Prepared for:
NYSEG
18 Link Drive
Binghamton, NY 13904

RG&E
180 S Clinton Avenue
Rochester, NY 14604

Submitted by:
LaBella Associates
300 State Street, Suite 201
Rochester, NY 14614

In partnership with:

The Grey Edge Group, LLC
2299 Shirley Road
Berkshire, NY

and

Aztech Geothermal
5 McCrea Hill Road, Suite 200
Ballston Spa, NY

LaBella
Powered by partnership.

Geothermal District Energy Study

NYSEG AND RG&E

MAY 2022

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

DEFINITIONS & ACRONYMS

Definitions

50/90 Rule	50% of the building's peak load accounts for 90% of annual operating hours.
Thermal Highway	A convective circulation circuit.

Commonly Used Acronyms & Abbreviations

ABAS	Advanced Building Automation System
AMI	Advanced Metering Infrastructure
APS	Advanced Power Strips
ASHP	Air Source Heat Pump
ASHRAE	American Society of Heating, Refrigeration, & Air-Conditioning Engineers
ASO	Automated System Optimization
ATL	Ambient Temperature Loop
BAS	Building Automation System
BMS	Building Management System
BTU	British Thermal Unit
CBECS	Commercial Building Energy Consumption Survey
CDD65	Cooling Degree Day, 65°F base temperature
CLCPA	Climate Leadership and Community Protection Act
COP	Coefficient of Performance
CO_2	Carbon Dioxide
CWA	Clean Water Act
DER	Distributed Energy Resource
DER CAM	Distributed Energy Resource Customer Adaptation Model (software)
DPS	Department of Public Service
EER	Energy Efficiency Ratio
EUI	Energy Utilization Index
GHX	Ground Heat Exchanger
GSHP	Ground Source Heat Pump
HDD65	Heating Degree Day, 65°F base temperature
HVAC	Heating, Ventilation, and Air Conditioning
kW	kilo-Watt (1,000 W)
kWh	Kilo-Watt hours
MT	Metric Tons
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research & Development Authority
O&M	Operation & Maintenance
PSC	Public Service Commission
PV	Photovoltaic
PVT	Solar Thermal
SDWA	Safe Drinking Water Act
SF	Square Foot
SPDES	State Pollutant Discharge Elimination System Permit
WETS	Waste Energy Transfer Systems
WSHP	Water Source Heat Pump

EXECUTIVE SUMMARY

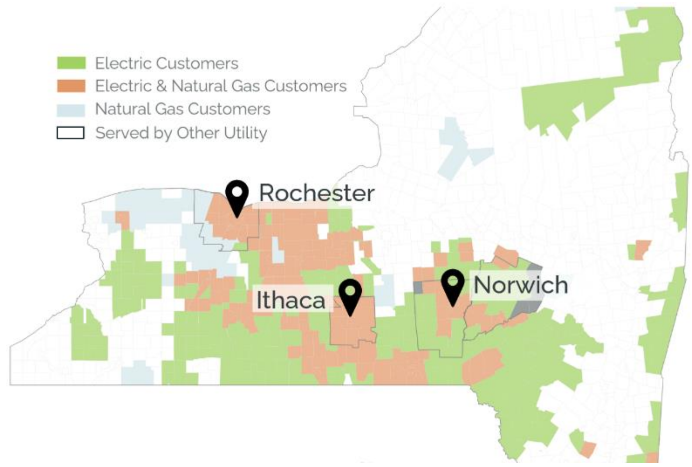


Figure 1: Potential Pilot Site Locations

Pursuant to the current Joint Proposal, New York State Electric and Gas (NYSEG) and Rochester Gas and Electric (RG&E, and together with NYSEG, the Companies), subsidiaries of Avangrid, Inc., engaged LaBella Associates, The Grey Edge Group, and Aztech Geothermal to perform a study on the feasibility of deploying geothermal district energy systems in the Companies' service territory including identifying sites for potential district geothermal system pilot projects within Monroe County, Tompkins County, Chenango County, and Otsego County.[8] For each potential pilot site, a group of buildings were selected, site geological conditions reviewed, a preliminary loop design was constructed, technical feasibility assessed plus a narrative was developed on the economic impact, technical feasibility, ownership options, and finally permitting & regulatory considerations, ownership options, and geology impacts. A narrative was also developed establishing a framework for future identification and selection of locations for district geothermal systems.

A high-level look at the four counties was performed that identified townships, villages, and cities that are the most densely occupied, and therefore have the highest energy density. Using this information, numerous potential host sites were identified with the potential for hosting a large district geothermal system with surrounding infrastructure that lends itself to future loop expansions of the clean thermal network. Weighted criteria were developed to objectively select the three highest ranked sites to be evaluated in more detail, which included load diversity (20%), on-site thermal resources (15%), expandability (15%), risk (15%), building diversity (10%), potential for ease of conversion (10%), and on-site electric resources for PV (5%).

Figure 2: Rochester Site Map

The first site that was identified is centered around the Spectrum Communication Center located in South Wedge, a neighborhood in Rochester, NY. This site contains a large office building, several small commercial buildings, and surrounding residential buildings. Adjacent to the site is the Genesee River. A conceptual system layout was developed using a 5G ambient temperature loop pulling

Figure 3: Norwich Site Map

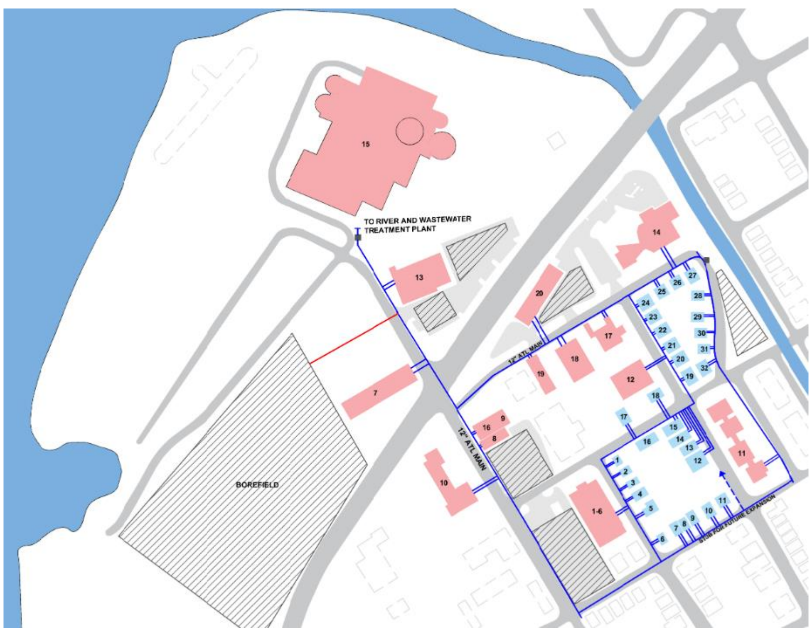


Figure 4: Ithaca Site Map

thermal capacity from the Genesee River, wastewater mains, and geothermal borefields located beneath a large parking lot.

The second site that was identified is centered around Tops Plaza in Norwich, NY. This site consists of a grocery store plaza with nearby residential and commercial buildings, The large parking lot serves as an excellent thermal resource for the neighboring areas and the large cooling load present in a grocery store balances the loop – reducing the need for more boreholes to offset the heating-dominant homes and small buildings seen in this region. A conceptual system layout was developed using a 5G ambient temperature loop pulling thermal capacity from vertical boreholes located beneath a large parking lot.

The third and final site that was identified is in a densely populated area in Ithaca in Tompkins County. This site consists of a small grocery store, a wastewater treatment plant, several commercial buildings, residential buildings, and the nearby Cayuga Inlet. This site has a multitude of potential thermal resources including parking lots, surface water, ground water and wastewater main lines. In addition, the grocery store presents a large cooling load used to balance a closed loop approach. Issues with site geology in the Ithaca region were noted as previous drillers encountered briny aquifers at depths of approximately 150 feet in the area. This limits the depth at which boreholes can be drilled and requires additional boreholes to provide sufficient BTUs to the site, or for thermal resources to be gathered from surface water or wastewater. A conceptual system layout was developed using a 5G ambient temperature loop pulling thermal capacity from the nearby Cayuga Inlet, wastewater mains, and shallow-depth boreholes located beneath a parking lot. An alternate approach would be to operate the district as a ground water or "open" system taking advantage of the generous pressurized aquifer to distribute ground water to heat exchangers located at each building. The advantages to be further investigated would include lower system pumping energy, higher annual building heat pump efficiency, less dependance on balancing building loads and lower installation costs. There are also a number of items to be addressed specific to this approach, including but not limited to: the location of supply wells, the viability of using an infiltration gallery (or other discharge methodology), protection of ground water, and potential maintenance issues that may outweigh the advantages.

Site geology had a large impact on the proposed system designs. Two of the most densely populated cities within the Companies' service territories, Ithaca and Rochester, have geological constraints that prohibit drilling of wells boreholes to depths of 500 feet – which is considered the most cost-effective way of accessing thermal resources for closed loop systems. Other methods of leveraging existing heat sources were included in the conceptual site layouts to demonstrate the technical feasibility of leveraging less common sources of energy.

PROJECT OVERVIEW

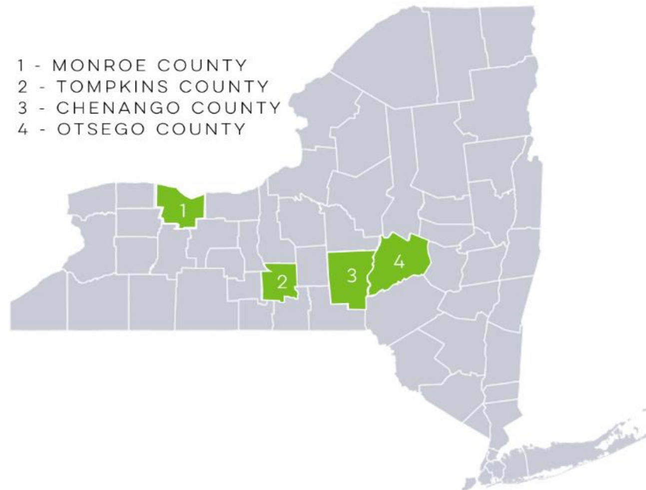


Figure 5: Target Counties

The New York State Climate Leadership and Community Protection Act (CLCPA) committed the state to a 40% reduction in greenhouse gas emissions by 2030 from 1990 levels to 2030 levels, 100% clean electricity by 2040, and ultimately an 85% reduction in carbon by 2050. The goals set forth by the state requires a decarbonization effort across all major economic greenhouse gas emitting sectors statewide.[1]

According to the Department of Environmental Conservation's (DEC) 2021 Statewide GHG Emissions Report, the Buildings Sector ranks #1, representing 32% of the States' total emissions. One of the largest uses of fossil fuels is associated with space heating of buildings, resulting in a significant carbon footprint rivaled only by the Transportation Sector coming in at 28%.[7] A common strategy to reduce the carbon footprint of buildings is to convert fossil fuel systems to electric-based systems with the knowledge that the utility scale electric generation sources will transition towards carbon neutral generation in the future. Common electric heating technologies in the marketplace today include water-source heat pumps, air source heat pumps, variable refrigerant flow systems, and electric resistance heating systems.

Geothermal heating and cooling systems most commonly interact directly with water-source heat pumps and utilize the mild, constant ground temperature as a means of heating or cooling water. This water is used as a thermal source and/or sink that in turn can be pumped to a heat pump to provide hot or cold air to the space for use in space conditioning or water heating. Electric resistance heating is 100% efficient, meaning 100% of the electricity used by the unit is translated into heat in the space; geothermal heating systems commonly perform up to an efficiency of between 300% to 500% (i.e., a Coefficient of Performance (COP) of 3 to 5) by using electricity to leverage thermal resources in the ground. This increase in efficiency not only reduces energy consumption and operating costs, but also helps reduce the increase in the peak electric load on the building and surrounding electric grid.

The reduction in energy consumption using geothermal energy resources can further be reduced by configuring multiple buildings in a district application whereas the loop can share in aggregate the diversity of heating and cooling loads and operate at an economy of scale that improves the total cost effectiveness of the system. Buildings with different cooling and heating load profiles are able to generally peak at a different time over the course of a day, reducing the need for an additional number of boreholes and therefore total system installation cost. This concept has been proven as technically and economically feasible across the world and can potentially serve as a means of replacing gas service in the future.

Despite their proven economic and technical feasibility, a number of barriers exist that have complicated the deployment of district geothermal systems in New York State. This study reviews both the technical aspects of district geothermal systems and their associated economic impacts in an effort to identify prospective pilot sites and establish a framework for future evaluation of sites on a broader scale.

The scope of this study entails a high-level look at four counties in the Companies' service territory to establish a set of criteria for identifying future sites along with the recommended sites for participation in a pilot program. The four counties are Monroe, Tompkins, Otsego, and Chenango counties – all of which have gas service, electric service, or both. Conceptual system layouts were identified with an accompanying overview of economic impact, ownership scenarios, and permitting and regulatory considerations.

Approach

The approach used in identifying pilot sites took a broad view, looking at energy intensities and population density in each of the four counties. Focusing on the most densely occupied areas, ten "short list" sites were selected which have infrastructure capable of supporting district geothermal loops, potential for replicability throughout the Companies' service territory, and the potential for being a cost-effective solution. Using this set of criteria and a weighted evaluation matrix, the three final sites were evaluated in more detail to identify loop configuration, energy performance, installation/conversion costs, ownership models, and other regulatory issues that require consideration.

The graphic below illustrates the process used to narrow-down potential pilot sites

- Develop evaluation criteria for selecting potential pilot project sites
- Identify potential sites with highest population centers based on community type, potential for renewable energy, load diversity, and building density
- Select different types of pilots that are most economically advantageous and replicable

- Identify state and local codes and regulations that influence the design, construction, and overall cost-effectiveness of pilots
- Define thermal energy exchange options that are feasible
- Identify the types of heat pumps and configuration options that can be supported to best suit thermal loads
- Develop district geothermal heating designs that are most economically advantageous
    - Evaluate different distribution piping system configurations
    - Evaluate piping interconnections
    - Evaluate what equipment is required to move, direct, meter, and control thermal energy flow through piping network

- Evaluate top potential pilot types in more detail, including:
    - Develop high-level design of proposed district loop with descriptions of key design features and capabilities
    - Identify key costs for design, installation, commissioning, operation, and maintenance
    - Model energy performance of loop and buildings to determine energy cost impacts, carbon reduction, and lifecycle costs of the system as it relates to the system owner and interconnected buildings
    - Evaluate ownership options of key systems including utility ownership, municipal ownership, or third-party ownership.

