratio of the upfront cost to the carbon emissions reduction over the baseline.

Table 8: Buffalo District Site System Cost Comparison

Scenario	Carbon Emissions (MT)	Upfront Cost	Cost ($/MT reduction)
Existing	2,423	-	-
Proposed Hybrid System	1,252	$39,883,735	$34,060
Existing (Incl. 1st Floor City Hall)	2,643	-	-
Proposed Hybrid System (Incl. 1st Floor City Hall)	1,425	$43,768,363	$35,924

Note that although the inclusion of the first floor of City Hall would increase project cost per metric ton of carbon emissions reduction, including the high profile building has inherent benefits from the perspective of public relations.

By combining the upfront cost with the annual operating and maintenance costs and projecting out over a 25-year period, the lifecycle cost of the proposed system can be estimated. Shown below is the lifecycle cost of the system. Note that the annual costs represent a minor fraction of the upfront cost.

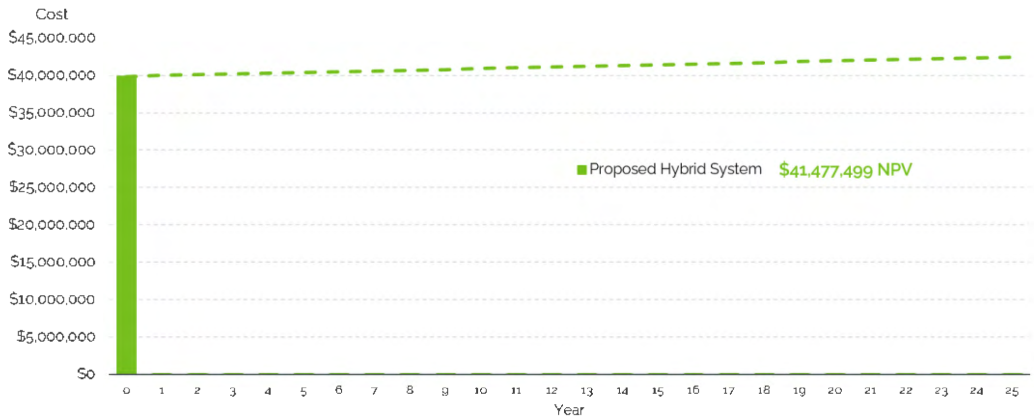

Figure 45: Estimated Buffalo District Site Lifecycle Cost

PERMITTING AND REGULATORY REVIEW

Many district systems are required to cross property boundaries in their construction. Because of this, there are a number of permitting and regulatory requirements that must be considered during the design. These considerations include, but are not limited to:

- Obtaining easements for locating infrastructure across public rights of way or across properties that are not included in the district.
- Gaining access to private property owners with protection and/or compensation.
- Coordination with existing utilities.
- Compliance with local standards and authorities having jurisdiction.

Any subsurface easements created for a district geothermal system must be conveyed via a written document which is signed and acknowledged by the creator. District geothermal systems which also cross public rights of way over land, such as roads and highways, must obtain easements from the state or municipal subdivision which controls these public rights of way. Through this study, (12) authorities having jurisdiction (AHJ's) were identified on Federal, State, and Local levels.

The following sections discuss some of the current challenges faced by entities owning or installing district geothermal systems which influence the widespread adaptation of the technology.[7]

Municipal Regulations for Geothermal Systems

In New York State, while some municipalities have developed permitting guidelines for single property closed loop geothermal systems, none have developed permitting guidelines for multi-property district systems, open-loop systems, and systems that involve special design considerations such as utilizing surface water as a thermal resource. This lack of municipal permitting regime and standards for equipment leads to increased risk, cost, and uncertainty as project developers navigate the various zoning, building, mechanical, environmental, and other regulations that may apply to geothermal systems but were not designed for district systems specifically.

Rights-of-Way and Approvals

Crossing property lines, streets, railroad tracks, and utility infrastructure to drill and install a district geothermal system will require easements to be granted from the various owners or authorities responsible for these locations. The costs of acquiring rights of way can be expensive and time-consuming. Utility infrastructure in particular can be a costly right-of-way to navigate as the respective utility will often need to travel to the site to ensure that their infrastructure is not being infringed upon.

Often times agreements will need to be made for rights-of-way on private property which include discussions on compensation, maintenance, decommissioning, and indemnification for liability of the district system. Because compensation for private property is difficult to objectively value, potential deadlocks in negotiations can occur which will add cost and increase risk to the project. Compensation may range from a one-time acquisition fee, annual fees, excessive or escalating fees, and fees regarding the time and cost of staff and legal professionals required to procure rights.

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[7] (Pace University, Pace Energy and Climate Center, 2021)

In New York State, investor-owned electric and natural gas utilities utilize franchise agreements with municipalities to resolve rights-of-way issues. For a utility-owned system, through these agreements, the utility is granted rights-of-way to install infrastructure within the municipality's jurisdiction for a specified period of service at a determined fee.

Drilling Regulatory Restrictions

New York State has recently lifted the additional regulations associated with drilling boreholes deeper than 500 feet.[8] By eliminating the additional restrictions on systems at depths exceeding 500 feet, certain systems can benefit from reducing the number of required boreholes by increasing the borehole depth. Assuming that the geology is conducive to drilling to depths beyond 500 feet, this creates an opportunity for sites with limited land area to increase the thermal capacity at the site – which is a current obstacle for buildings in urban environments.

Drilling Cost and Liability

Drilling costs and liability are major obstacles in installation of district geothermal systems. Drilling for district geothermal systems involves large, heavy mobile drilling rigs which produce large volumes of sludge that needs to be removed from the work site. Drilling in dense urban areas or areas which do not have suitable geology present additional challenges, risk, and cost. The following outlines potential complications with site geology:

- When excessive groundwater is encountered at the site, the cost of pumping and removing this water can be significant. The saltwater produced from boring cannot be reinjected into the ground but instead must be removed from the site.
- Geology with high-density rock may have fluids with high corrosive elements or high solid content which slows rate of penetration and shortens drill bit life.
- Areas with shallow natural gas pockets cannot be drilled safely due to fire hazards
- Hydrogen sulfide which is commonly encountered during drilling is corrosive, toxic, and flammable
- Unknown infrastructure or other manmade artifacts

As previously discussed, a test bore was not included at this stage of the project. In future design phases of the project, a test bore will be included to characterize the geology found on site and confirm assumptions originally made. Including a test bore will help mitigate drilling and construction risks.

[8] (New York State Senate, 2023)

A summary of all AHJ's including any permitting that may be required with associated timeframes for approval is shown below. AHJ's relevant to the systems as presented in this report are emboldened.

Table 9: Authorities Having Jurisdiction

Agency Level	AHJ	Description of Permit/Approval	Estimated Timeframe of Approval
Federal	United States Environmental Protection Agency (EPA)	Authorizes "by rule" the use of geothermal wells as class V injection wells under the UIC program. Specific inventory information on the wells and the site's hydrogeologic conditions must be submitted prior to construction. Vertical closed loop and open loop supply wells are exempt.	4 to 6 weeks
State	NYS Department of Transportation (NYS DOT)	Permitting approval required for subsurface work across state highways or railroads. Agreement between project developer and railroad on compensation, maintenance, and decommissioning.	Several weeks
State	**NYS Department of Environmental Conservation (NYS DEC)**	**CWA Section 401 Water Quality Permit (open loop or surface water thermal system).** **SPDES Permit (open loop or surface water thermal system).** **Division of Water Approval for wells less than 500 feet or over 500 feet.**	**Unknown**
State	NYS Office of Renewable Energy Siting (NYS ORES)	Additional siting requirements may apply for projects over 25 MW of thermal capacity.	Up to 12 months
State	NYS Department of Health (NYS DOH)	Design must not return water used in conjunction with heat exchangers back to the public water system.	N/A
State	**NYS Public Service Commission (NYS PSC)**	**Requires approval for pricing for geothermal service, if regulated.** **Requires submetering and notices**	**6 to 12 months**
State	NYS Department of Public Service (NYSDPS) and NYS Historic Preservation Office (NY SHPO)	Requires approval for design which interferes with historical or cultural resources.	Unknown
Local	**Buffalo Sewer Authority**	**Requires Stormwater Pollution Prevention Plan (SWPPP)** **Requires approval to connect to water or sewer systems**	**Unknown**
Local	**City of Buffalo Department of Permit and Inspection Service's Permit Office**	**Requires general construction permit**	**60 days**
Non-Government	**Private Property Owners Served by System**	**Agreement between developer and property owner to install system on private property, with an agreement on pricing, maintenance, and decommissioning.**	**Several months**
Non-Government	Private Property Owners Not Served by System	Private easement from property owner to install and maintain parts of district system on or across private property, with an agreement on compensation, maintenance, and decommissioning.	Several months
Non-Government	**Utilities (electric, gas, water, sewer, cable, telephone)**	**Confirm project infrastructure does not interfere with utility infrastructure** **Project developer to notify all utility operators of project and receive "all clear" from utilities** **Project design which interferes with utility infrastructure or requires infrastructure upgrade requires agreement on compensation, maintenance, decommissioning, and liability.**	**Several months**

OWNERSHIP MODELS AND METERING

The following section outlines considerations for ownership of the UTEN equipment, effectively metering the system, and potential lines of demarcation between utility owned and customer owned equipment. It is meant to serve as a guide for National Fuel in implementing the UTEN system and highlight some of the decision points that will need to be made should the project proceed into design and eventual construction.

There have been several groups dialoging about potential business models regarding district geothermal systems for communities. Those conversations tend to fall in three (3) main categories with associated pros and cons related to each:

1. <u>Private Ownership</u> – If an individual or group can raise the capital, obtain permission from landowners and building owners, design, install and operate a geothermal district system, that's an option. This assumes that they follow the necessary codes and standards available and have the funding to push through some of the inevitable inefficiencies of an early adopter privately owned and operated system. Options could be privately funded and a third-party company can be hired to operate the system.
2. <u>Municipal Ownership</u> – In NYS, municipalities can create utilities, raise funds through bonds, design, install and operate a new utility. They can also grant others permission to take on the design, installation, and operation for them. While they may not have as many barriers in terms of satisfying the Authorities Having Jurisdiction, there are still standards they will need to either adhere to and/or develop to be successful with a sizable district geothermal project.
3. <u>Regulated Utility Ownership</u> – The details around regulated utility ownership of thermal energy networks are currently being addressed by the New York Public Service Commission in Case 22-M-0429. It is likely to be modeled at least in part to the regulatory structures of existing natural gas and/or electric utilities. There are a number of specific issues to consider as to the areas of regulation or the rules to participate in the regulated market:
    a. **Distribution vs. Generating Assets** – Will a new regulated district geothermal utility follow the deregulated structure, or will it include all types of thermal assets that contribute to the system? Our present deregulated gas and electric infrastructure have separated distribution assets (e.g., wires & pipes connecting buildings), and generating assets (e.g., electric generating plants), creating competitive markets for the supply of energy, while the distribution assets are a regulated regional monopoly to help ensure reliability for social benefit. These concepts may be applied to a district geothermal network with supply being any thermal source/sink representing the generating assets, and the network of pipes representing the regulated utility whose construction and operation provide a shared benefit to the connected buildings:
        i. In pilot projects and early-stage expansions, it's likely simpler to have a common owner for many of the major sources/sinks requiring installation (e.g., closed loop vertical heat exchangers) and the same owner for the distribution piping connecting the buildings in the network
        ii. Since the number of thermal sources/sinks are incredibly diverse, it's likely that as the number of clean thermal utilities increase and extend to adjacent sets of buildings. Mechanisms will be developed to recognize the contributions of these various sources/sinks, somewhat similar to distributed electric generating assets. Thermal sources can

add value to the network with the addition or extraction of thermal energy that benefits the network. Supply assets could include vertical heat exchangers, solar thermal panels, or even a bank of chillers cooling a data center. The distribution assets are similar to utilities that have existed for centuries, such as water and sewer infrastructure bringing and removing water from buildings.

b. **Regulated with Regional Exclusivity or Competitive Market** – Whether or not the regulation covers distribution and generating assets (above), should there be regional exclusivity granted or should there be a more open market that is still regulated?
c. **Individual Building vs. Two+ Separately Owned Properties -** The concept of defining a "geothermal plant" as needing to service two (2) or more separately owned properties has its basis in large central plant utilities. It goes to why the state may or may not grant a territorial monopoly and fits well with gas and electric service models we are accustomed to seeing in the regulated space. There will be continued discussion on what constitutes a "regulated utility" for GSHP systems but recognize there may be a societal benefit to having a large, regulated utility offer ground heat exchanger installations to individual buildings where a district system is not practical.

Metrics for Evaluating Effectiveness

During the pilot stage of the project, it is important to capture a robust dataset monitoring the system's performance. This should provide sufficient data to quantify the flow of thermal energy and corresponding electric consumption on a frequent basis. The Department of Public Service has highlighted key points that need to be metered by the UTEN pilot projects on either an hourly, monthly, or annual basis.[9] Note that this list is still in flux and is subject to change.

Customer-Side Metering Points

- Input electricity to each installed heat pump
- Heat exchanger inlet and outlet temperatures, utility side
- Heat exchanger inlet and outlet temperatures, customer side

Thermal Energy Resource Metering Points

- Electric consumption of circulation pump(s)
- Electric consumption of heat pump(s)
- Inlet and outlet temperatures from each heat source/sink
- Thermal energy for heating from each heat source
- Thermal energy for cooling from each heat sink
- Electric consumption for each thermal resource
- Thermal energy for heating in to or out of thermal energy storage (if applicable)
- Thermal energy for cooling in to or out of thermal energy storage (if applicable)
- Temperature gauges within thermal storage tank (if applicable)

Central Plant Metering Points

- Heat pump operating capacity
- Heat pump hours of operation
- Heat pump evaporator inlet and outlet temperatures
- Heat pump condenser inlet and outlet temperatures

[9] (Department of Public Service, 2024)

Utility Distribution System

- Thermal energy for heating and cooling provided by the utility distribution system
- Hours of operation that the loop supply temperature is outside of design-specified range
- Electric consumption of pumps
- Pressure and temperature throughout the distribution system
- Replenishment of heat transfer medium

Energy Center

- Supply temperature to customer, energy center side
- Return temperature from customer, energy center side

Peaking/Backup Equipment (if applicable)

- Other fuel consumption for thermal energy resource
- Thermal energy (heating or cooling)
- Inlet and outlet temperatures
- Number of startups
- Hours of operation

Borehole Balancing Equipment (if applicable)

- Electric consumption
- Heat in and out
- Number of startups
- Hours of operation

A number of different metering technologies are available on the market that are regularly used in commercial HVAC projects. Further identification of meter types is typically defined in the final stages of the engineering design. In addition to providing valuable information on the exchange of energy throughout the loop for evaluating potential business models, these data points are critical in controlling the system and monitoring for potential issues. Not unlike a large commercial building, it would be beneficial to the design team and National Fuel to integrate all of the controls to a central control system instead of running cables to each building, Wi-Fi communication between buildings is now possible and a cost-effective alternative. By combining controls to a central system, the loop operators are able to quickly identify and rectify issues with the system as a whole. Aside from the operational benefits attributed to thorough metering, there are a number of other metrics that can be calculated for National Fuel's use. These are summarized at a high level below:

Energy Performance Metrics

- Thermal performance of ground heat exchangers
- Overall Building efficiency (normalized per square foot)
- HVAC system performance/efficiency
- Increase/decrease in electric consumption & demand
- Decrease in natural gas consumption & demand
- Aggregate efficiency of UTEN

Financial Metrics

- Customer cost per BTU compared to natural gas, air-source heat pump systems
- Net capital cost threshold to meet minimum ROI criteria
- Net impact on customer utility bills
- Maintenance staffing costs
- Pumping costs
- System repair costs

Points of Demarcation

A clear line of demarcation is required in order to effectively separate utility and customer owned equipment. An effective point of demarcation limits intrusion into the customer's building while ensuring that operation and maintenance activities are appropriately distributed among the utility and the customer. For the Buffalo District system, the proposed line of demarcation is at the isolation valve located on the customer side of the Energy Transfer Station heat exchanger. This is depicted below for a typical residential home for the proposed system.

Equipment located "downstream" of this isolation valve will be owned, operated, and maintained by the customer, whereas equipment located upstream of the isolation valve will be owned, operated, and maintained by the utility. Additional considerations should be taken into account for the proposed line of demarcation based on certain unique factors. Ownership of customer-side equipment may impact the ability to acquire certain funding opportunities such as the IRA's Investment Tax Credit. In addition, maintenance responsibilities of customer-side equipment could be part of the negotiating process in order to entice customers to participate in the pilot.

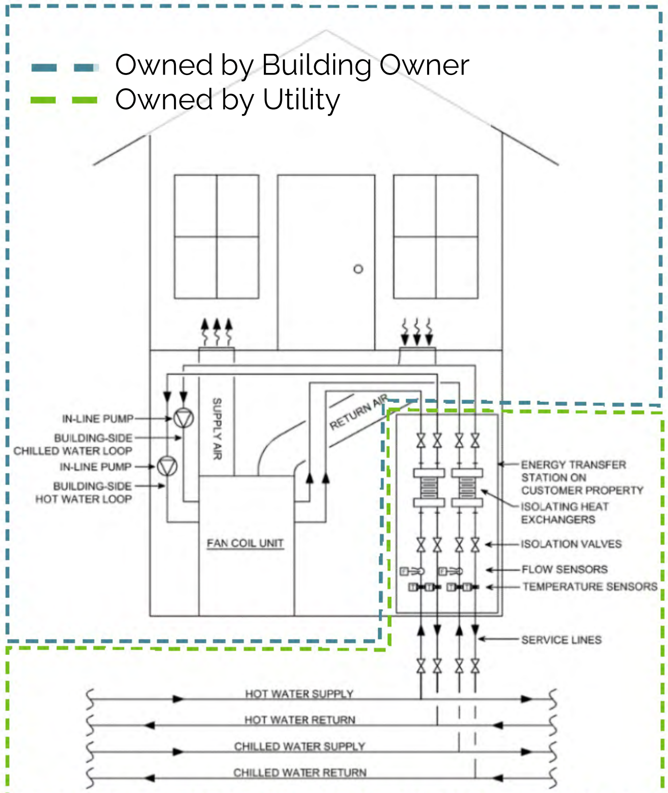

Figure 46: Proposed Point of Demarcation

Like the line of demarcation between utility and customer owned assets on the distribution side of the UTEN, a line of demarcation can also exist in systems where a thermal resource is owned by a third party. In this situation, the line of demarcation would exist at an isolation valve separating the thermal resource from the remainder of the UTEN. The owner of the thermal resource would be responsible for all operations and maintenance activities pertaining to the thermal resource, whereas the utility would be responsible for operations and maintenance activities pertaining to the UTEN.