Figure 6: Project Approach

The methodology laid out in the following sections provides a basis for the Companies to evaluate future potential district geothermal sites based on publicly available information. Characteristics such as load diversity and thermal exchange resources are explained in this report to provide a high-level understanding of the selection criteria for the Companies to consider for broader application within its respective service territories.

GEOTHERMAL SYSTEMS

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, earth's relatively constant temperature is used as an exchange medium instead of outside air.

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. 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.

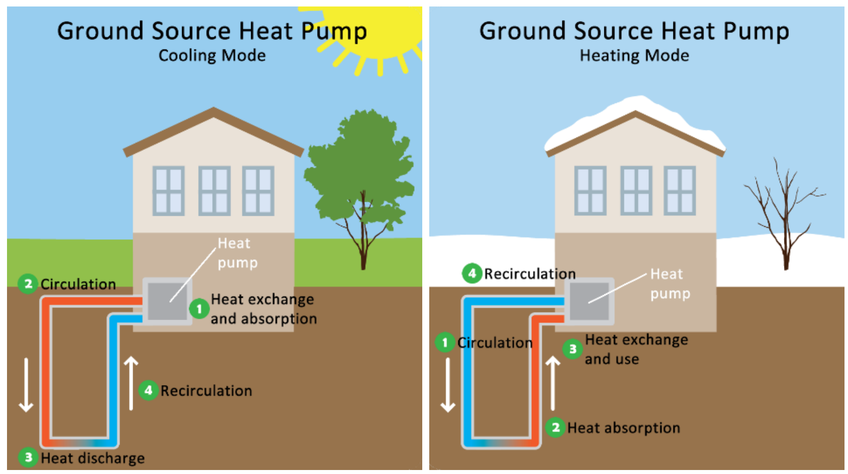


Figure 7: Geothermal Heating & Cooling Conceptual Diagram [14]

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 is piped into a single building serving its heating and cooling loads. With recent legislation discouraging the use of fossil fuels, the concept of district geothermal applications have become more popular; link 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 horizontal borefields, perched aquifers, geothermal piles, sewer main lines, complimentary building loads, and surface water resources.

DISTRICT ENERGY SYSTEMS

The primary concept behind a district geothermal 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.

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 installed 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 referred to as 3rd generation (3G), 4G, 5G, 6G, and so on. The different generations of loop technology demonstrate advances made in loop design over the course of the last 20 years. The proposed loop design for the pilot projects is a 5G ambient temperature loop.

4G Systems

A 4G thermal energy network 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 and are much higher than needed for the discharge air and the water setpoints for cooling are colder than needed for cooling discharge air – resulting in lower overall system-wide efficiency.

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 in this scenario.

5G systems

A 5G ambient temperature loop system features a network of autonomous, interconnected single-pipe loops. Ambient temperature water is circulated and maintained between 45-95F. Multiple sources of thermal energy resources can be connected to the loops including ground source, solar thermal, surface water, and wastewater.

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 – therefore allowing it to operate more efficiently with a lower upfront cost.

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 equal in order to avoid thermally saturating the loop – which leads to a decease in loop efficiency. Figure 8 demonstrates the disproportionate amount of heating required in cities throughout New York State in comparison to cooling loads. There are approximately

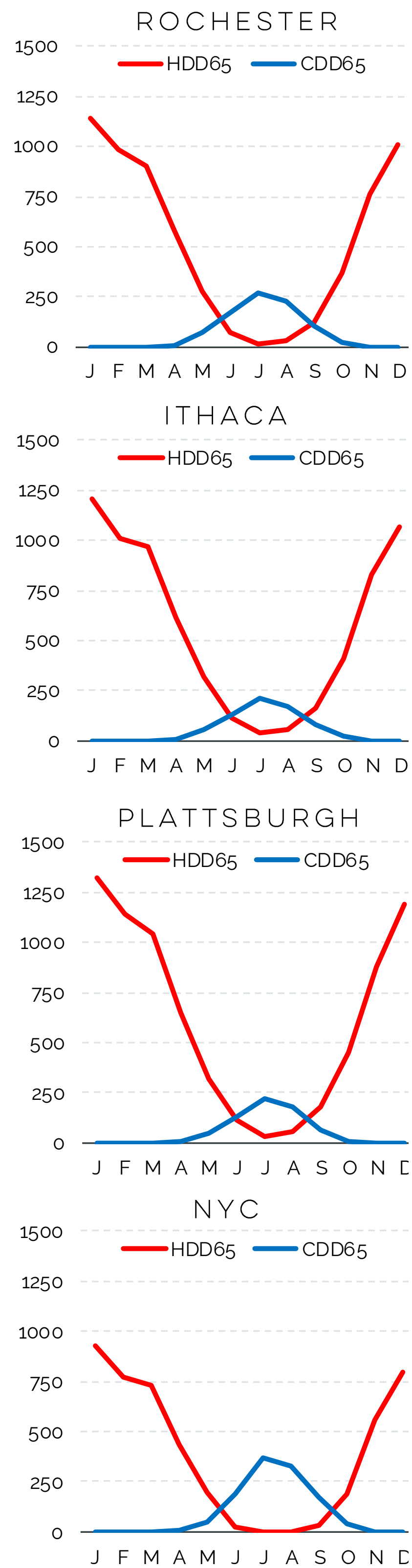


Figure 8: Degree Days per City

twice as many heating degree days than cooling degree days over the course of a year.

One method of combating that imbalance is to install supplemental heating technologies to reduce the excess heating 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.

Volumes are monitored through a central control system, with leak detection placed at each building with automatic shut-off valves to ensure the integrity of the system.

Benefits from 5G systems include modularity, scalability, expandability, component location flexibility, and allowance for incorporation of technology upgrades. 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.

Given the modular nature of the loop, technology upgrades of any of the individual components of the system can be integrated without interrupting the operation of the ambient temperature loop (ATL) network system. Pumps and valves can be upgraded within easily accessible mechanical rooms and pumping stations. Heat pumps within buildings can be replaced and large heat pump capacities can be upgraded by simply plugging in expansion units.

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. This type of piping is also resistant to water freezing and has heat-fused joints that are stronger than the pipe itself.

The system is also resistant to polar vortexes or heat waves in that it is sized to accommodate for those weather events. Coexistence with existing gas infrastructure will enable the district geothermal system to relieve pressure on the distribution during a peak event. Standby generation in the event of power outages can be integrated in order to maintain operation of the circulation pumps.

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

The proposed layout of the loop is a primary-secondary system. The primary is typically a one-pipe loop, generally running along a street in front of or behind the connected buildings. The buildings and other assets may be attached in parallel or

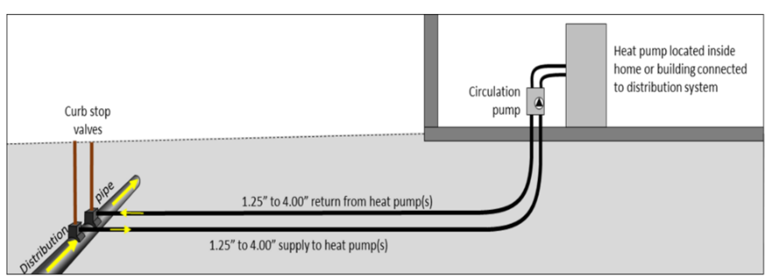


Figure 9: Conceptual System Interconnection

in three pipe configurations, depending on the application. The connection to the building-level system may or may not have an isolating heat exchanger to separate the building loop from the network loop. This is determined on a case-by-case basis.

Other piping systems include parallel piping, standard central plant piping, and three pipe systems. These systems are not considered here due to their lower efficiency and lack of versatility.

Thermal Resources

Several different thermal resources can be integrated into district geothermal 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.

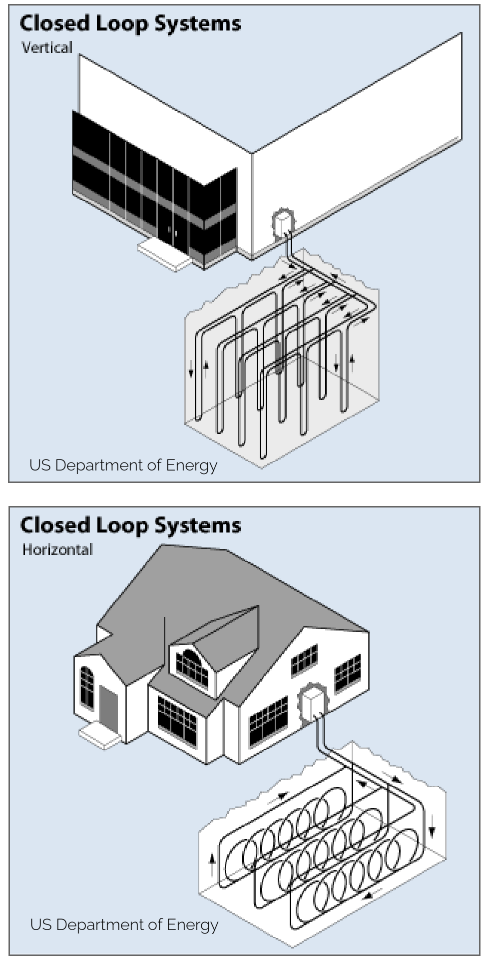


Figure 10: Example GHX Configurations [13]

Ground Source Heat Exchangers

Ground source systems are among the most popular types of systems seen in the marketplace today. 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.

Horizontal ground source systems are another variation on the loop and are typically installed in trenches at least four feet deep and 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 (or 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 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 multifamily 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 11 below illustrates this concept. It should be noted that the wastewater never comes into direct contact with the geothermal fluids.

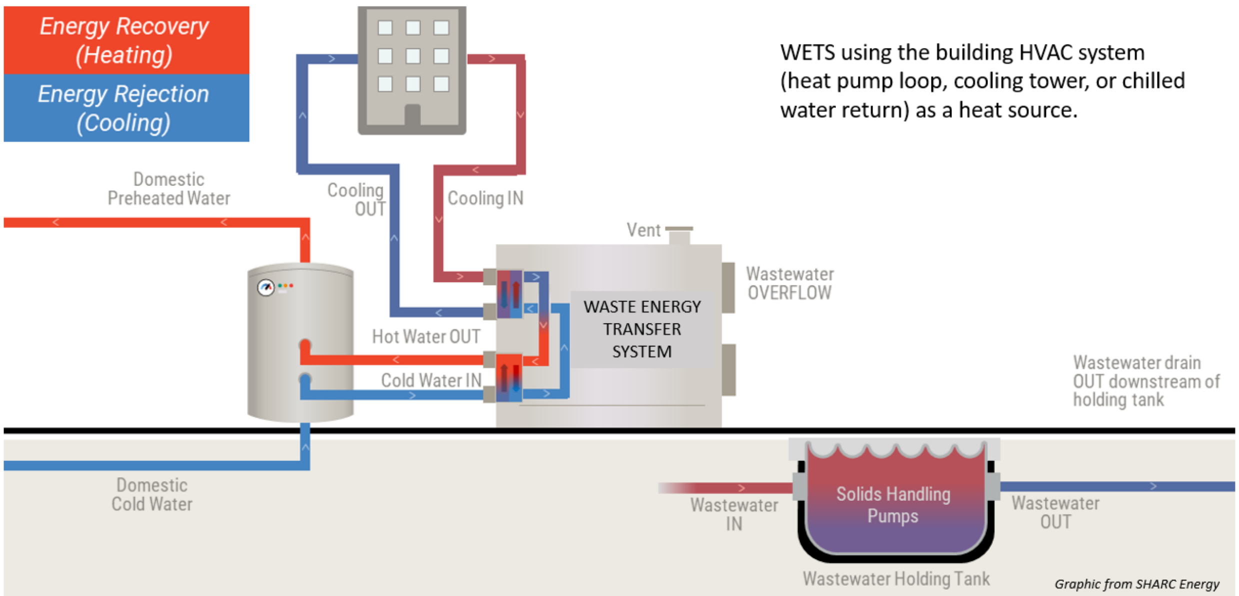


Figure 11: Building-Level WETS using building wastewater as a heat source/sink

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 District Energy Loop (ATL) depending upon the ATL temperature and the wastewater temperature.

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, BC.

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.

Surface Water

Surface water (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 NYS DEC 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 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 temperature sensors, or a smart pump VFD (which calculates flow +/- 3-5% accuracy) with two temperature sensors.

Solar Thermal

Solar Thermal (PVT) systems include the attachment of a hydronic heat transfer panel to the backside of each solar PV panel, then connecting these panels via tubing to a pump and heat exchanger. In New York, this type of installation could yield up to 4 MMBtu of heat per year per square meter of solar PV. Refer to the figure below.