REFERENCES

Ballantyne, D., & LLC Ballantyne Consulting. (n.d.). *Overview of Piping Systems and their Seismic Vulnerability.*

DeMott, L., Stumm, F., & Finkelstein, J. (2023). *Bedrock-surface elevation and overburden thickness maps of the five boroughs, New York City, New York.* Reston, VA: U.S. Geological Survey.

Department of Public Service. (2024). Performance Metrics Technical Conference., (p. 7).

Kozlowkski, A., Backhaus, K., & Leone, J. (2020, August 13). *Glacial Stratigraphic Framework of the Cayuga Inlet Valley and Ithaca Delta Plain.* Retrieved from https://www.nysm.nysed.gov/sites/default/files/mc132_cayinletstrat.pdf

New York Consolidated Laws, Public Service Law, PBS § 2 (10 10, 2023).

New York State Joint Utilities. (2022). *New York State Technical Resource Manual.*

New York State Senate. (2023, August 7). *Senate Bill S6604.* Retrieved from New York State Senate: https://www.nysenate.gov/legislation/bills/2023/S6604#:~:text=JUSTIFICATION%3A%20This%20bill%20will%20reduce,building%20decarboniza%2D%20tion%2C%20open%20new

NYS Department of Environmental Conservation. (2023, August). *Establishing a Value of Carbon.* Retrieved from Climate Change Guidance Documents: https://extapps.dec.ny.gov/docs/administration_pdf/vocguide23final.pdf

NYSEG/RGE. (2023, July 28). *PV Hosting Capacity.* Retrieved from ArcGIS: https://www.arcgis.com/apps/webappviewer/index.html?id=84de299296d649808f5a149e16f2d87c

Pace University, Pace Energy and Climate Center. (2021, June). *Overcoming Legal and Regulatory Barriers to District.* New York: New York State Energy Research and Development Authority.

SHARC Energy. (2024). *Wastewater Holding Tank Design and Installation Guide.* SHARC Energy.

Solar Energy Technologies Office. (2023, July 27). *Federal Solar Tax Credits for Businesses.* Retrieved from Office of Energy Efficiency & Renewable Energy: https://www.energy.gov/eere/solar/federal-solar-tax-credits-businesses

Solar Impulse Foundation. (2023, 10 3). *Energy Geostructures*. Retrieved from Solar Impulse: https://solarimpulse.com/solutions-explorer/energy-geostructures

U.S. Energy Information Administration. (2024, January 2). *Residential Energy Consumption Survey (RECS).* Retrieved from 2020 RECS Survey Data: https://www.eia.gov/consumption/residential/data/2020/c&e/pdf/ce1.2.pdf

United States Environmental Protection Agency. (2023, July 27). *GHG Emission Factors Hub.* Retrieved from EPA Center for Corporate Climate Leadership: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

APPENDIX A: DRAWINGS

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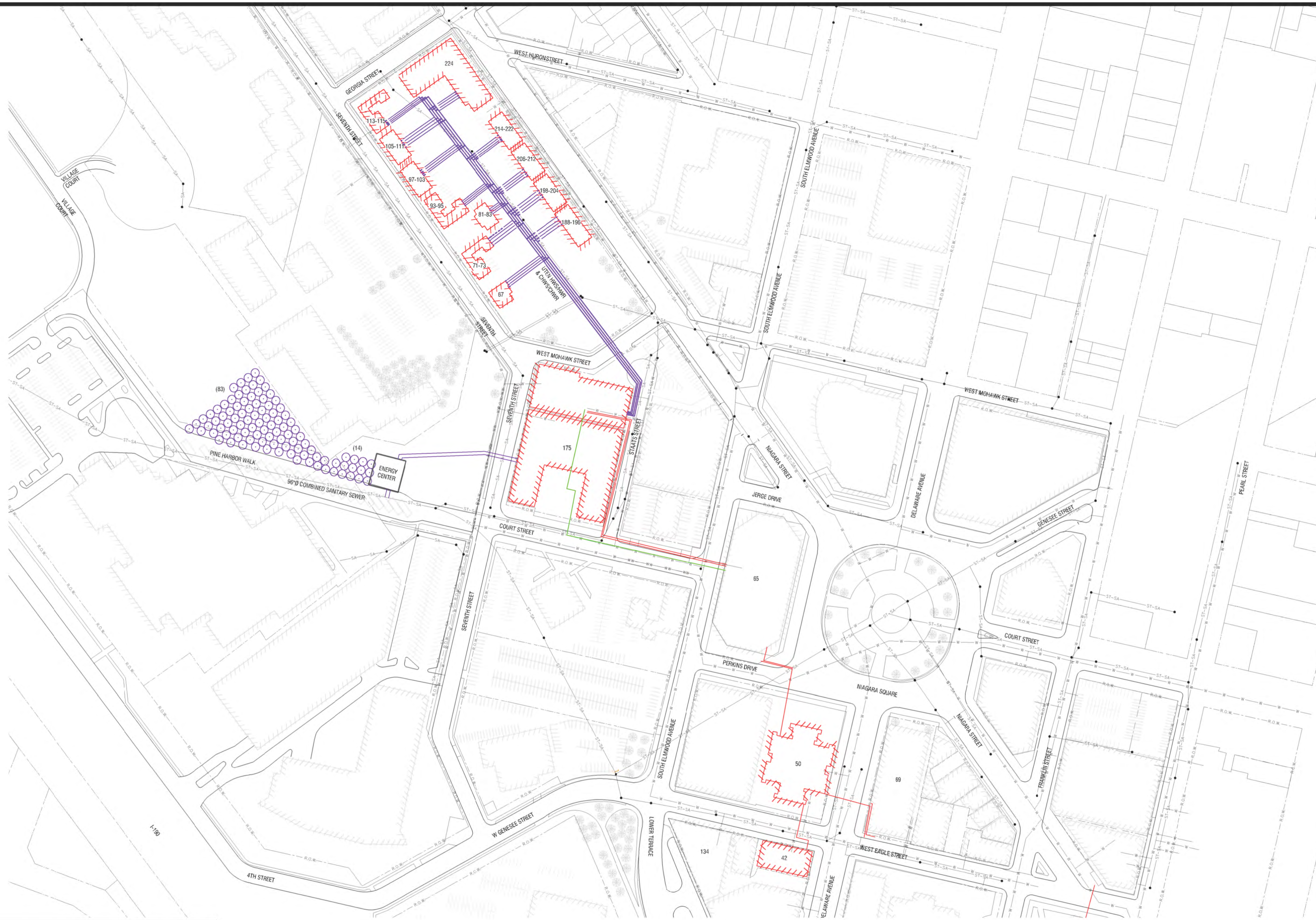

LEGEND

- VERTICAL BOREHOLE
- BUILDING IN SCOPE
- DISTRIBUTION PIPING
- EXISTING DISTRICT STEAM SYSTEM
- EXISTING DISTRICT HYDRONIC SYSTEM

1 / M101 — CONCEPTUAL SITE LAYOUT
SCALE: 1" = 250'

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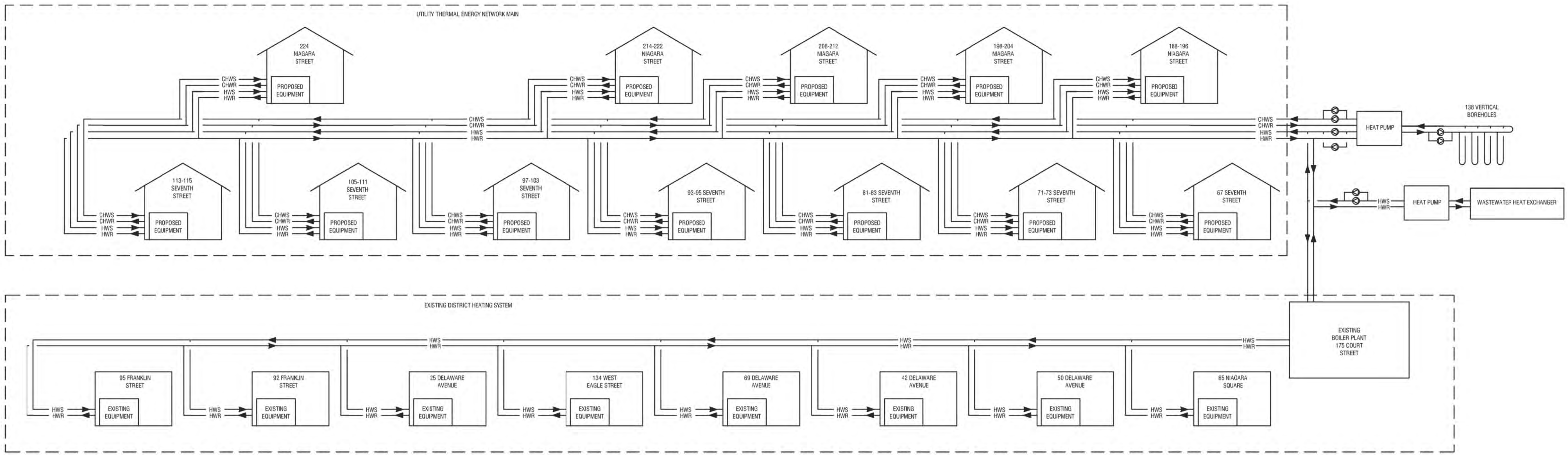
300 Pearl Street, Suite 130
Buffalo, NY 14202
716-551-6281
labellapc.com