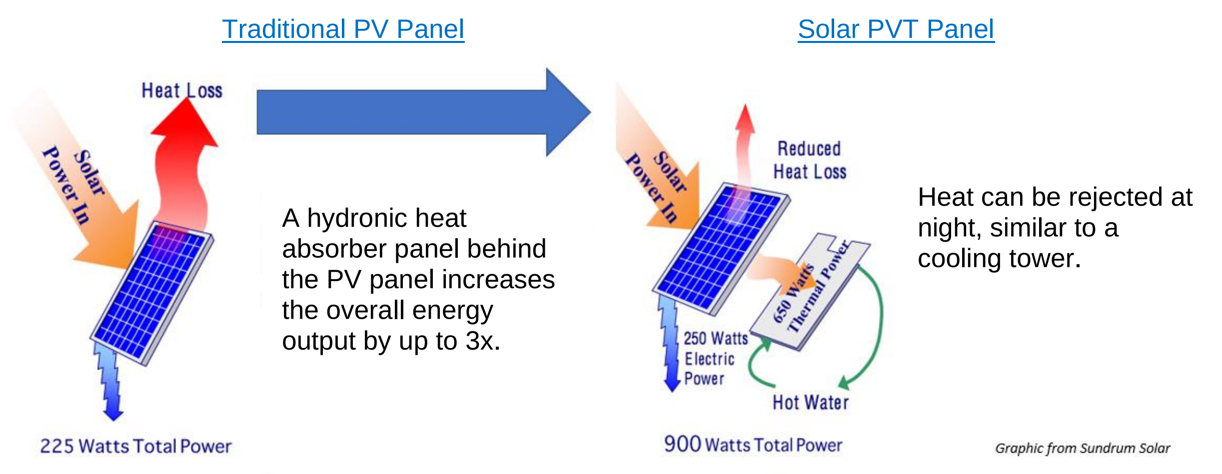


Figure 12: Example of Solar PVT impact on net energy production

In the heating mode, the hydronic panel absorbs heat from the backside of the solar PV panel, cooling the panel and increasing its nominal efficiency by 2-3%. At night or when the air temperatures are favorable, these hydronic panels can also provide heat rejection (nominally 1 ton per 10 square meter) with fans, water consumption, chemical treatment, or any chance of Legionella. In many applications, the added thermal capture will increase the overall energy input (electric & thermal) by up to three times the original capacity.

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.

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

The primary driver behind most conversions to electric HVAC systems is its ability to displace fossil fuel 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.

Current electric heating and cooling technologies in the marketplace today include water source heat pumps (WSHP), ground source heat pumps (GSHP), 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 gas. Equipped with a reversing valve, the direction of flow can be changed to reverse the cycle and alternate between heating and cooling modes.

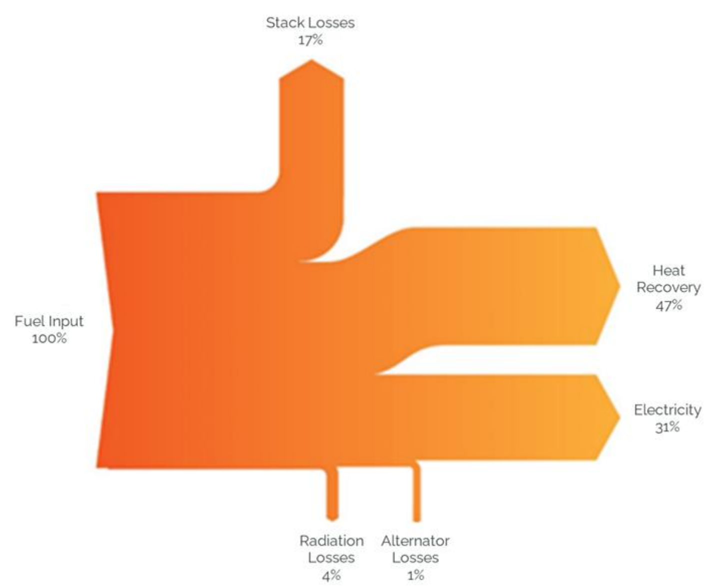


Figure 13: CHP System Sankey Diagram

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.[13] 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).[15]

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. [20]

Geological Considerations

The site geology plays a critical role in the design of a ground heat exchanger. The service territories of NYSEG/RG&E contain a wide range of geological conditions that impact the 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 Central and Western New York's regional geothermal drilling capacity, ideal conditions would feature a few feet of unconsolidated material (i.e., overburden) followed by some type of competent rock for lowering installation costs and having good thermal properties. But even less-than-ideal geology can often produce satisfactory economics and performance if the challenge is well characterized and prepared for by the project team. 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 depths and encourage the project to access other sources of thermal energy, such as nearby surface water or available wastewater resources to compensate.

None of the three highlighted sites have classically ideal geology but all have sufficient thermal resources to support the diverse mix of buildings. Natives on geology for Rochester, Ithaca, and Norwich are laid out below, based on surveys from the US Geological Survey maps for surficial (surface) and bedrock geology, insight from local contractors & engineers, plus NYSDEC Water Well Logs as another good reference.

Ithaca Site Geological Information

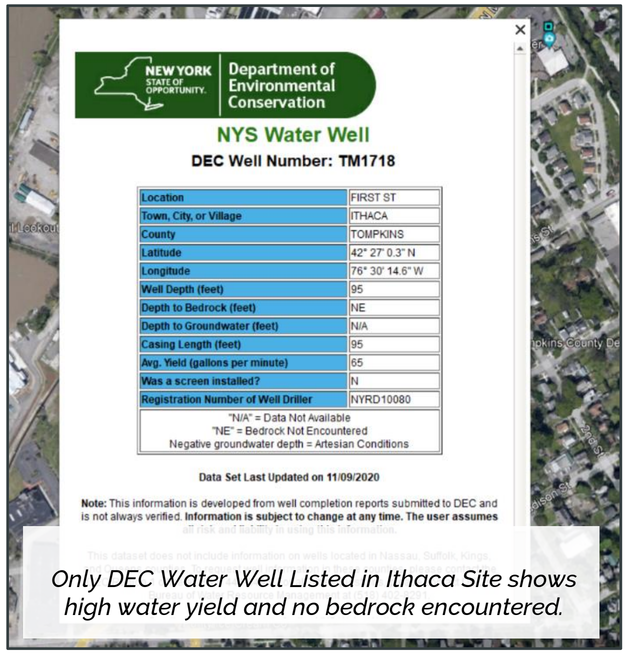
Tomkins County DMV Site: 311 3rd St, Ithaca, NY 14850

Our team conferred with Kevin Moravec of Barney Moravec Well Drilling. Mr. Moravec referred to the flat areas in downtown Ithaca as an old lake bottom, consisting of sand, gravel, and clay. Drillers will encounter a pressurized aquifer between 125 feet and 170 feet with the borehole yielding in excess of 100 GPM. These conditions present an especially large challenge in a dense urban environment as water management becomes time consuming and expensive. As mentioned earlier, if you prepare for this, the water can be managed but still will likely result in closed loop boreholes that are between 125 feet and 225 feet in depth.

Our team also spoke with Dominick DeLucia, a Senior Engineer with Taitem Engineering, PC (located in Ithaca) concerning the Purity Ice Cream ground source heat pump system. Mr. DeLucia underscored the difficulties encountered by the geothermal drillers, who installed thirty (30), 220-foot boreholes, with casing extending the full length, so no bedrock was encountered. The formation thermal conductivity test showed a 1.0 thermal conductivity, which is lower than found in most formations across NYS. The Purity Ice Cream system did ultimately prove successful in its operation and provides a basis for the means, methods, and projected cost of installing a closed loop system in this part of town, which is within 0.3 miles of the Ithaca DMV site.

While less common, a networked groundwater system may be a more viable option for this flat section of town. A ground water or "open" system might use larger, re-purposed "gas rigs" to drill into the aquifer which could manage the backpressure from the water and install a series of central supply wells. Water in the system would be isolated from any building mechanical equipment and then discharged back into the ground, ideally in a low-pressure strategy – like "infiltration gallery". An open loop system would replace the same volume of water that is extracted – minimizing the affects or the volume and pressure of the aquifer that may impact nearby wells. Any open system approach would require careful study to ensure the protection ground water and close collaborations with the with the City of Ithaca and the NYSDEC.

DEC NYS Water Well Database available on Google Earth shows a listed well adjacent to the building 14 labeled "Science Center" which is in the footprint of the Ithaca Site in our study. Not surprisingly showing 95 feet in depth with matching casing of 95 feet and rock "not encountered" (NE) with 65 GPM – so relatively high-water yield.


NEW YORK STATE OF OPPORTUNITY. Department of Environmental Conservation

NYS Water Well

DEC Well Number: TM1718

Location	FIRST ST
Town, City, or Village	ITHACA
County	TOMPKINS
Latitude	42° 27' 0.3" N
Longitude	76° 30' 14.6" W
Well Depth (feet)	95
Depth to Bedrock (feet)	NE
Depth to Groundwater (feet)	N/A
Casing Length (feet)	95
Avg. Yield (gallons per minute)	65
Was a screen installed?	N
Registration Number of Well Driller	NYRD10080

"N/A" = Data Not Available
"NE" = Bedrock Not Encountered
Negative groundwater depth = Artesian Conditions

Data Set Last Updated on 11/09/2020

Note: This information is developed from well completion reports submitted to DEC and is not always verified. **Information is subject to change at any time. The user assumes all risk and liability in using this information.**

Only DEC Water Well Listed in Ithaca Site shows high water yield and no bedrock encountered.

Figure 14: Ithaca Site Nearby DEC Water Well Log

US Geological Survey maps for surficial and bedrock geology:

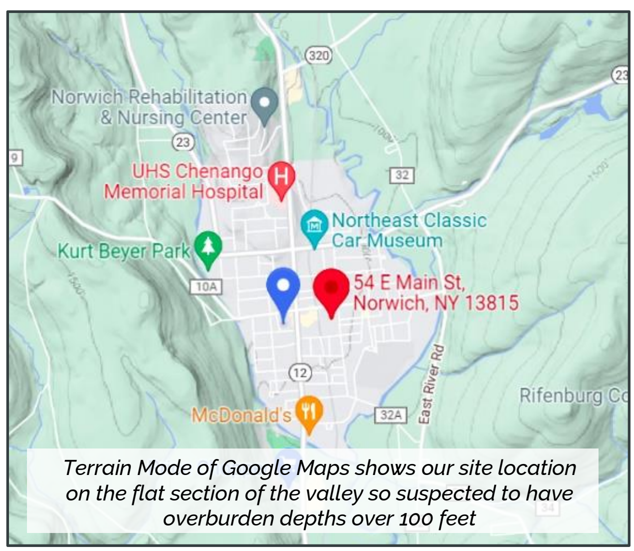
Surficial geology in the area of the site has been mapped by the New York State Museum – Geological Survey on the Surficial Geologic Map of New York – Finger Lakes Sheet as: Glacial Outwash consisting of Sand Deposits associated with large bodies of water, generally a near shore deposit or near a sand source, well sorted & stratified, generally quartz sand, 2 to 20 meters (6.5 to 66 feet) in thickness.

The subsurface geology (bedrock) in the area of the site has also been mapped by the United States Geological Survey – Mineral Resources Online Spatial Data – Geologic Maps as the Genesee Formation that consist of gray shale and mud stone that ranges in thickness from 200 to 1,000 feet. This rock formation is Upper Devonian in age. Secondary rock types within the Genesee Group consist of Siltstone and Limestone beds indicating that this area was a transitional zone when the sediments were deposited.

Norwich Site Geological Information

Chenango County, Town Center, TOPS Plaza Site: 54 E. Main St, Norwich, NY 13815

In consultation with Barney Moravec Well Drilling the Norwich site is in a valley area of flat terrain but surrounded by higher elevations. There is no DEC Water Well listed in our immediate site location. Water wells surrounding the site with similar surface geology are showing 90 feet to rock so it is suspected this area of the Tops Plaza maybe be in the range of 100 feet to bedrock. Based on some registered water wells north and south of this location in similar conditions, the static water levels are 10 to 30 feet with yields of 25 to 100 GPM. High static water level and good yielding wells are typically associated with good thermal properties for ground heat exchangers. The geology would suggest that full depth (up to 500 feet) ground heat exchanges would be cost effective to drill on this site.



Terrain Mode of Google Maps shows our site location on the flat section of the valley so suspected to have overburden depths over 100 feet

Figure 15: Norwich Site Terrain View

US Geological Survey maps for surficial and bedrock geology:

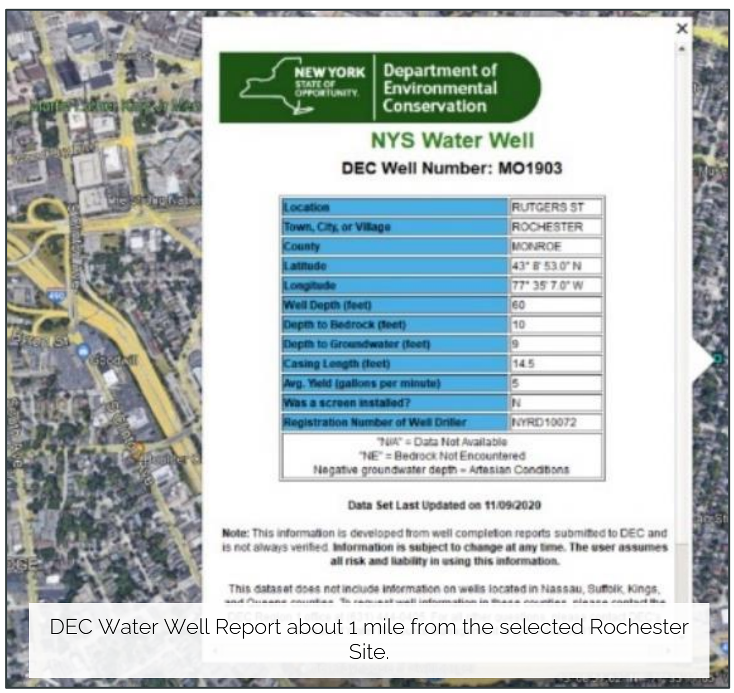
Surficial geology in the area of the site has been mapped by the New York State Museum – Geological Survey on the Surficial Geologic Map of New York – Hudson-Mohawk Sheet as: Lacustrine Sand consisting of coarse to fine Gravel with Sand (sandy Gravel), proglacial fluvial deposition, well rounded and stratified, generally finer texture moving away from the glacier border, 2 to 20 meters (6.5 to 66 feet) in thickness.

The subsurface geology (bedrock) in the area of the site has also been mapped by the United States Geological Survey – Mineral Resources Online Spatial Data – Geologic Maps as: Unadilla, Laurens, New Lisbon, and Gilboa Formations (with the Gilboa Formation underlying the site) which are part of Genesee Group and are 1,200 to 1,500 feet in thickness. Secondary unit description from USGS Lexicon website (ref. NY046) and NY021: Gilboa Formation is described at Stevens Mountain Quarry, Grand Gorge, and Hardenburgh Falls as 2- to 6-meter-thick sandstone beds separated by thinner mudstone-dominated intervals. The Gilboa unit is divided into four 15- to 20-meter-thick sections by three thick mudstone beds. The mudstones are dark gray, sparsely fossiliferous, and typically bioturbated. Variations in rock beds throughout the Gilboa Formation suggest increasing marine influence through the lowest 20 m and decreasing influence through the upper 30 m. The Gilboa Formation overlies the Moscow Formation. The age of the Gilboa formation is Middle Devonian.