C.A. NUMBER:
GEOLOGICAL: 018750
LAND SURVEYING: 017976
PROFESSIONAL ENGINEERING: 018281

ISSUED FOR:	ISSUED FOR REVIEW
DRAWING NAME:	SITE 1 - BUFFALO DISTRICT PROPOSED UTEN SITE PLAN
DRAWN BY:	TP
DATE:	05/2024
PROJECT NO.:	2240646
PROJECT NAME:	UTEN FEASIBILITY STUDY PHASE 2, BUFFALO, NY
DRAWING NUMBER:	M-101

GENERAL NOTES:

1. REFER TO THE G501 FOR ADDITIONAL HEAT PUMP INSTALLATION INFORMATION.



1 G101 CONCEPTUAL SYSTEM FLOW DIAGRAM

NOT TO SCALE

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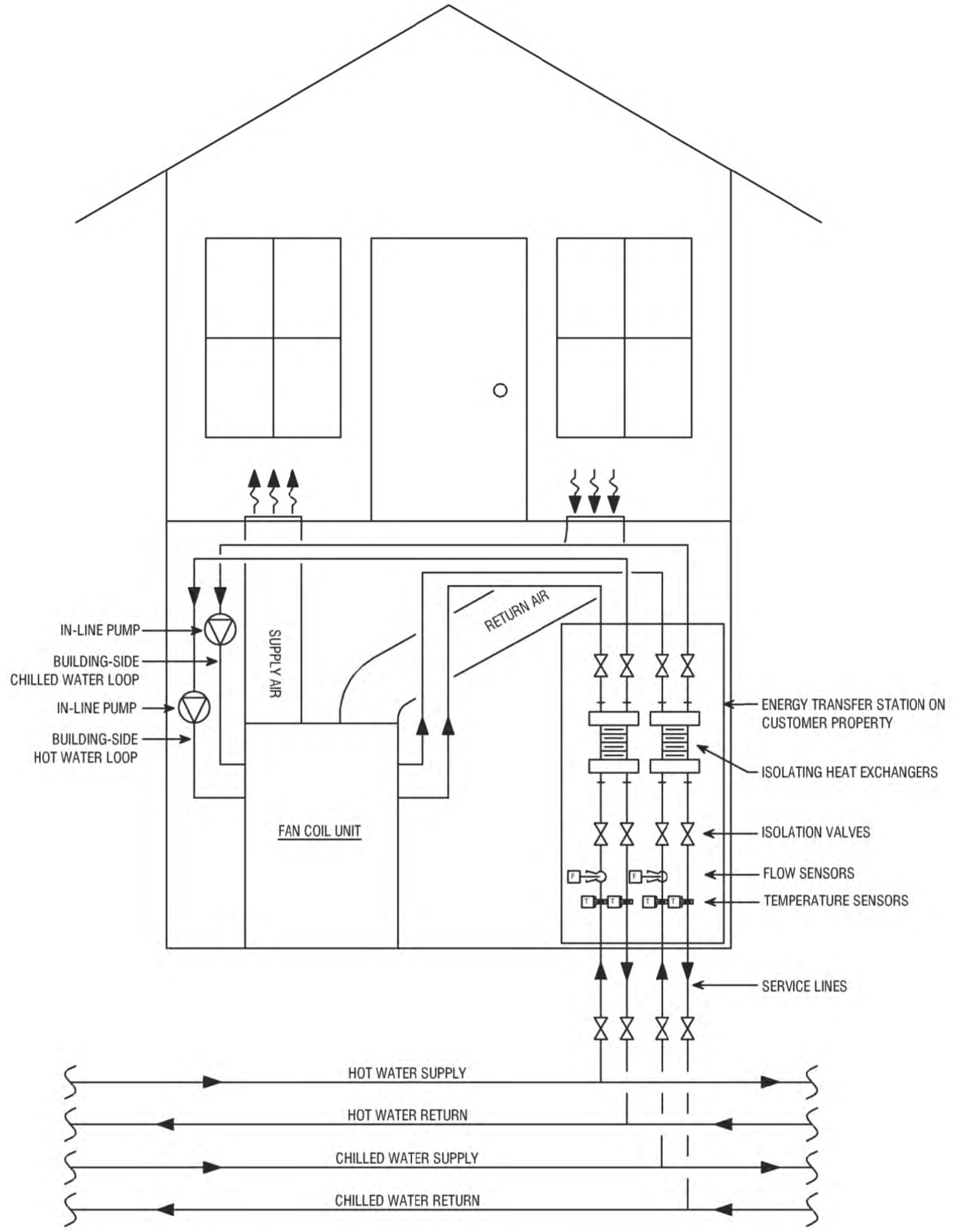
C.A. NUMBER:
GEOLOGICAL: 018750
LAND SURVEYING: 017976
PROFESSIONAL ENGINEERING: 018281

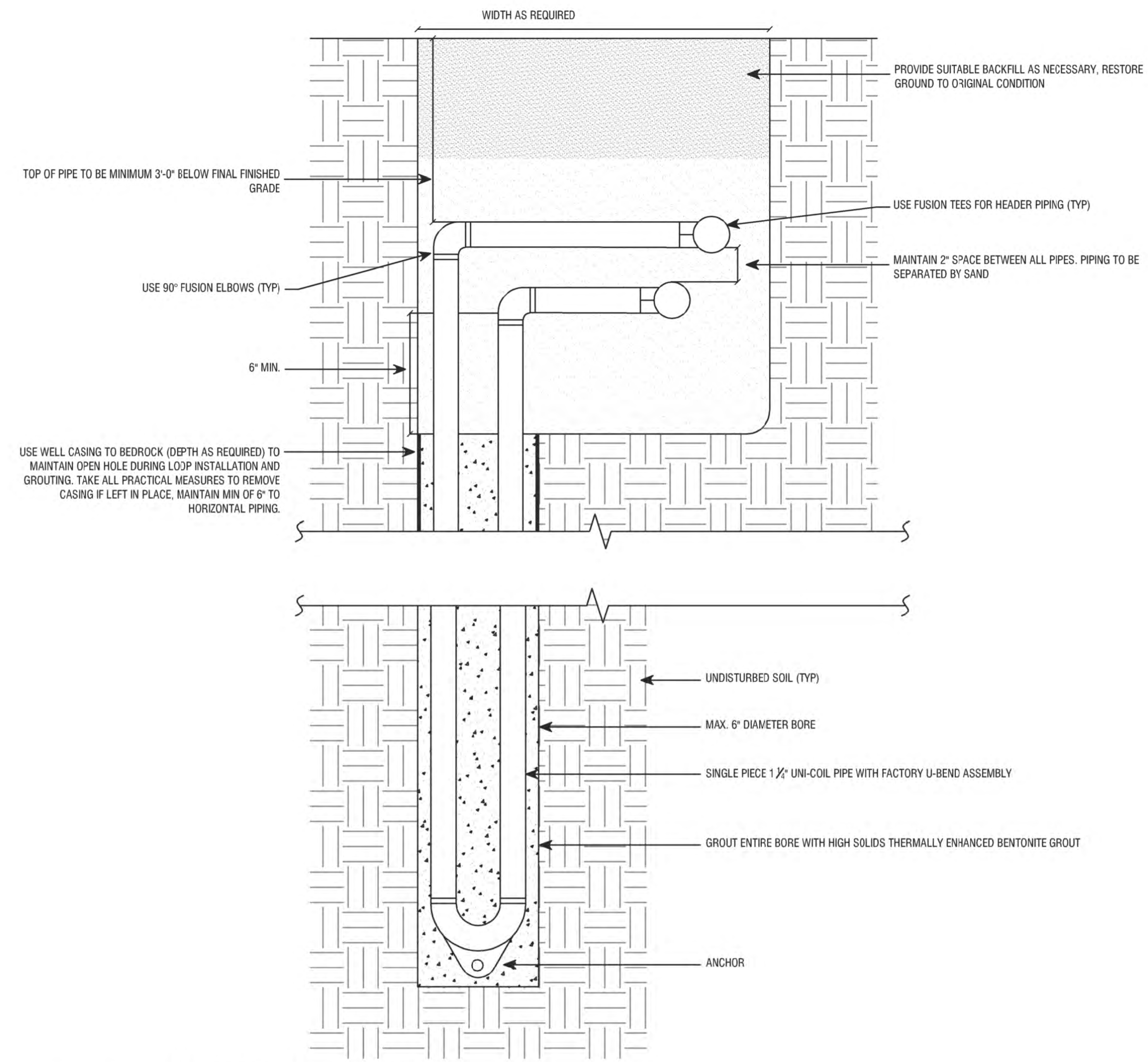
ISSUED FOR:	ISSUED FOR REVIEW
DRAWING NAME:	SITE 1 - BUFFALO DISTRICT SYSTEM FLOW DIAGRAM
DRAWN BY:	TP
DATE:	05/2024
PROJECT NO.:	2240646
PROJECT NAME:	UTEN FEASIBILITY STUDY PHASE 2 BUFFALO, NY
DRAWING NUMBER:	G-101



1
G501

TYPICAL BUILDING CONNECTION

NOT TO SCALE



2
G501

TYPICAL BOREHOLE DETAIL

NOT TO SCALE

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C.A. NUMBER:
GEOLOGICAL: 018750
LAND SURVEYING: 017976
PROFESSIONAL ENGINEERING: 018281

ISSUED FOR: ISSUED FOR REVIEW

DRAWING NAME: SITE 1 - BUFFALO DISTRICT DETAILS

DRAWN BY: TP

DATE: 05/2024

PROJECT NO.: 2240646

PROJECT NAME: UTEN FEASIBILITY STUDY PHASE 2
BUFFALO, NY

DRAWING NUMBER: G-501

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APPENDIX B: WATER WELL LOGS

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

(1) County ERIE   Buffalo

(2) Township

(3) DEC Well Number E2217

WELL COMPLETION REPORT

(4) OWNER: MLP Plumbing

(5) ADDRESS: 120 W. Tupper St - Buffalo

(6) LOCATION OF WELL (Also see reverse): 341 Delaware Buffalo, NY

(7) DEPTH OF WELL BELOW LAND SURFACE (Feet): 345'

(8) DEPTH TO GROUNDWATER BELOW LAND SURFACE (Feet):

CASINGS

(9) DIAMETER: 6 in. | — in. | — in. | — in.