Rochester Site Geological Information

Monroe County Spectrum Comm Center Site: 71 Mt. Hope Ave, Rochester, NY 14620 (next to the Genesee River)

The Rochester site is in a very densely populated area, with longstanding municipal water and sewer services. As a result, the DEC NYS Water Well Database shows only one (1) well log a mile east of our selected site and on a similar elevation. Bedrock was encountered at 10 feet for this relatively shallow well, 60-foot depth in total. The well does not have a particularly high-water yield at 5GPM but also not dry, so indications are the thermal conductivity is likely to be in a range of average or above average performance.



DEC Water Well Report about 1 mile from the selected Rochester Site.

Figure 16: Rochester Site Nearby DEC Well Log

The City of Rochester and surrounding areas are known for shallow gas deposits and in several areas, it is recommended to restrict closed loop geothermal drilling to 300 feet. The team spoke to A.C.E.S., the largest GSHP installer in NYS, which has the Rochester metropolitan area in their service territory. They report occurrences of gas deposits as shallow as 125 feet in some areas but the ability to achieve a full 500 feet with no issues in other areas. Working with an experienced well driller in the area, a test bore can be drilled targeting 300 feet and an assessment be made if a deeper borehole can be achieved in a safe and predictable manner at the location.

The project team has also considered other thermal sources, such as the Genesee River, potential for sewer waste heat recovery or solar thermal resources to possibly compensate if drilling depths are limited.

US Geological Survey maps for surficial and bedrock geology:

Surficial geology in the area of the site has been mapped by the New York State Museum – Geological Survey on the Surficial Geologic Map of New York – Finger Lakes Sheet as: Kame Morane overlying Lacustrine Sand and Clay. The Kame Morane consists of variable texture (size and sourting) from boulders to sand deposited at an ice margin during deglaciation. The Kame Morane ranges 10 to 20 meters (35 to 100 feet) in thickness.

The subsurface geology (bedrock) in the area of the site has also been mapped by the United States Geological Survey – Mineral Resources Online Spatial Data – Geologic Maps as: Lockport Group that is 80 to 175 feet in thickness of Eramosa Dolomite and allows uniformity of nomenclature and stratigraphy with an interval in Ontario, CAN.[16] The revised Eramosa consists of massive, pale brownish-weathering, vuggy, commonly biostromal dolomite with intervals of sparsely fossiliferous, medium-bedded, flaggy-weathering, brownish-gray, bituminous dolomite, and stromatolite bioherms.

Note: The USGS bedrock information reports a large number of references to biological elements in the formations (e.g., biostromal dolomite, stromatolite bioherms, coral biostromes) which can foreshadow methane deposits in the bedrock.

Permitting & Regulatory Compliance

Existing Barriers to Widespread Adaptation

Ground Source Heat Pump are arguably the "best fit" for NYS to transform buildings considering the CLCPA goals. Below is **NY-GEO's Benefits Slide** (Figure 17) generated originally in 2012 to educate policymakers. Despite a strong list of systemic operational and environmental accolades listed, GSHPs are arguably the least popular HVAC solution for buildings in NYS. The technology presently requires building owners to make a large permanent energy infrastructure investment to activate the benefits. A level of investment that can be avoided by all other comparatively inferior HVAC equipment solutions which boast only a fraction of the efficiency or environmental benefits demonstrated by ground source systems.

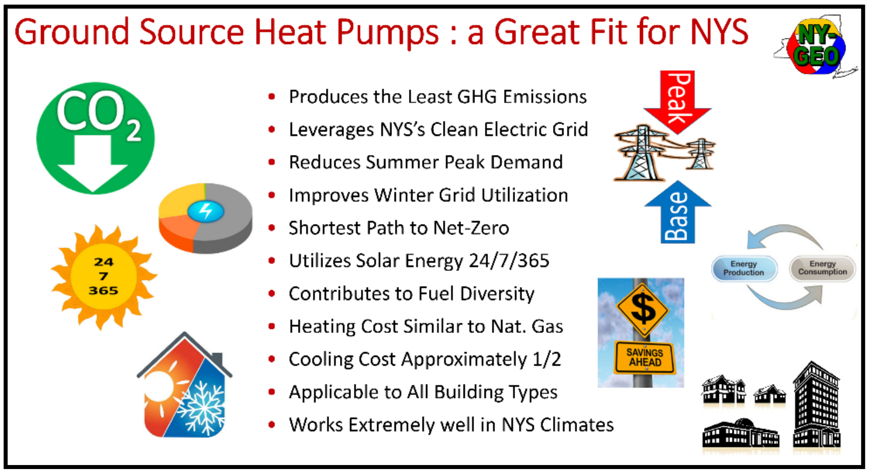


Figure 17: Despite the many benefits, GSHP's infrastructure investment has prevented widespread adoption. NY-GEO Benefits Slide 2012

GSHPs as a district style approach, while also uncommon, are reasonably well established as a viable method for a campus of buildings, with some added efficiencies when optimized for that purpose. Taking this concept to broader adoption of district geothermal networks to groups of buildings *not* under common ownership, provides us only a handful of examples in North America with varying levels of system complexity, cost structures and operating models.

Taking a utility approach to the ground heat exchanger investment may be the key to broader adoption. Our present distributed natural gas and electric utilities serve as examples of investments in energy infrastructure made affordable to building owners through a monthly billing function, accounting for delivery and supply costs. Even with these obvious examples in place, there will still be several barriers before broad implementation of networked geothermal communities. We cannot automatically apply the guidelines in place for existing utilities, which was pointed out in ***Overcoming Legal and Regulatory Barriers to District Geothermal in New York State*** prepared by Pace Energy and Climate Center for NYSERDA in 2021.[9] Among issues to be resolved for District Geothermal Systems include:

- Obtaining easements to located geothermal infrastructure across/beneath public right-of-way
- Easements on private land may impose restrictions on how private property owners may use their land and influence property values.
  - This may lead to property owners declining participation or refusal to grant access to their property without adequate protections or compensation.

- Co-location of geothermal infrastructure and utility infrastructure requires utility cooperation
- Local municipalities lack local codes, standards and permitting regimes for district geothermal applications
- NY laws and related regulations governing public utilities create uncertainty with regards to the business model and how the systems can be regulated and priced in the future.

Standard practice used by utilities in NYS has been using franchise agreements with municipalities, which allows the utility to acquire property and easement rights. This would effectively remove a variable from the process of implementing the district system by standardizing the rights and obligations between municipalities and utilities concerning rights-of-way access and such issues as indemnification, permitting, and insurance requirements.[9]

Regulations & Permitting

District geothermal systems, akin to traditional geothermal systems, are subject to several environmental laws, regulations, and permitting requirements. The following outline the statewide and federal implications, not including local municipal codes and requirements.[9]

Coastal Zone Management Act – allows coastal states to develop coastal management programs. Projects in coastal lands must comply with the state's Coastal Zone Management Program.

Clean Water Act (CWA) – allows the NYSDEC to manage water pollution and develop pretreatment programs to regulate indirect charges of pollutants into municipal waterways.

Safe Drinking Water Act (SDWA) – allows the EPA to establish regulations setting minimum requirements for state water quality. Under the Underground Injection Control program, standing column wells and open loop diffusion wells are considered Class V injection wells. Injection wells are prohibited from any activity that allows the movement of fluids containing any contaminants into underground sources of drinking water. Most Class V injections can be operated without a permit as long as the owners submit inventory information to the EPA and verify that they are allowed to drill the well in a way that does not endanger underground sources of fresh water.

New York State Water Withdrawal Permits – only applicable to open loop systems, water withdrawal permits are required for all water withdrawal systems exceeding 100,000 gallons per day of intake.

State Pollutant Discharge Elimination System Permit (SPDES) – regulated by the NYSDEC, systems are reviewed to determine if they require a permit. All systems that reject heat or pollutants to a body of water require a permit. This applies directly to open loop systems and may or may not apply to closed loop systems, depending on the circumstances.

Drilling Permits - For wells less than 500 feet in depth, permitting is regulated by the NYSDEC Division of Water. A series of reporting on the driller's registration, certifications, and well reports are required. For wells exceeding 500 feet in depth, the NYSDEC Division of Mineral Resources regulates the drilling of wells. A permit must be applied for prior to drilling with details on the drilling methodology used. An Environmental Assessment Form must also be submitted to determine whether further permitting is required.

There is uncertainty over whether the Public Service Commission possesses the authority to regulate the manufacturing, conveying, and sale of heat itself through district geothermal systems aside from natural gas networks and district steam systems.

While there is no state legislation explicitly allowing the creation of a new thermal utility, Governor Kathy Hochul has proposed an amendment to Public Service Law in the ***FY 2023 NYS Executive Budget Proposal*** to allow natural gas or electric utilities to own and operate a "geothermal plant"– which would likely open a much more active dialog with the PSC regarding appropriate regulation of this new utility.[4]

Recently in utility rate cases, the Department of Public Service Staff has signaled a reluctance to use gas or electric ratepayer money to fund geothermal district pilot projects. DPS Staff has recommended the investor-owned utilities direct their pilot activities through **NYSERDA's newly created PON 4614, the Community Heat Pump System Program.**[6] This is a three-stage process with awards starting out for Scoping Studies ($100K, no matching required), leading to Detailed Engineering (up to $500k/project with 50% match preferred) and finally assistance on Construction (up to $4MM/project with 50% match preferred). NYSERDA has had the initial $15MM in funding expanded and claims they plan to approve over 50 scoping studies by the end of 2022.

Projects are allowed to skip stages of the PON 4614 structure choosing to fund aspects of the district system without NYSERDA's assistance as long as they meet the requirements of the stage they are seeking NYSERDA funding.

Ownership Options

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

1. Private Ownership
2. Municipal Ownership
3. Regulated Utility Ownership

Since NYS Public Service Law does not presently allow for a new thermal utility, we could ignore that option but there does seem to be an increasing sense that such a utility with some degree of statewide regulation is increasingly likely.

1. Private Ownership – 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 their option; assuming they follow the necessary codes and standards available and have the funding to push through some of the inevitable inefficiencies of an early adopter, a privately owned and operated system. Options could be privately funded and a company cen be hired to operate the system.
2. Municipal Ownership – 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 Authority 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. Regulated Utility Ownership – This will require a change in NYS Public Service Law or other laws taking precedence and then some additional development by the PSC and DPS staff before it can become a reality. 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 utilities 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, with 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. This could be the most obvious supply assets, like vertical heat exchangers, solar thermal panels, or even a bank of chillers cooling a data center. The distribution assets are similar to utilities we have had for centuries, like 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 but still regulated.

c. **Individual Building vs. Two+ Separately Owned Properties -** The concept of defining a "geothermal plant" as needing to service two 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. Areas presently served by expensive delivery fuels in the NYSEG/RG&E service territory would be some of the buildings receiving the most benefit of reduced operating costs if a utility was permitted or encouraged to convert these homes and businesses on the more practical individual ground heat exchanger, which is the most cost effective in low density areas.

Billing Structure of Pilots

There are currently four other pilot district geothermal projects across the Northeastern United States in various stages of development by natural gas utilities. Relevant background information on these projects is provided below.

Riverhead, Long Island (National Grid)

Status: Built and operational, approved from 2016 rate case

Source of Funding: Gas Ratepayer Money

Scope: Ten homes in a 55+ retirement community were connected to a 30-ton common loop. The loop has no central pumping and the system replaced kerosene and propane heating. Customers experienced positive qualitative benefits including improved indoor air quality, reduced equipment noise, and more consistent temperatures in their homes. Load diversity resulted in a peak load that was 80% of nominal load.

Billing Structure: Customers pay $21.66 per month which is the minimum gas charge for Long Island. Overall customers saved 43% compared with their previous heating and cooling systems.

Framingham, Massachusetts (Eversource)

Status: Funded with site selection, moving to detailed engineering

Source of Funding: Gas Ratepayer Money, D.P.U. 19-120

Scope: Approximately 60 units are targeted for conversion. They include a variety of building styles including low-income housing and buildings needing delivery fuel conversion in addition to others. The project is funded in three stages: site selection, detailed engineering, and construction- each of which will be bid out separately. The pilot will install clean thermal heat exchangers, buried horizontal piping to connect the selected buildings, and will replace the heating system in the buildings with heat pumps which include any internal distribution upgrades or changes to make the conversion successful. The pilot only covers conversion of space heating. Funds are not allocated towards replacement or conversion of other fossil fuel appliances such as domestic hot water, gas stoves, and gas dryers. The pilot does not officially cover conversion or addition of air conditioning, but it is envisioned that air conditioning will be provided as a byproduct of the heating conversion. This will also help to thermally balance the loop.

Billing Structure: From the DPU order, Residential customers will have fixed charges ranging from $10 to $20 per month depending on income level to connect to the service during the period of the pilot. At an April 14, 2022 community meeting, it was stated it would be $10 per month for all homes in the selected site. Commercial customers will pay $15 per month to connect. All customers will pay the added electricity that the heat pump will use in addition to the fixed charges. This works out to be approximately cost-neutral for natural gas conversions and stated as a ~40% savingings in energy costs for delivery fuel conversions.

Upstate New York (National Grid, Niagara Mohawk)

Status: Proposed but not funded as part of the most recent Joint Proposal,[17] Guided to apply for NYSERDA PON 4614

Source of Funding: Gas Ratepayer Money

Scope: Install 2,600 tons of capacity over 3 years in a shared-loop. A mixture of projects for customers who are being served by gas assets that will be replaced as well as customers who are not connected to the gas system is being explored. Installations will occur "in partnership with the competitive suppliers of geothermal heat pumps, with the company (i.e., NMPC) owning the shared loop infrastructure and supplying thermal energy to connected customers under a long-term contract rate." Put another way, the building conversions are not funded through pilot, and building owners are assumed to take advantage of any utility rebates and tax credits to help with affordability of the geothermal heat pump installations.

Billing Structure: National Grid's Future of Heat team attempted to structure the cost recovery from the new pool of geothermal customers only when calculating customer charges, to mimic natural gas distribution assets recovery and customer charge methodologies. Customers would pay a monthly fixed rate based on their connected capacity of $22.69/ton/month (weighted average cost of a ton). Many stakeholder groups applauded the pilot concept but felt the connection charge, combined with requiring building owners to purchase their own heat pump equipment, would prove unsecussful in terms of customer adoption.

Massachusetts (National Grid)

Status: Four geothermal district pilots were approved by DPU as part of National Grid's most recent rate case. Site selection discussions are currently underway between National Grid and various local organizations. [17] No RFP has been issued at the time of this report.

Source of Funding: Gas ratepayer money, D.P.U. 21-24

Scope: Select 4 sites for conversion and install 876 tons of capacity among these 4 sites over 3 years. The scope is similar to the Eversource proposal and will focus exclusively on shared-loop, mixed-use systems with the goal of understanding how to optimize the value of shared loops and their diverse loads. The significant difference is the National Grid will be replacing all gas appliances and discontinue gas service to the building in most instances. As a result the pilot will fund the replacement of gas stoves, driers, and hot water heaters, in addition to the heat pump equipment with appropriate distribution system in the home/building. This simplifies the end of pilot options and will also be interesting to see how replacing all gas appliances impacts customer acceptance.

Billing Structure: National Grid has two separate charges for pilot participants to contribute towards the cost of the geothermal shared-loop sites and to evaluate a customer's willingness to pay for a geothermal system. First, the Company proposed monthly customer charges for residential, residential low-income, and commercial and industrial ("C&I") customers of four dollars, three dollars, and four dollars, respectively (Ex. FOH-1, at 24). The Company designed the proposed customer charges based on a portion of the customer-related costs underpinning the Company's existing gas customer charges, such as billing and customer service, to approximate customer charges under wide-scale deployment of geothermal service (Ex. FOH-1, at 24).

Second, the Company proposed to charge participating customers a participant fee for the first 60 months of $60 per month per GSHP unit for residential customers, $45 per month per GSHP unit for residential low-income customers, and $90 per month per GSHP unit for C&I customers. After netting out the customer charge and participant fee revenue, National Grid proposed to recover the revenue requirement for the Geothermal Project costs through a reconciling factor called the geothermal district energy demonstration program factor ("GDEDPF") in the Company's local distribution adjustment clause ("LDAC") tariff. The Company projected that a typical residential heating customer would experience a bill increase between $0.24 and $3.48 per year compared to rates effective at the time of the filing, depending on their service territory and the year of the demonstration project.

SITE SELECTION

The following section outlines the methodology used to select candidate project sites and includes a narrative on the (3) potential pilot sites that were selected to be evaluated in more detail. The process used to identify and select sites began with a high-level look of the four counties in the scope to identify the most densely occupied areas with the highest energy usage. More detailed analysis on this stage in the selection process is located in Appendix A.

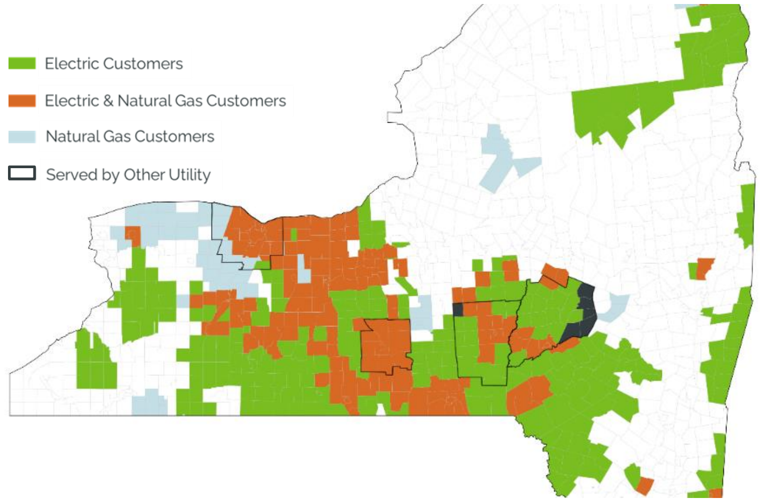


Figure 18: NYSEG and RG&E Service Territories within NYS

The four counties are outlined in black on the Companies' service territories map shown in Figure 18 above. NYSEG provides both electric and gas service to all of Tompkins County. RG&E provides both electric and gas service to about 2/3 of Monroe County with natural gas only in the remaining third. NYSEG serves gas to portions of Chenango and Otsego counties, most of the remainder have only electric service.

Looking at the most densely occupied areas, community centers were identified that had available thermal resources and diversity of building loads. Sites containing buildings with large cooling loads were identified and sites with multiple large thermal sources to maximize the load diversity in the loop and provide opportunity for future expansion.

Ten sites were identified and then evaluated based on a set of weighted criteria to select three potential pilot sites for more detailed evaluation.

Overview of Service Territories

Site selection began with identifying highest density population centers in each of the four counties. These population centers were then analyzed to identify potential areas for a district geothermal system based on additional, site-specific factors. Feasible sites typically have a large parking lot or plot of open land that could be used to host a geothermal borefield. In addition, feasible sites ideally have a diverse set of loads between both commercial buildings, some residential housing, and additional sources of renewable energy.

Table 1 outlines the population densities for each town, village, and city within the four counties. The population density, as expected, aligns closely with the energy consumption per the Utility Energy Registry shown in Figure 19.

Table 1: Population Densities of Municipality [11]

Otsego County

#	Town/City/Village	Population	Sq. Mi.	Pop. / Sq. Mi.
1	*City of* Oneonta	13,901	4.4	3,188
2	*Village of* Richfield Springs	1,264	1.0	1,251
3	*Village of* Cooperstown	1,852	1.6	1,129
4	*Village of* Unadilla	1,050	1.0	1,010
5	*Village of* Otego	1,010	1.2	871
6	*Village of* Laurens	263	0.1	2,023
7	*Village of* Milford	415	0.4	988
8	*Village of* Cherry Valley	489	0.5	959
9	*Village of* Morris	583	0.8	777
10	*Village of* Butternuts	399	1.0	399
11	*Town of* Oneonta	5,229	32.9	159
12	*Town of* Unadilla	4,392	46.3	95
13	*Town of* Richfield	2,388	30.9	77
14	*Town of* Otsego	3,900	53.9	72
15	*Town of* Otego	3,115	45.6	68
16	*Town of* Milford	3,044	46.1	66
17	*Town of* Laurens	2,424	42.0	58
18	*Town of* Hartwick	2,110	40.1	53
19	*Town of* Morris	1,878	39.1	48
20	*Town of* Worcester	2,220	46.7	48
21	*Town of* Edmeston	1,826	44.3	41
22	*Town of* Maryland	1,897	52.4	36
23	*Town of* Pittsfield	1,366	38.0	36
24	*Town of* Middlefield	2,114	63.3	33
25	*Town of* Butternuts	1,786	53.8	33
26	*Town of* Springfield	1,358	42.9	32
27	*Town of* Plainfield	915	29.5	31
28	*Town of* Exeter	987	32.1	31
29	*Town of* Cherry Valley	1,223	40.4	30
30	*Town of* Westford	868	33.9	26
31	*Town of* Burlington	1,140	44.9	25
32	*Town of* New Lisbon	1,114	44.4	25
33	*Town of* Roseboom	711	33.4	21
34	*Town of* Decatur	353	20.6	17

Chenango County

#	Town/City/Village	Population	Sq. Mi.	Pop. / Sq. Mi.
1	*City of* Norwich	13,901	4.4	3,188
2	*Village of* Greene	1,264	1.0	1,251
3	*Village of* Bainbridge	1,852	1.6	1,129
4	*Village of* New Berlin	1,050	1.0	1,010
5	*Village of* Sherburne	1,010	1.2	871
6	*Village of* Smyrna	263	0.1	2,023
7	*Village of* Oxford	415	0.4	988
8	*Village of* Earlville	489	0.5	959
9	*Village of* Afton	583	0.8	777
10	*Village of* Butternuts	399	1.0	399
11	*Town of* Bainbridge	3,308	34.3	96
12	*Town of* Norwich	3,998	42.0	95
13	*Town of* Sherburne	4,048	43.6	93
14	*Town of* Greene	5,604	75.1	75
15	*Town of* Oxford	3,901	60.1	65
16	*Town of* North Norwich	1,783	28.1	63
17	*Town of* Afton	2,851	45.8	62
18	*Town of* New Berlin	2,682	46.1	58
19	*Town of* Guilford	2,922	61.7	47
20	*Town of* Plymouth	1,804	42.2	43
21	*Town of* Coventry	1,655	48.7	34
22	*Town of* Smyrna	1,280	42.1	30
23	*Town of* Preston	1,044	34.9	30
24	*Town of* Pitcher	803	28.5	28
25	*Town of* Otselic	1,054	38.0	28
26	*Town of* Smithville	1,330	50.4	26
27	*Town of* Columbus	975	37.4	26
28	*Town of* McDonough	886	39.0	23
29	*Town of* Pharsalia	593	38.8	15
30	*Town of* Lincklaen	396	26.3	15
31	*Town of* German	370	28.4	13

Tompkins County

#	Town/City/Village	Population	Sq. Mi.	Pop. / Sq. Mi.
1–4	*City of* Ithaca	30,014	5.4	5,568
5	*Village of* Cayuga Heights	3,729	1.8	2,107
6	*Village of* Northeast Ithaca	2,655	1.5	1,770
7	*Village of* Groton	2,363	1.7	1,358
8	*Village of* East Ithaca	2,231	1.7	1,312
9	*Village of* Trumansburg	1,797	1.4	1,293
10	*Village of* South Hill	6,673	5.9	1,131
11	*Town of* Dryden	1,890	1.8	1,074
12	*Town of* Lansing	3,529	4.6	766
13	*Town of* Ithaca	1,115	2.9	384
14	*Town of* Newfield	759	1.2	633
15	*Town of* Ithaca	572	0.3	1,907
16	*Town of* Dryden	520	1.1	491
17	*Town of* Ithaca	19,930	28.9	689
18	*Town of* Lansing	11,033	60.5	182
19	*Town of* Dryden	14,435	93.6	154
20	*Town of* Ulysses	4,900	32.9	149
21	*Town of* Groton	5,950	49.4	120
22	*Town of* Enfield	3,512	36.7	96
23	*Town of* Newfield	5,179	58.8	88
24	*Town of* Danby	3,329	53.6	62
25	*Town of* Caroline	3,282	54.8	60

Monroe County

#	Town/City/Village	Population	Sq. Mi.	Pop. / Sq. Mi.	Town/City/Village	Population	Sq. Mi.	Pop. / Sq. Mi.
1	*Town of* East Rochester	6,587	1.3	4,971	*City of Rochester*	210,565	35.8	5,885
2	*Town of* Irondequoit	51,692	15.0	3,446	City of Rochester (DT)	729	0.1	13,755
3	*Town of* Brighton	36,609	15.4	2,375	City of Rochester (DT)	176	0.0	6,769
4	*Town of* Greece				City of Rochester (DT)	200	0.0	6,667
5	*Town of* Greece	96,095	47.5	2,022	City of Rochester (DT)	817	0.1	5,713
6	*Town of* Gates	28,400	15.2	1,868	City of Rochester (DT)	287	0.1	5,627
7	*Town of* Perinton				City of Rochester (DT)	359	0.1	5,439
8	*Town of* Perinton	46,462	34.2	1,359	City of Rochester (DT)	610	0.1	5,259
9	*Town of* Webster	42,641	33.5	1,272	City of Rochester (DT)	117	0.0	3,900
10	*Town of* Pittsford	29,405	23.2	1,268	City of Rochester (DT)	300	0.1	3,659
11	*Town of* Henrietta				City of Rochester (DT)	150	0.1	3,000
12	*Town of* Henrietta	42,581	35.4	1,205	City of Rochester	10,189	0.6	16,982
13	*Town of* Henrietta	42,581	35.4	1,205	City of Rochester	3,497	0.3	11,281
14	*Town of* Penfield	36,242	37.2	974	City of Rochester	38,693	4.1	9,437
15	*Town of* Chili	28,625	39.5	725	City of Rochester	3,406	0.4	7,671
16	*Town of* Ogden	19,856	36.5	544	City of Rochester	4,131	0.6	7,351
17	*Town of* Sweden	14,175	33.7	421	City of Rochester	2,460	0.3	7,288
18	*Town of* Parma	15,633	42.0	372	City of Rochester	18,093	2.5	7,237
19	*Town of* Mendon	9,152	39.5	232	City of Rochester	12,694	1.9	6,752
20	*Town of* Hamlin	9,045	43.5	208	City of Rochester	6,838	1.2	5,946
21	*Town of* Clarkson	6,736	33.2	203	City of Rochester	7,051	1.2	5,876
22	*Town of* Riga	5,590	35.0	160	City of Rochester	3,406	0.6	5,805
23	*Town of* Wheatland	4,775	30.4	157	City of Rochester	17,663	3.7	4,813
24	*Town of* Rush	3,478	30.3	115				