(10) LENGTH: 52 ft. | — ft. | — ft. | — in.

(11) GROUT TYPE: Bentonite

(12) GROUT INTERVAL (Feet) FROM ______ TO ______

SCREENS

(13) MAKE & MATERIAL

(14) OPENINGS

(15) DIAMETER in. | in. | in. | in.

(16) LENGTH ft. | ft. | ft. | in.

(17) DEPTH TO TOP OF SCREEN, FROM TOP OF CASING (Feet)

WELL TEST

(18) DATE: 7-14-03

(19) DURATION OF TEST

(20) LIFT METHOD ☐ Pump ☒ Air Lift ☐ Bail

(21) STABILIZED DISCHARGE (GPM): 200+ GPM

(22) STATIC LEVEL PRIOR TO TEST (feet/inches below top of casing)

(23) MAXIMUM DRAWDOWN (Stabilized) (feet/inches below top of casing)

(24) RECOVERY (Time in hours/minutes)

(25) Was the water produced during test discharged away from immediate area? Yes ___ No ___

PUMP INSTALLATION

(26) DATE

(27) PUMP INSTALLED? YES ___ NO X

(28) PUMP INSTALLER

(29) TYPE

(30) MAKE

(31) MODEL

(32) MAXIMUM CAPACITY (GPM)

(33) PUMP INSTALLATION LEVEL FROM TOP OF CASING (Feet)

(34) METHOD OF DRILLING ☒ Rotary ☐ Cable Tool ☐ Other ______

(35) USE OF WATER (see instructions for choices): Test hole Commercial

(36) DATE DRILLING WORK STARTED: 7-10-03

(37) DATE DRILLING WORK COMPLETED: 7-12-03

(38) DATE: 7/31/03

(39) DRILLER & COMPANY: Trent Caster CASTER WELL DRILLING

(40) DEC REGISTRATION NO.: 10084

* Show log of geologic materials encountered with depth below ground surface, water bearing beds and water levels in each; casings; screens; pump; additional pumping tests and other matters of interest, e.g., water quality (sulphur, salt, methane). Describe repair work.

See further instructions titled "Instructions for New York State Well Completion Report".

LOG *

Ground Surface EL. ______ ft. above sea level

Top Of Casing is located ______ ft.above (+) or below (-) ground surface

TOP OF WELL

0'-6"	Blacktop
6"-1'	gravel
1'-20'	Fine brown Sand (dry)
20'-30'	gray Sand (damp)
30'-52'	Saturated gray sand 100 gpm @ 32'
52'-345'	Dolamite

BOTTOM OF HOLE

COPY - DRILLER RETAIN

Buffalo

LOCATION OF WELL

DEC WELL #:________

(USE ONE OR MORE OF THE FOLLOWING METHODS)

Method 1: Enter coordinates of latitude and longitude in the area provided below. If driller has on-line capability, use DEC's on-line map coordinate assistant found on DEC's web site (www.dec.state.ny.us). This feature gives coordinates of latitude and longitude that can be entered in the area indicated. NOTE: The method of determining coordinates MUST be shown. The use of global positioning system (GPS) equipment is highly recommended to determine the latitude and longitude of the well. If a GPS is used, include information on the manufacturer and model of the unit.

Method 2: If method 1 is not used, photocopy a section of a 1:24,000 scale United States Geologic Survey (USGS) map or a 1:24,000 New York State Department of Transportation (NYSDOT) map and locate the well on the map. ***Write the map name on the photocopy and attach to log completion.***

Method 3: If USGS or NYSDOT maps are not available, photocopy a pertinent section of a detailed county road map and locate the well on the map. ***Write the map name on the photocopy and attach to log completion.***

Method 4: Sketch location of well in the area provided at bottom of page. Locate the well with respect to at least two roads. Indicate north direction.

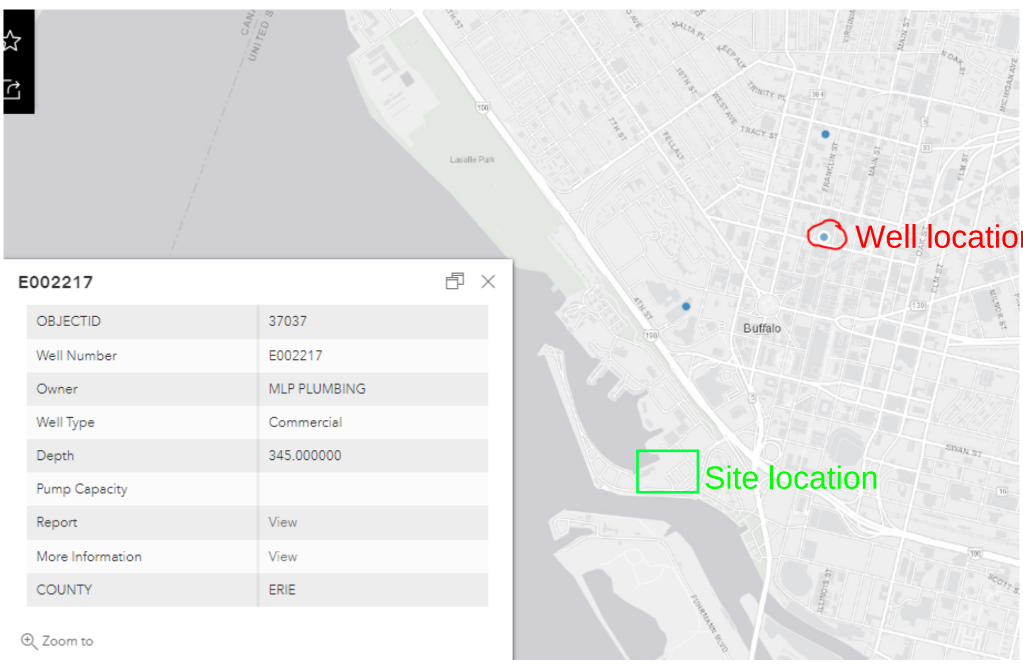
Latitude (degrees minutes seconds)	Longitude (degrees minutes seconds)
N42 53.351'	W78 52.501'

Example: 42 36 01.7 N 73 24 51.1 W

How were coordinates determined?

- ☐ DEC on-line map coordinate assistant
- ☒ GPS Manufacturer Grummin Model GPS III
- ☐ Map interpolation

LOCATION SKETCH (indicate north direction and road intersections)



Buffalo

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

(1) County ERIE

(2) Township Buffalo

(3) DEC Well Number E 2343

WELL COMPLETION REPORT

(4) OWNER: MLP Plumbing PROJ: Righteous Babe

(5) ADDRESS: 3198 Union Road

(6) LOCATION OF WELL (See Instructions On Reverse)
Show Lat/Long if available and method used: N 42° 53.607' W078° 52.495'
☒ GPS ☐ DEC Website ☐ Map Interpolation
341 Delaware Ave, Buffalo, NY

(7) DEPTH OF WELL BELOW LAND SURFACE (Feet): 305'

(8) DEPTH TO GROUNDWATER BELOW LAND SURFACE (Feet): DATE MEASURED:

CASINGS

(9) DIAMETER: 6 in. | in. | in. | in.

(10) LENGTH: NONE ft. | ft. | ft. | in.

(11) GROUT TYPE / SEALING: Bentonite

(12) GROUT / SEALING INTERVAL (Feet) FROM ______ TO ______

SCREENS

(13) MAKE & MATERIAL

(14) OPENINGS

(15) DIAMETER: in. | in. | in. | in.

(16) LENGTH: ft. | ft. | ft. | in.

(17) DEPTH TO TOP OF SCREEN, FROM TOP OF CASING (Feet)

YIELD TEST

(18) DATE

(19) DURATION OF TEST

(20) LIFT METHOD ☐ Pump ☐ Air Lift ☐ Bail

(21) STABILIZED DISCHARGE (GPM)

(22) STATIC LEVEL PRIOR TO TEST (feet/inches below top of casing)

(23) MAXIMUM DRAWDOWN (Stabilized) (feet/inches below top of casing)

(24) RECOVERY (Time in hours/minutes)

(25) Was the water produced during test discharged away from immediate area? Yes ___ No ___

PUMP INSTALLATION

(26) PUMP INSTALLED? YES ___ NO X

(27) DATE

(28) PUMP INSTALLER

(29) TYPE

(30) MAKE

(31) MODEL

(32) MAXIMUM CAPACITY (GPM)

(33) PUMP INSTALLATION LEVEL FROM TOP OF CASING (Feet)

(34) METHOD OF DRILLING ☒ Rotary ☐ Cable Tool ☐ Other

(35) USE OF WATER (see instructions for choices): Geothermal

(36) DATE DRILLING WORK STARTED: 12-10-03

(37) DATE DRILLING WORK COMPLETED: 12-31-03

(38) DATE REPORT FILED: 4-7-04

(39) DRILLER & COMPANY: Trent Caster, Caster Drilling Ent, LLC

(40) DEC REGISTRATION NO.: 10084

LOG *

Ground Surface EL 664 ft. above sea level

Top Of Casing is located ______ ft. above (+) or below (-) ground surface

TOP OF WELL

0"-6"	Black top
6"-1'	Gravel
1'-20'	Fine dry brown sand
20'-30'	damp gray sand
30'-52'	Saturated grey sand 100gpm @ 52'
52-342'	Dolamite
@165' - 285'	= good drilling softer formation
285'-345'	Very Hard