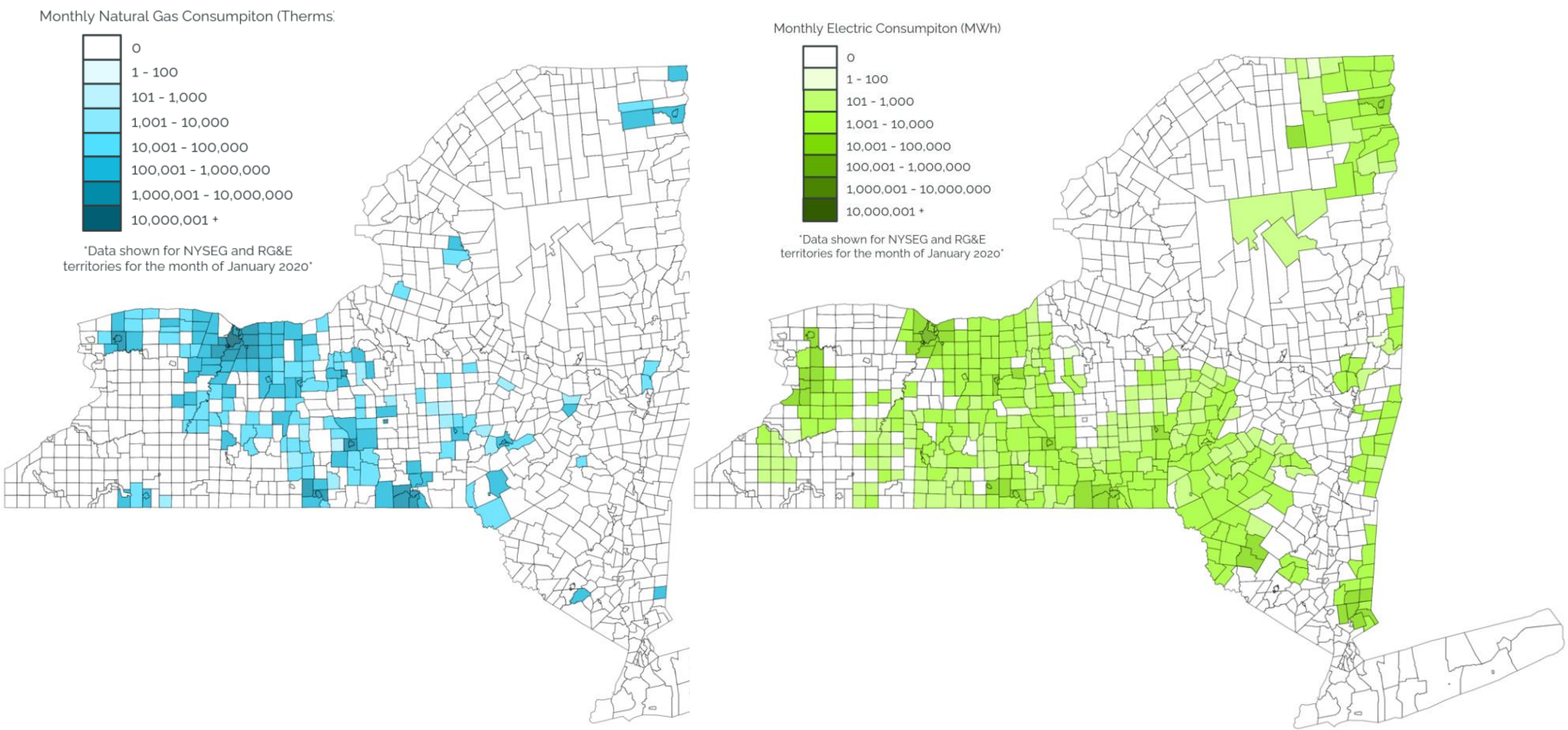


Figure 19: Natural Gas (Left) and Electric (Right) Consumption per Municipality [5]

Site Identification

After dense population centers were identified, the site identification process began. Around densely occupied areas, buildings were identified that had the following:

- Cooling dominant / diverse building loads
- Large thermal resources (such as parking lots, fields, surface water, wastewater)
- Surrounding areas suitable for future expansion
- Mix of commercial and residential buildings

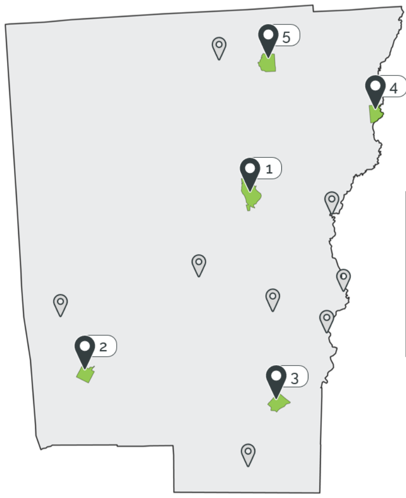
To maximize the overall system efficiency and cost effectiveness, it is advantageous to have buildings with diverse heating and cooling load profiles, whereas they don't peak at the same time to reduce peak system capacity. Based on the climate in New York State, buildings are generally heating dominant where there are no additional cooling or refrigeration loads. Selecting buildings with large cooling loads such as grocery stores or ice rinks allows for an opportunity to better balance the loop and therefore reduce overall system cost.

At a high-level, large parking lots, open fields, rivers, lakes, ponds, and wastewater infrastructure were identified as potential thermal resources to leverage in the district system. For many sites this presents options in the case the geology limits the depth of drilling.

The images below outline the sites in the most densely occupied areas within each county. From these lists, ten sites were identified to be evaluated in more detail.

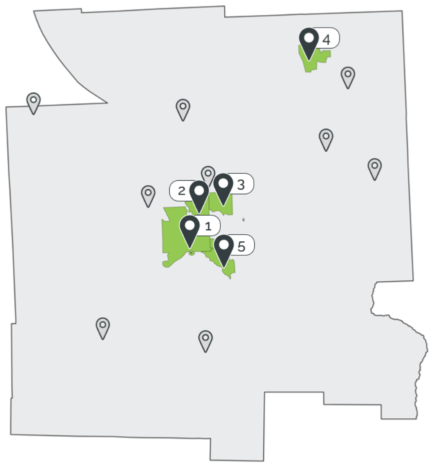
	City / Villages	Candidate Sites	Pop / Sq. Mile
1	City of Oneonta	Boys & Girls Club	3,188
2	Richfield Springs	RS Central Schools	1,251
3	Cooperstown	Price Chopper Plaza	1,129
4	Unadilla	Unitago Elementary	1,010
5	Otego	Otego	871

Figure 20: Densest Population Centers in Otsego County



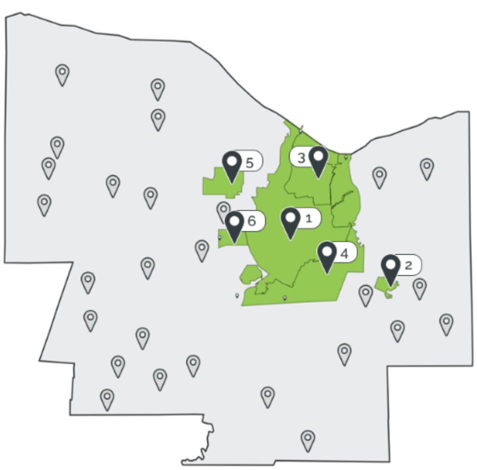
	City / Villages	Candidate Sites	Pop / Sq. Mile
1	City of Norwich	Tops Plaza	3,392
2	Greene	Town Center	1,477
3	Bainbridge	Scoville-Meno Truck	1,034
4	New Berlin	New York Pizzeria	961
5	Sherburne	China King	899

Figure 21: Densest Population Centers in Chenango County



	City / Villages	Candidate Sites	Pop / Sq. Mile
1	City of Ithaca	Southside Ithaca	5,568
1	City of Ithaca	South Meadow Square	
1	City of Ithaca	Dept. Motor Vehicles	
1	City of Ithaca	Purity Ice Cream Area	
2	Cayuga Heights	First Congregational Church	2,107
3	Northeast Ithaca	TST BOCES / Northeast Elementary	1,770
4	Groton	Groton Elementary	1,358
5	East Ithaca	East Hill Plaza	1,312

Figure 22: Densest Population Centers in Tompkins County



	Town / City / Villages	Candidate Sites	Population	Pop / Sq. Mile	Sq Mile
1	City of Rochester	-	210,565	5,885	35.78
2	Town of East Richester	Hollycake House/Public Library	6,587	4,971	1.33
3	Town of Irondequoit	East Irondequoit - Wegman's	51,692	3,446	15.00
4	Town of Brighton	Brighton Metro Park, MCC, Rustic Village, Gray's Iceplex	36,609	2,375	15.42
5	Town of Greece	Wegmans/ Mall at Greece Ridge	96,095	2,000	48.00
6	Town of Gates	Wegmans			

Figure 23: Densest Population Centers in Monroe County

Top Ten Sites Evaluation

Candidate sites were selected for each of the four counties based on population density and a preliminary overview of their renewable energy potential. Each of the sites in the refined list had sufficient load diversity and thermal capacity to build a successful geothermal loop. The diversity in site characteristics among this refined list is testament to the feasibility of geothermal loops across New York State regardless of a specific community or building type. Shown below is a table outlining the refined list of sites.

Table 2: Refined Ten Sites

Location	Site
Chenango, Norwich	Tops Plaza
Chenango, Greene	Greene Town Center
Otsego, Oneonta	Oneonta, B&G Club
Otsego, Cooperstown	Price Chopper / CVS
Monroe, Scottsville	Cooper Vision
Monroe, Brockport	Brockport Corner Mall
Monroe, Southwedge	Spectrum Comm Ctr
Tompkins, Ithaca	Dept Motor Vehicles
Tompkins, Ithaca	Purity Ice Cream Area
Tompkins, Groton	Groton Elementary Area

To identify pilot sites that would advance to the district geothermal design phase of the project, a decision matrix was developed. The decision matrix outlined metrics that were deemed important to site selection and compared these metrics between the different sites. An overview of each metric along with its associated weighting is shown below.

- **Load Diversity (20%):** Diversity in building loads – specifically heating vs cooling loads
- **On-site Thermal (15%):** Potential for thermal sources in the area (ground source, solar heating, surface water, wastewater)
- **Expandable (15%):** Does the surrounding area lend itself to future expansion?
- **Conversion Risk (15%):** How dependent is the loop on one or two nonresidential customers?
- **Replicable (10%):** How repeatable is the project across the state?
- **Building Diversity (10%):** # of residential buildings vs. # of nonresidential buildings and respective size of each
- **Ease of Conversion (10%):** How many owners need to be consulted? Any major technical challenges?
- **On-site Electricity (5%):** Space potential for additional on-site generation

These metrics prioritized a site that was able to provide a balanced load to the district loop. Ideal sites had one or more buildings which were cooling dominant (such as a grocery store). These buildings helped balance the heating dominant loads commonly found in the rest of the community (residential homes, office buildings, etc.). In areas where no cooling dominant building exists, additional thermal resources such as surface water thermal and wastewater thermal can be used to help balance the load. The Spectrum Communications Center site is a good example of an area that can implement this strategy. The decision matrix summarizing the Spectrum site and the rest of the 10 selected sites is shown below.

Table 3: Decision Matrix

Candidate Decision Matrix	Criteria								Weighted Total
	Load Diversity	Building Diversity	On-site Thermal	On-site Electric	Expandable	Replicable	Ease of Conversion	Conversion Risk	
Site	20%	10%	15%	5%	15%	10%	10%	15%	100%
Tops Plaza	10	9	10	7	10	10	7	8	9.2
Greene Town Center	6	6	9	7	6	8	8	7	7.1
Oneonta, B&G Club	7	7	10	10	6	9	8	8	7.9
Price Chopper / CVS	10	9	8	6	7	10	7	9	8.5
Cooper Vision	8	5	9	6	6	6	8	6	7.0
Brockport Corner Mall	7	8	6	5	8	8	9	8	7.5
Spectrum Comm Ctr	8	10	10	7	8	9	8	9	8.7
Dept Motor Vehicles	9	9	10	8	8	8	6	9	8.6
Purity Ice Cream Area	10	9	9	7	8	9	7	7	8.5
Groton Elementary Area	3	6	9	10	3	9	10	10	6.9

As apparent from the decision matrix, the Tops Plaza in Norwich, Spectrum Communication Center in South Wedge, and Department of Motor Vehicles in Ithaca were the three sites with the highest weighted total. Each of these three sites had an ideal combination of residential and nonresidential buildings in addition to access to thermal resources such as parking lots or surface water thermal. The following section will go into more detail on each site.

Pilot Site #1: Norwich

Figure 24: Norwich Site Map

The site with the highest weighted total is the Tops Plaza site in Norwich, NY. As shown in the figure above, it has a good mix of residential (blue) and nonresidential (red) buildings. In addition, it has several large parking lots (light grey) that can be used to house boreholes. Building T1-T6 is a strip mall that houses a grocery store and several other smaller businesses. The grocery store has a cooling dominant load due to its refrigeration demands. This cooling dominant load will help offset the heating dominant loads of the surrounding neighborhoods. An overview of the thermal loads found at this site is shown in the graph below. Note that heating loads include space heating and domestic hot water heating while cooling loads include cooling and refrigeration.

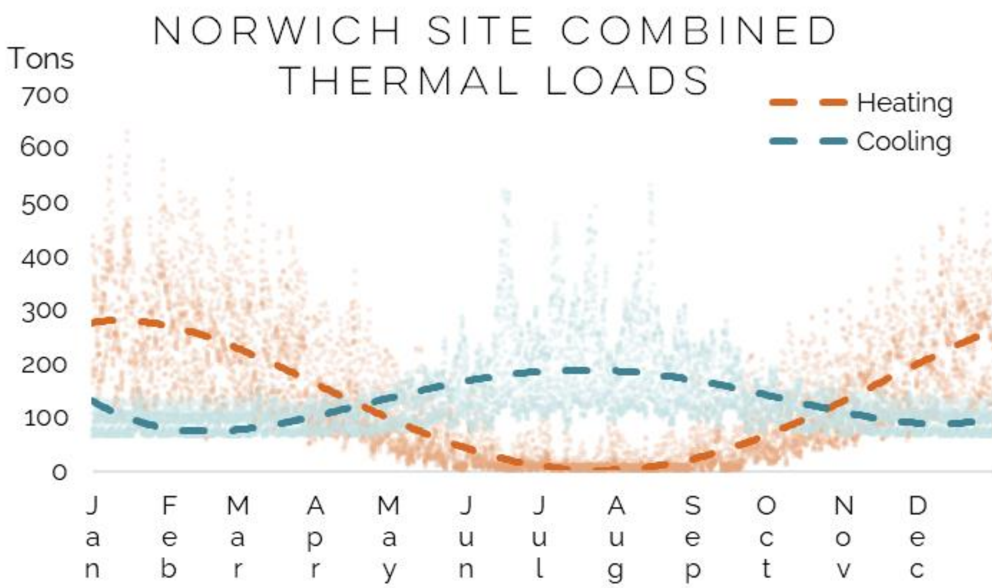


Figure 25: Thermal Load Profile for Norwich Site

The cooling load never reaches zero during the winter because of the refrigeration load found at the grocery store. This helps keep the loop balanced. In terms of replicability, a similar setup can be commonly found across the state as grocery stores tend to be built near neighborhoods. Although there isn't any surface water thermal potential at this site, the size and frequency of parking lots allows for sufficient thermal capacity to house a loop.

PILOT SITE #2: ROCHESTER

Figure 26: Rochester Site Map

The site with the second highest weighted total is the site centered around Spectrum Communication Center in Rochester, NY. As shown in the figure above, it has a good mix of residential (blue) and non-residential (red) buildings. In addition, it has several large parking lots (light grey) that can be used to house boreholes and a large river that can serve as a surface water thermal energy source. Although no building in the direct area of scope is cooling dominant, this issue can be addressed with use of the surface water thermal source.

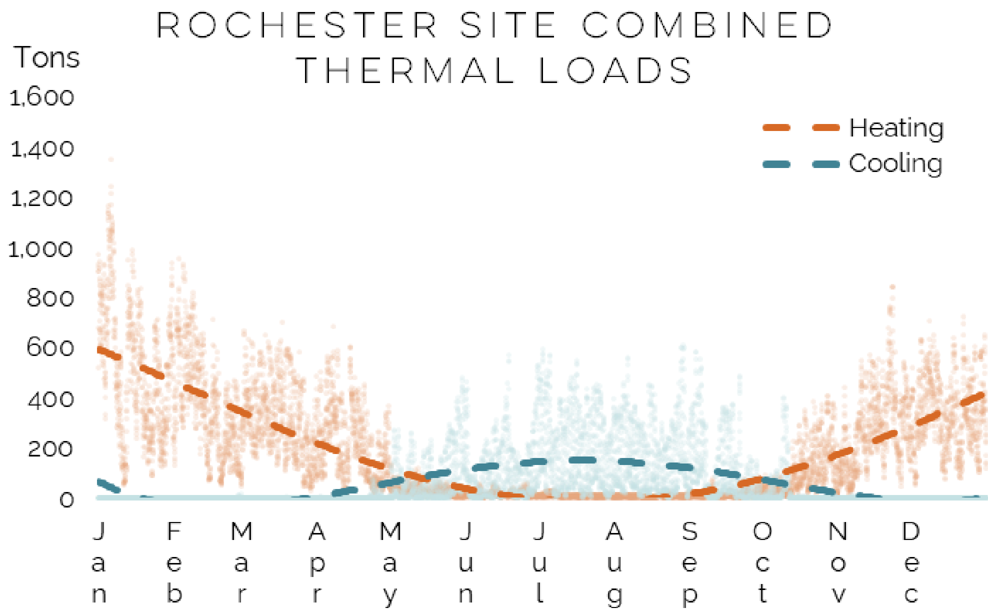


Figure 27: Thermal Load Profile for Rochester Site

As previously discussed, the site is primarily heating dominant. However, by utilizing surface water thermal, additional thermal energy can be extracted from the river. This will help bring balance to the loop. Additional solar thermal domestic hot water heating or supplemental boilers are potential solutions to help minimize the loop imbalance.

PILOT SITE #3: ITHACA

Figure 28: Ithaca Site Map

The site with the third highest weighted total is the Ithaca site, centered around the Ithaca DMV. As shown in the figure above, it has a good mix of residential (blue) and nonresidential (red) buildings. In addition, it has several large parking lots (light grey) that can be used to house boreholes and a river that can serve as a surface water thermal energy source. Building 15 is a wastewater treatment facility which serves as an additional source of thermal energy. Building 13 is a grocery store with a primarily cooling dominant load profile due to their year-round refrigeration usage.

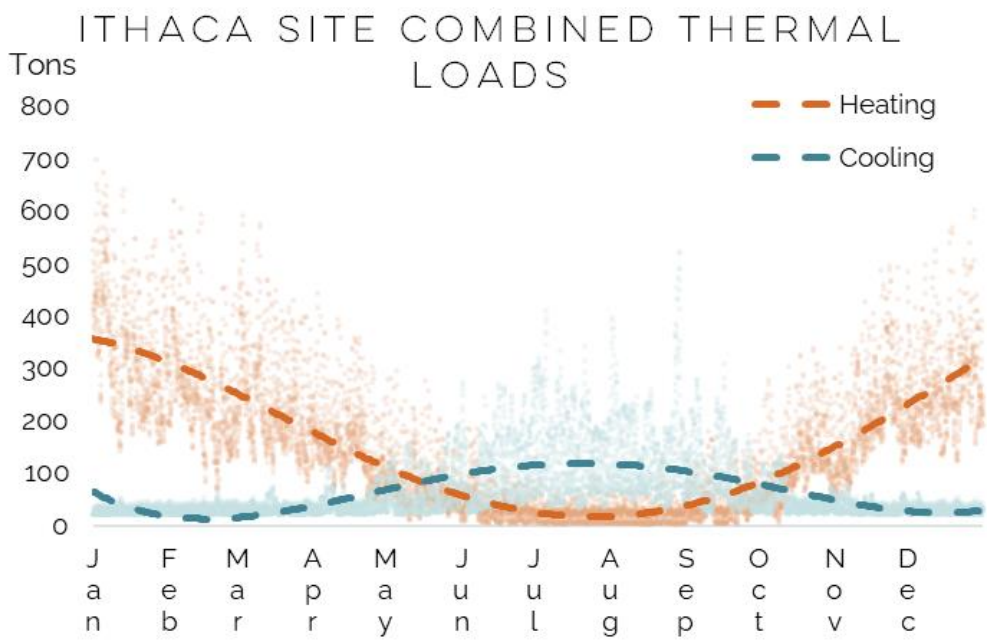


Figure 29: Thermal Load Profile for Ithaca Site

As shown in the figure above, the refrigeration load at the grocery store helps balance out the loop. However, the loop overall is still primarily heating dominant. This can be offset by utilizing the thermal energy available in the river and at the wastewater treatment plant.

As noted in the Summary, an alternate approach would be to operate the district as a ground water or "open" system taking advantage of the generous pressurized aquifer to distribute ground water to heat exchangers located at each building. A principal advantage of this approach is much less dependance on balancing building loads annually.

SITE 1: ROCHESTER

BUILDINGS

The Rochester site consists of (10) non-residential and (31) residential buildings on a city block located in the South Wedge neighborhood, just south of downtown Rochester. This site has a large heating & cooling load associated with the Spectrum Communication Center and is located along the Genesee River. Several parking lots are located throughout the site that are potential areas for ground heat exchanger borefields.

Table 4: Rochester Buildings

#	Building Name	SF	Classification
48	House 48	2,114	Residential
49	House 49	3,936	Residential
50	House 50	1,615	Residential
51	House 51	1,182	Residential
52	House 52	2,560	Residential
53	House 53	2,516	Residential
54	House 54	2,800	Residential
55	House 55	1,854	Residential
56	House 56	2,598	Residential
57	House 57	1,975	Residential
58	House 58	2,108	Residential
59	House 59	1,988	Residential
60	House 60	1,764	Residential
61	House 61	2,092	Residential
72	House 72	3,464	Residential
73	House 73	2,249	Residential
74	House 74	1,896	Residential
75	House 75	1,700	Residential
76	House 76	3,013	Residential
77	House 77	3,280	Residential
78	House 78	1,966	Residential
79	House 79	1,635	Residential
82	House 82	1,726	Residential
85	House 85	1,479	Residential
86	House 86	1,382	Residential
87	House 87	1,920	Residential
88	House 88	1,766	Residential
89	House 89	1,640	Residential
90	House 90	2,020	Residential
91	House 91	554	Residential
92	House 92	1,256	Residential
3	Flower City Glass	34,512	Warehouse
9	Endeavor Counseling Services	40,197	Office
10	Hoopers Tire Outlet	2,216	Retail
11	Apartment Complex	9,714	Midrise Apartment
19	Kennedy Mechanical	12,919	Warehouse
20	D&B Auto Service	4,077	Warehouse
22	Krudco Skate Shop/Foreign Auto Parts	12,802	Retail
23	MacInTak Computers Sales & Service	2,679	Office
25	My Locksmith	13,701	Office
36	Spectrum Communication Center	72,721	Office

Blue text indicates estimated SF based on building footprint.

Figure 30: Rochester Site Map

LOAD PROFILES

Based on the buildings included in the scope and their square footages, load profiles were generated for every hour of the year for each building type to model the loop's heating and cooling loads as a whole. For each building type, load profiles from the NREL ComStock and ResStock Databases were generated and scaled based on square footages and expected peak thermal loads per facility type. [2, 3]

Load profiles were broken down by end use and further filtered into heating loads, cooling loads, refrigeration loads, and "other" non-thermal loads. The graphs below illustrate load profiles for apartment buildings and offices to demonstrate the difference in peak hours for each. Existing natural gas profiles are shown for the month of January and electric profiles are shown for the month of July. Load profiles for all building types are included in Appendix B.

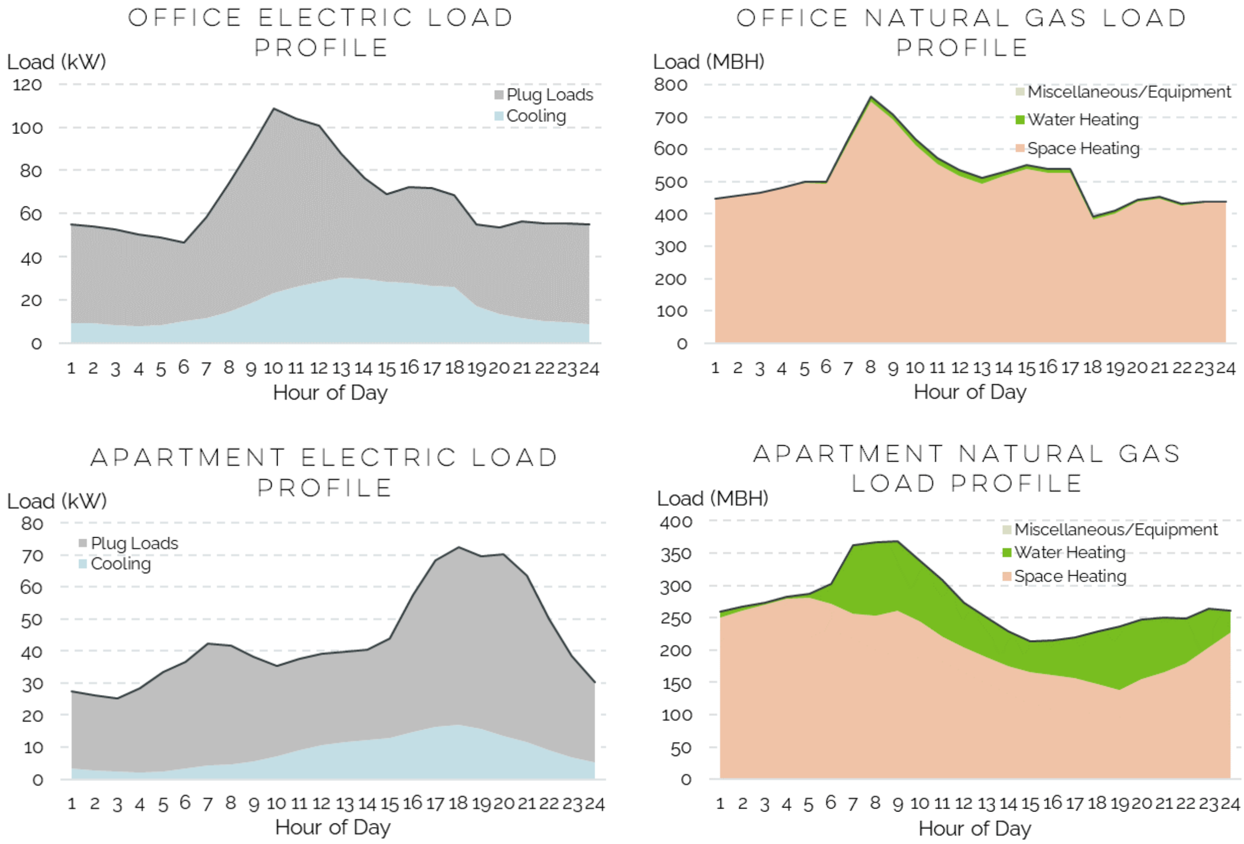


Figure 31: Rochester Site Electric (July) & Natural Gas (January) Load Profiles

Loop Design

Based on the combined thermal loads and site characteristics, a preliminary loop layout was developed, shown in Figure 32. A more detailed site layout is located in Appendix C.

The proposed thermal sources include vertical boreholes drilled to depths of approximately 300 feet beneath the Spectrum Communication Center parking lot, thermal capture from wastewater mains running along the street, and a surface water heat exchanger using the adjacent Genesee River.

As previously discussed, the Rochester area is known for its shallow gas deposits and is recommended in some areas to restrict drilling to 300 feet. With this in mind, a depth of 300 feet is included in the preliminary loop design – with the possibility for additional thermal capture from wastewater mains and surface water heat exchangers using the Genesee River.

The preliminary proposed loop configuration is a single-pipe ambient temperature loop with 14" main piping. Small pumping buildings are located throughout the district to house circulation pumps above-ground. Note that the location of these buildings is flexible and can be changed.