Water encountered at following zones

52'	2 GPM
55'	40 GPM
165'	30 GPM
285'	40 GPM
330'	100 GPM

Total flow rate 200+GPM

Static water height 20' from grade

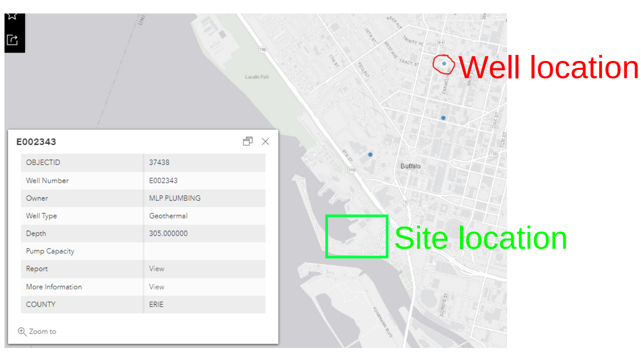
BOTTOM OF HOLE

* Show log of geologic materials encountered with depth below ground surface, water bearing beds and water levels in each; casings; screens; pump; additional pumping tests and other matters of interest, e.g., water quality (sulphur, salt, methane). Describe repair work. Attach separate sheet if necessary.

See further instructions titled "Instructions for New York State Well Completion Report".

NYSDEC COPY

LOCATION SKETCH - Indicate north



APPENDIX C: COST ESTIMATES

Project Estimate Summary Sheet

PROJECT:	National Fuel UTEN - Buffalo District Heating	DATE:	May 2024
PROJECT NUMBER:	2240646	SHEET:	1 OF 1
LOCATION:	Buffalo, NY	PREPARED BY:	AAC

Div.	ITEM - DESCRIPTION	TOTAL COST
8	BUILDING OPENINGS	$ -
13	SPECIAL CONSTRUCTION	$ 4,020,000.00
22	PLUMBING	$ 150,000.00
23	HEATING, VENTILATING & AIR CONDITIONING	$ 18,383,342.32
26	ELECTRICAL	$ 407,000.00
31	EARTHWORK	$ 1,345,500.00
SUBTOTAL:		**$ 24,305,842.32**

CONTINGENCY	30.0%	$ 7,291,752.70
SUBTOTAL (M&L)		**$ 31,597,595.01**
CONTRACTOR O&P	*12%*	$ 3,791,711.40
SUBTOTAL		**$ 35,389,306.42**
PERMITS, BONDS, INSURANCE	*3%*	$ 1,061,679.19
SUBTOTAL		**$ 36,450,985.61**
COMMUNITY OUTREACH, UTILITY SOFT COSTS	*2%*	$ 729,019.71
SUBTOTAL		**$ 37,180,005.32**
ENGINEERING DESIGN	*10%*	$ 3,718,000.53
SUBTOTAL		**$ 40,898,005.85**
INTEREST DURING CONSTRUCTION	*6.0%*	$ 2,453,880.35
TOTAL:		**$ 43,351,886.20**
INCENTIVES & REBATES		$ 3,468,150.90
NET TOTAL COST		$ 39,883,735.31

LaBella Assoicates, D.P.C. **DATE:** May 2024

PROJECT NUMBER: 2240646

PROJECT NAME: National Fuel UTEN Pilot

LOCATION: Buffalo, NY

SHEET NO. 2 of 2

ASSET	ITEM	QTY.	UNIT	MATERIAL COST PER UNIT ($)	MATERIAL COST ($)	LABOR COST PER UNIT ($)	LABOR COST ($)	EQUIP. COST PER UNIT ($)	EQUIP. COST ($)	ITEM COST PER UNIT ($)	ITEM COST ($)
DIVISION 13 - Special Construction											
Utility	Closed Loop Vertical boreholes- Drill/Loop/Grout @ 500ft/borehole	48500	LF	-	-	-	-	-	-	$35.00	$1,697,500
Utility	Allowance for Horizontal Piping - manifold to supply/return to ATL	48500	LF	-	-	-	-	-	-	$10.00	$485,000
Utility	Mechanical Building (70'x75')	5250	SF	-	-	-	-	-	-	$350.00	$1,837,500.00
										DIVISION 13 SUBTOTAL	**$4,020,000.00**
DIVISION 22 – PLUMBING											
Owner	DHW hydronic accessories & connection	60	EA	-	-	-	-	-	-	$2,500.00	$150,000.00
										DIVISION 22 SUBTOTAL	**$150,000.00**
ASSET	**ITEM**	**QTY.**	**UNIT**	**MATERIAL COST PER UNIT ($)**	**MATERIAL COST ($)**	**LABOR COST PER UNIT ($)**	**LABOR COST ($)**	**EQUIP. COST PER UNIT ($)**	**EQUIP. COST ($)**	**ITEM COST PER UNIT ($)**	**ITEM COST ($)**
DIVISION 23 – HEATING, VENTILATING AND AIR CONDITIONING											
Utility	UTEN Loop pumps (50 hp, M&L)	8	EA	-	-	-	-	-	-	$25,000.00	$200,000.00
Utility	WW Loop Hot Water Pumps (50 HP, M&L)	2	EA	-	-	-	-	-	-	$25,000.00	$50,000.00
Utility	WW Loop Condenser Water Pumps (50 HP, M&L)	2	EA	-	-	-	-	-	-	$25,000.00	$50,000.00
Utility	Wastewater Holding Tank with Wastewater Pumps	1	EA	-	-	-	-	-	-	$6,233,342.32	$6,233,342.32
Utility	WW Chiller	1	EA	$2,000,000.00	$2,000,000.00	-	$250,000.00	-	-	-	$2,250,000.00
Utility	WW Heat Exchangers (Sharc 880)	2	EA	$500,000.00	$1,000,000.00	-	$750,000.00	-	-	-	$1,750,000.00
Utility	Water to Water Heat Pumps	275	TONS	-	-	-	-	-	-	$12,000.00	$3,300,000.00
Utility	General piping connections, valves, & appurtenances	1	LS	-	-	-	-	-	-	$500,000.00	$500,000.00
Utility	UTEN loop controls	1	LS	-	-	-	-	-	-	$750,000.00	$750,000.00
Owner	Residential Heat Pump Conversion	275	TONS	-	-	-	-	-	-	$12,000.00	$3,300,000.00
										DIVISION 23 SUBTOTAL	**$18,383,342.32**
ASSET	**ITEM**	**QTY.**	**UNIT**	**MATERIAL COST PER UNIT ($)**	**MATERIAL COST ($)**	**LABOR COST PER UNIT ($)**	**LABOR COST ($)**	**EQUIP. COST PER UNIT ($)**	**EQUIP. COST ($)**	**ITEM COST PER UNIT ($)**	**ITEM COST ($)**
DIVISION 26 - Electrical											
Owner	Heat Pump/DHW general electric work	12	EA	$2,500.00	$30,000.00	$2,250.00	$27,000.00	$0.00	$0.00	$4,750.00	$57,000.00
Utility	Loop pump electrical connections	1	EA	$250,000.00	$250,000.00	$100,000.00	$100,000.00	$0.00	$0.00	$350,000.00	$350,000.00
										DIVISION 26 SUBTOTAL	**$407,000.00**
DIVISION 31 – EARTHWORK											
Utility	Horizontal Piping (trenching, boring, piping, backfill, & restoration)	2,750	LF	-	-	-	-	-	-	$450	$1,237,500.00
Utility	Service Connections (trenching, boring, piping, backfill, & restoration)	360	LF	-	-	-	-	-	-	$300	$108,000.00
										DIVISION 31 SUBTOTAL	**$1,345,500.00**
										SUBTOTAL	**$24,305,842.3**
										ITC-Qualified Costs:	**$24,305,842.3**

ASSET	ITEM	QTY.	UNIT	RATE PER TON ($)	Section 48 ITC Rate (%)	FED CORP. TAX RATE (%)	NYS CORP. TAX RATE (%)				FINANCIAL INCENTIVES ($)
Incentives & Rebates											
	Section 48										
	Investment tax credit (ITC)	-	-	-	8%	-	-	-	-	-	$3,468,151
										Incentives & Rebates Total:	**$3,468,150.90**

Notes:
1) Pricing for commercial HVAC conversions assume $8,000 per ton
2) Pricing for residential HVAC conversions assume $12,000 per ton
3) NYS Clean Heat Custom Incentive has been excluded.
4) Horizontal piping and earthwork include mains and service lines.
5) ITC rates assume prevailing wage with apprentice program for base ITC credit
6) ITC-qualified costs include soft costs, exclude building efficiency measures

APPENDIX D: INCENTIVES

An analysis of all available incentives and rebates was conducted. The main sources for rebates on geothermal projects are through the Inflation Reduction Act and through the NY Clean Heat Program. The NY Clean Heat Program incentives have been removed from this analysis per the directive from the PSC. The tables below outline the qualifiers for the Inflation Reduction Act as it applies to these pilot projects. For the cost estimates, a conservative rate of 8% was used.

Table D.1: Investment Tax Credit Summary

Investment Tax Credit Summary (source: EERE)		Start of Construction			
		2023 to 2033	The later of 2034 (or two years after applicable year)	The later of 2035 (or three years after applicable year)	The later of 2036 (or four years after applicable year)
Full Rate (if project meets labor requirements)	Base Credit	30%	22.5%	15%	0%
	Domestic Content Bonus	10%	7.5%	5%	0%
	Energy Community Bonus	10%	7.5%	5%	0%
Base Rate (if project does not meet labor requirements)	Base Credit	6%	4.5%	3%	0%
	Domestic Content Bonus	2%	1.5%	1%	0%
	Energy Community Bonus	2%	1.5%	1%	0%

Where "Applicable Year" is defined as the later of (i) 2032 or (ii) the year the Treasury Secretary determines that there has been a 75% or more reduction in annual greenhouse gas emissions from the production of electricity in the United States as compared to the calendar year 2022. "Labor requirements" entail certain prevailing wage and apprenticeship conditions being met. Source: EERE

The IRA direct payments are available to both taxable and tax-exempt building owners using IRS form 3468. The following provides a high-level overview on the nature of each of the line items according to current industry guidance. A tax attorney should be consulted in the administration of this rebate to ensure compliance.

Base Rate: Projects under 1MW qualify for the 30% base rate and projects over 1MW qualify for the 6% base rate, with the satisfaction of prevailing wage and apprenticeship requirements.

Domestic Content Bonus: An additional 10% of the project costs are eligible for reimbursement if the manufactured product within the project was made in the United States. For projects exceeding 1MW, this bonus is reduced to 2% if prevailing wage and apprenticeship requirements are not met. According to current guidance, projects that begin construction after 2026 are eligible for an additional 15% for meeting this requirement.

Energy Community Bonus: Areas in which a coal mine or coal-fired power plant has closed or that have been economically reliant on the extraction, transport, or storage of coal, oil, and natural gas are eligible for an additional 10% payment (maximum of 50% including 30% base rate and 10% domestic content bonus).

Accelerated Depreciation of Energy Property: Qualified energy property is classified as a 5-year property in section 168(e)(3)(B)(vi) of the Internal Revenue Code, indicating that the cost of the system can be deducted on an accelerated Modified Accelerated Cost Recovery System (MACRS) basis. The cost basis must be reduced by one half of the energy tax credit. Additionally, a one-time bonus payment is available is available that allows the taxpayer to receive the depreciation payments as a percentage of the first costs instead of depreciating the costs on a 39-year straight-line basis. Bonus payments begin at 80% in 2023, 60% in 2024, and are gradually reduced to 0% in 2027. These depreciation rates can be claimed on IRS Form 4562.

Additional bonus payments are available for wind and solar projects in low-income communities or on tribal land. More information on this is available through the IRS.

IRA Investment Tax Credit Estimate

Building: Buffalo District Site

Measure Description: *This calculation calculates the available incentive through the investment tax credit (ITC)*

Incentive Summary	Year 1	Total
Funding Total	$3,468,151	$3,468,151

Assumptions and Constants

$43,351,886	Total Project Cost	Non-Taxable Entity	Business Type
$0	Additional Incentives	0%	Federal Tax Rate
$43,351,886	Net Project Cost	0%	State Tax Rate (New York)
6%	Energy Credit (%)	0%	Income Tax Rate
2%	Domestic Content Credit (%)	2025	Project Completion Year
0%	Energy Community Credit (%)	Q1	Project Completion Quarter
8%	Total Credit	Yes	Use Special Allowance?
$41,617,811	MACRS/Special Depreciation Total	Assumes 5 year, mid-quarter depreciation at 200% rate	

Year	5 Year MACRS (%)	5 Year MACRS	Tax Credits	Depreciation Tax Savings	Total Tax Savings	Special (%)	Special Allowance
2025	35.00%	$8,739,740	$3,468,151	$0	$3,468,151	40%	$16,647,124
2026	26.00%	$6,492,378		$0	$0		
2027	15.60%	$3,895,427		$0	$0		
2028	11.01%	$2,749,273		$0	$0		
2029	11.01%	$2,749,273		$0	$0		
2030	1.38%	$344,595		$0	$0		
2031				$0	$0		
2032				$0	$0		
2033				$0	$0		
2034				$0	$0		

Cumulative Tax Savings **$3,468,151**

NPV, 4% **$3,206,500**

https://www.energy.gov/eere/solar/federal-solar-tax-credits-businesses#:~:text=Solar%20systems%20that%20are%20placed,megawatt%20(MW)%20in%20size.

APPENDIX E: PIPE SPACING ANALYSIS

Methodology from *2016 ASHRAE Handbook Chapter 12: District Heating and Cooling* was consulted to determine the recommended spacing between pipes for each pipe configuration. The analysis involved estimating the heat transfer between the individual pipes and the soil around the pipes. From there, correction factors were applied based on the location of the nearby pipe, temperature water in each of the pipes, and thickness of insulation where applicable. Once the model was set up in accordance with *Two Buried Pipes or Conduits: Example 8*, the distance between pipes was varied from 0 feet to 14 feet in order to assess the impact pipe separation had on heat transfer. Pipe spacing in a two-pipe ambient temperature system impacts the rate of heat transfer within each pipe, as shown in the figure below.

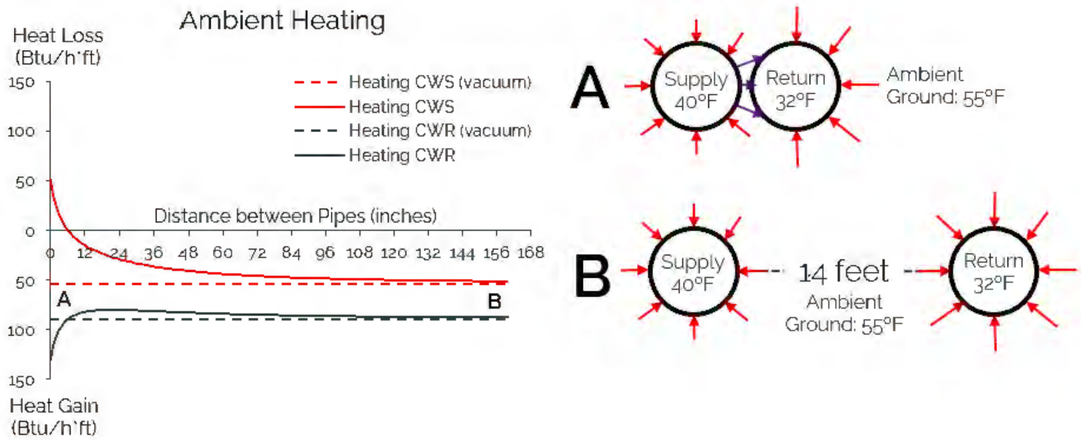


Figure E.1: Ambient Heating Pipe Separation Heat Transfer Sensitivity

As apparent from the figure above, the amount of heat gain for the supply and return piping decreases the closer the two pipes are together. In a vacuum, as apparent at point B, the pipes face maximum heat gain from the ambient ground. Once the pipes are spaced close enough, thermal bridging begins to occur as the supply piping, shown in red, begins to transfer heat to the return piping, shown in black. This occurs at point A and should be avoided for this pipe configuration. The ideal pipe spacing for heating thus exists at a minimum of 6 inches, with larger spacing preferred to maximize heat gain. A similar process can be found for ambient cooling, as shown in the figure below.

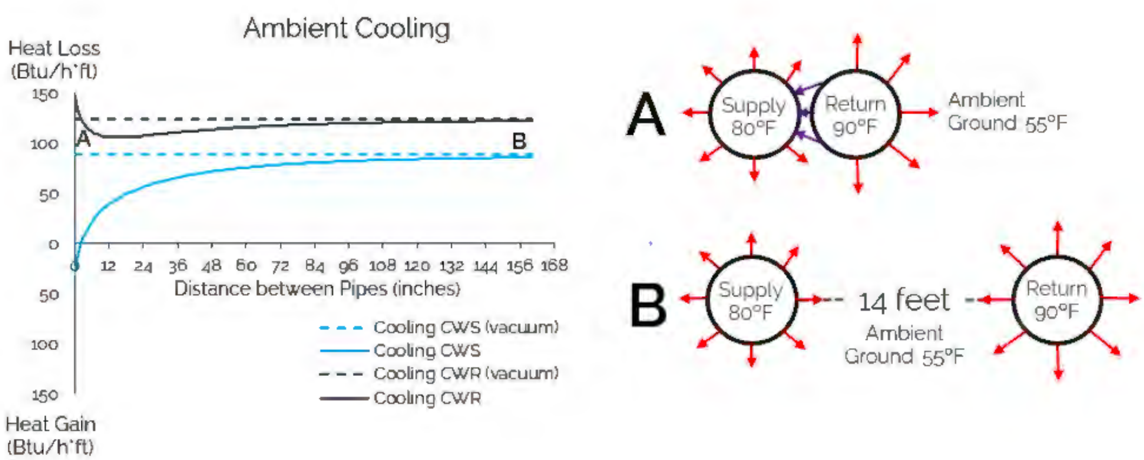


Figure E.2: Ambient Cooling Pipe Separation Heat Transfer Sensitivity

As apparent from the figure on the previous page, the amount of heat loss for the supply and return piping decreases the closer the two pipes are together. In a vacuum, as apparent at point B, the pipes face maximum heat loss from the ambient ground. Once the pipes are spaced close enough, thermal bridging begins to occur as the return piping, shown in black, begins to transfer heat to the supply piping, shown in blue. This occurs at point A and should be avoided for this pipe configuration. The ideal pipe spacing for cooling thus exists at a minimum of 2 inches, with larger spacing preferred to maximize heat rejection. After assessment of the above results, 12 inch spacing was determined to be the most practical for a two-pipe ambient temperature system.

A similar process was followed for a four-pipe system, comparing pipe distance for supply and return piping along with distance between hot water return piping and chilled water return piping. Shown below is the heat transfer profile for varying pipe distances between hot water supply and return pipes.

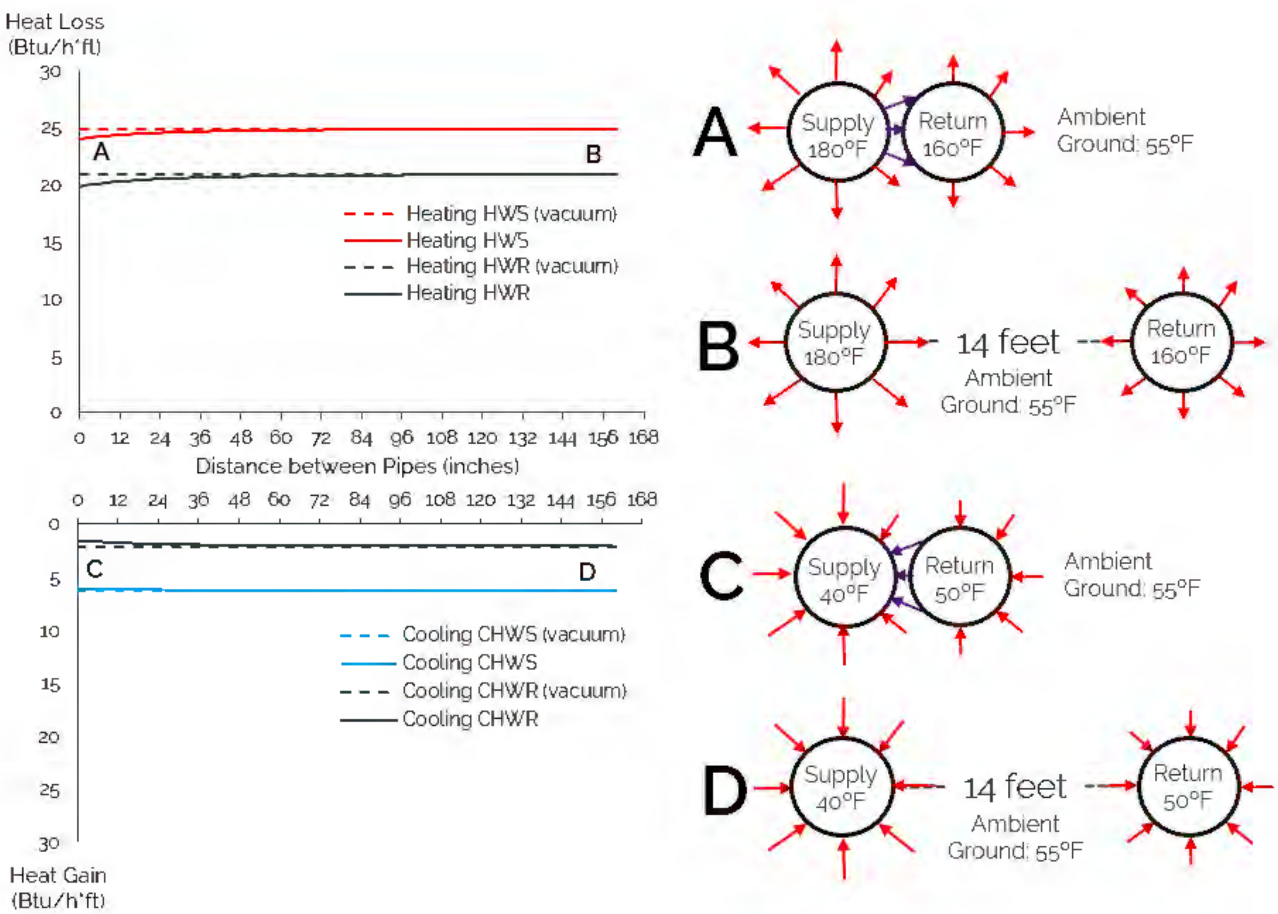


Figure E.3: Four-Pipe Supply/Return Pipe Separation Heat Transfer Sensitivity

As apparent from the figure above, heat loss for supply and return piping is minimized when the pipes are placed closer together during heating (point A). Similarly, heat gain for supply and return piping is minimized when the pipes are placed closer together during cooling (point C). By placing the supply and return piping closer together, the change in temperature surrounding the pipes is reduced and subsequently heat loss/gains are also reduced. Note that due to the insulation surrounding each pipe, the impact that spacing has towards overall heat losses and gains is minimal. Therefore, the pipes should be separated based on serviceability requirements.

The impact that insulation has on heat transfer is also apparent in spacing hot water return piping from chilled water return piping. While it is beneficial to space these pipes away from one another to the greatest extent practical, the impact that spacing has on the subsequent heat transfer is minimal, as evident in the graphic below.

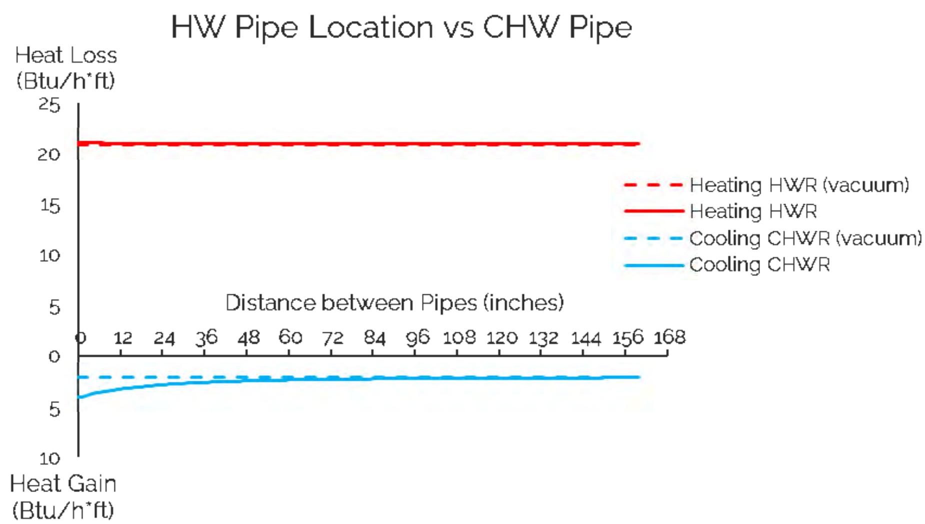


Figure E.4: Four-Pipe Hot/Chilled Water Return Pipe Separation Heat Transfer Sensitivity

For the purposes of this example, a separation of 12 inches was maintained.

APPENDIX F: GLD MODEL RESULTS

Ground Loop Design

Borehole Design Project Report - 5/9/2024

Project Name:			
Designer Name:			
Date:	4/29/2024	**Project Start Date:**	4/29/2024
Client Name:			
Address Line 1:			
Address Line 2:			
City:		**Phone:**	
State:		**Fax:**	
Zip:		**Email:**	

Calculation Results

Design Method: *Monthly*	**COOLING**	**HEATING**
Total Bore Length (ft):	**52440.0**	**52440.0**
Borehole Number:	**138**	**138**
Borehole Length (ft):	**380.0**	**380.0**
Ground Temperature Change (°F):	**N/A**	**N/A**
Peak Unit Inlet (°F):	**82.5**	**39.9**
Peak Unit Outlet (°F):	**89.6**	**38.1**
Total Unit Capacity (kBtu/Hr):	**4126.1**	**1507.5**
Peak Load (kBtu/Hr):	**4126.1**	**1507.5**
Peak Demand (kW):	**287.5**	**113.5**
Heat Pump EER/COP:	**14.3**	**3.9**
Seasonal Heat Pump EER/COP:	**18.3**	**4.1**
Avg. Annual Power (kWh):	**2.02E+5**	**2.68E+5**
System Flow Rate (gpm):	**1031.5**	**376.9**

Input Parameters

Fluid		**Soil**	
Flow Rate	3.0 gpm/ton	Ground Temperature:	50.0 °F
Fluid:	32.0% Propylene Glycol	Thermal Conductivity:	1.60 Btu/(h*ft*°F)
Specific Heat (Cp):	1.01 Btu/(°F*lbm)	Thermal Diffusivity:	1.00 ft^2/day
Density (rho):	62.4 lb/ft^3		

Piping

Pipe Type:	1 1/4 in. (32 mm) - SDR11
Flow Type:	Turbulent
Pipe Resistance:	0.104 h*ft*°F/Btu
U-Tube Configuration:	Single
Radial Pipe Placement:	Average
Borehole Diameter:	5.00 in
Grout Thermal Conductivity:	1.60 Btu/(h*ft*°F)
Borehole Thermal Resistance:	0.174 h*ft*°F/Btu

Input Parameters (Cont.)

Pattern		Modeling Time Period	
Vertical Grid Arrangement:	69 x 2		
Borehole Number:	138	Prediction Time:	20 years
Borehole Separation:	20.0 ft	Long Term Soil Temperatures:	
Bores Per Circuit	1	*Cooling:*	50 °F
Fixed Length Mode	On	*Heating:*	50 °F
Grid File	None		
File:			

Default Heat Pumps

Manufacturer: - Default Generic

Series: Generic Medium Efficiency

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 (%)	100%	67%
Geo Total (%)	100%	98%
Hybrid Peak (%)	0%	33%
Hybrid Total (%)	0%	2%

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

Buffalo_District.zon