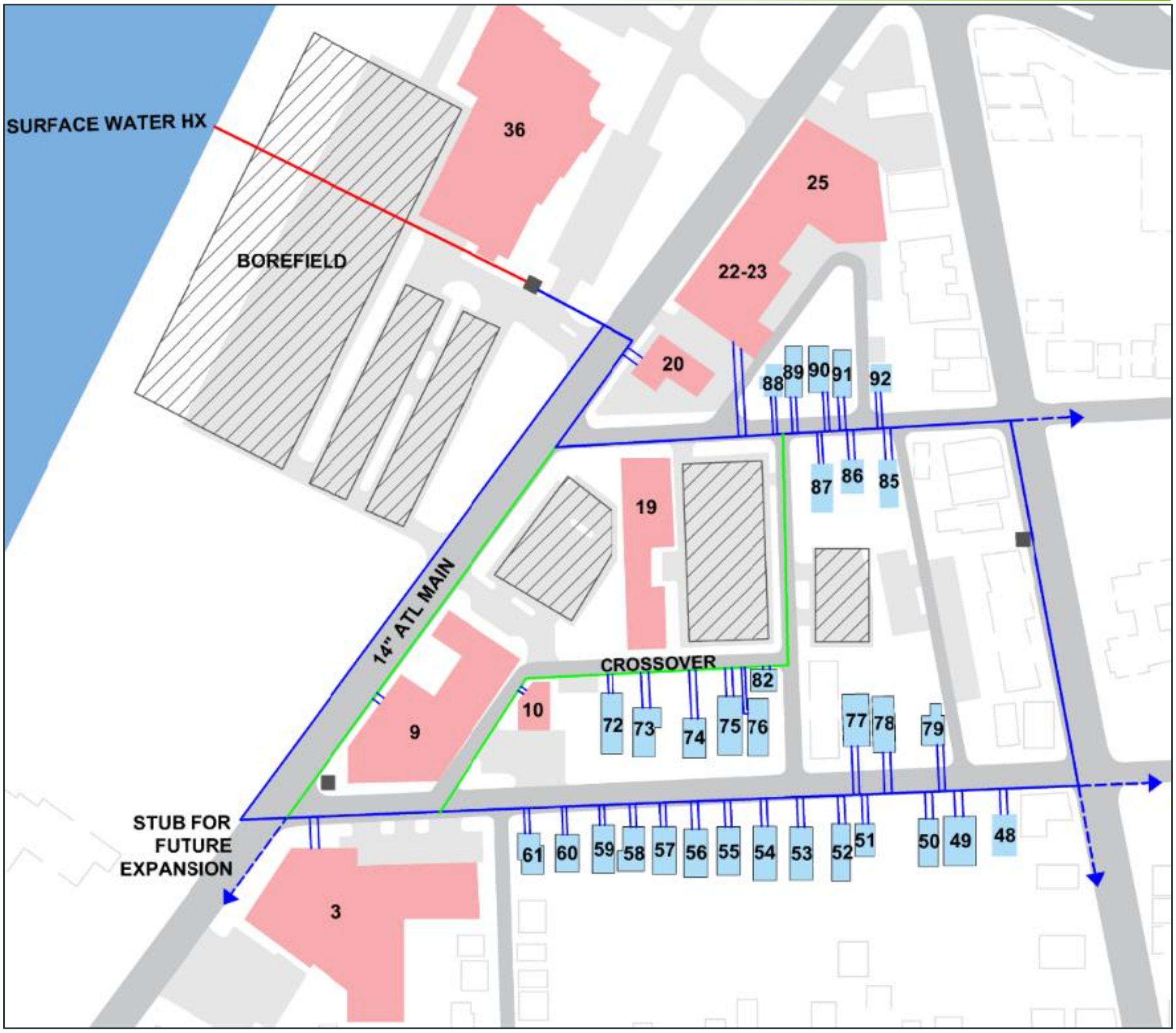


Figure 32: Rochester Preliminary Loop Layout

Additional parking lots have been highlighted indicating other potential thermal resources to tap into. Future expansion for the loop can be accommodated in all directions along roadways as indicated by stub-outs in several locations.

Crossover runs of piping along two North-South streets allow the system to remain operational during maintenance. Not included in this analysis is specific information on the existing HVAC systems at the buildings. It is expected that the buildings currently use traditional gas-fired heating systems and will need to be converted to water-source heat pump systems.

Energy & Carbon 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 converting the fossil fuel heating systems to electric heat pumps.

Based on the projected increase in peak electric load at the site, there is potential for co-location of PV and battery storage to offset strain on the surrounding electric infrastructure. This analysis is outside of the scope of this study but should be included as a part of the engineering design.

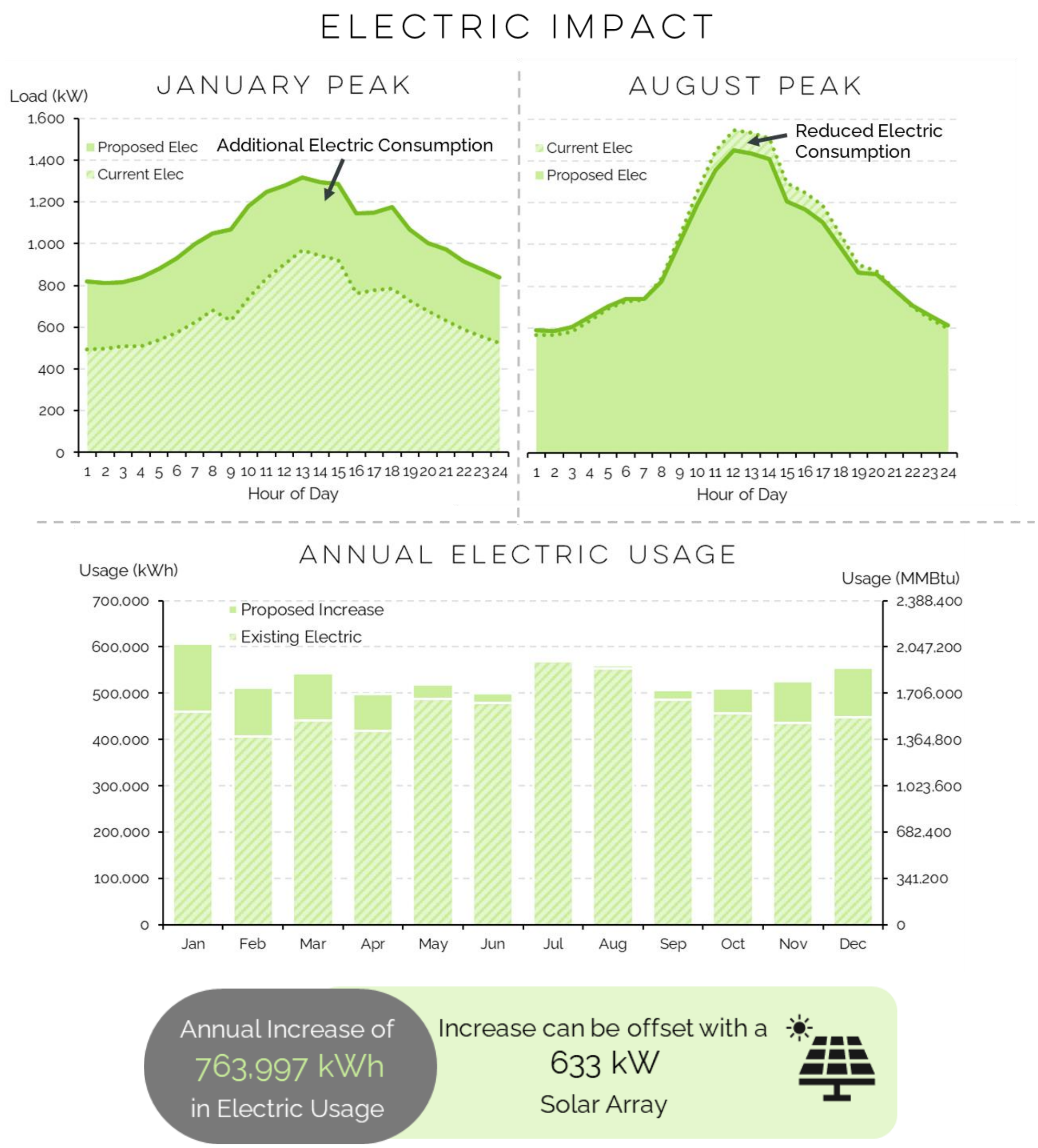


Figure 33: Estimated Electric Impacts at Rochester Site

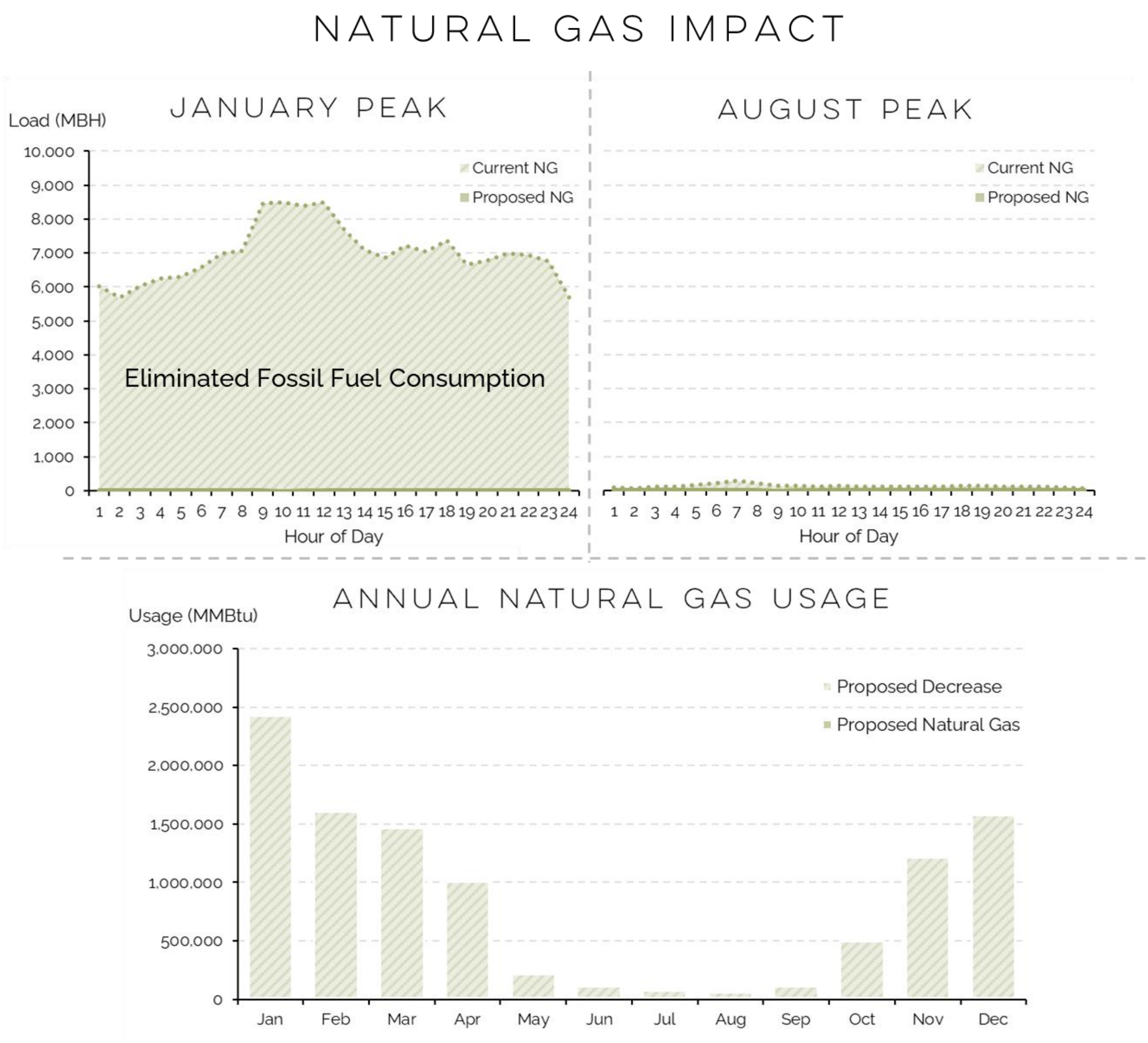


Figure 34: Estimated Natural Gas Impacts at Rochester Site

Based on the calculated annual energy savings the associated annual carbon savings are shown in the figure below. From the offsetting of fossil fuel heating to electric heating 184 metric tons of carbon emissions are estimated to be offset. The graphic below indicates equivalent emissions reductions based on US EPA emissions data.

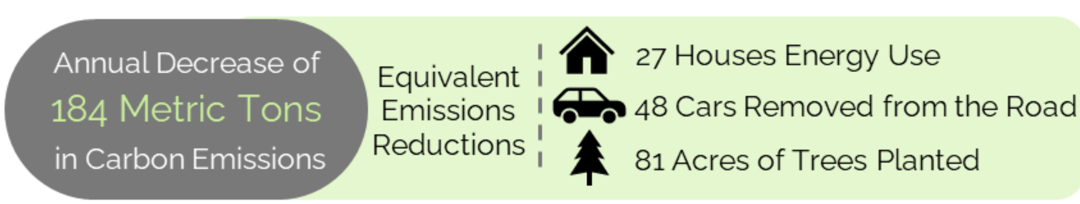


Figure 35: Estimated Carbon Reduction at Rochester Site

Economic Analysis & Ownership Models

Using other district geothermal pilot projects as the only comparable price point on the market so far, the estimated cost per ton for a pilot system in the Northeast is estimated to be $30,000 per ton of installed capacity. Large commercial buildings with GSHP systems have the potential to achieve a cost range of roughly $10,000 per installed ton and the expectation is a broad geothermal utility would achieve economics closer to this range after the design and installation becomes more routine. The tables and figures below illustrate the estimated installation costs broken down by major category, in addition to estimated system operation & maintenance costs based on other systems installed throughout the United States.

Rochester Site Estimated Pilot Project Cost

	Estimated Cost
Engineering Design & Permitting	$ 1,629,000
Drilling	$ 2,443,500
Horizontal Piping	$ 4,887,000
HVAC Conversions	$ 6,516,000
General Construction	$ 814,500
Total:	**$ 16,290,000**

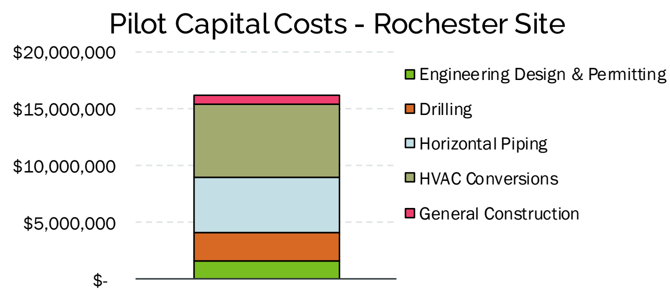


Figure 36: Rochester Site Estimated Capital Costs

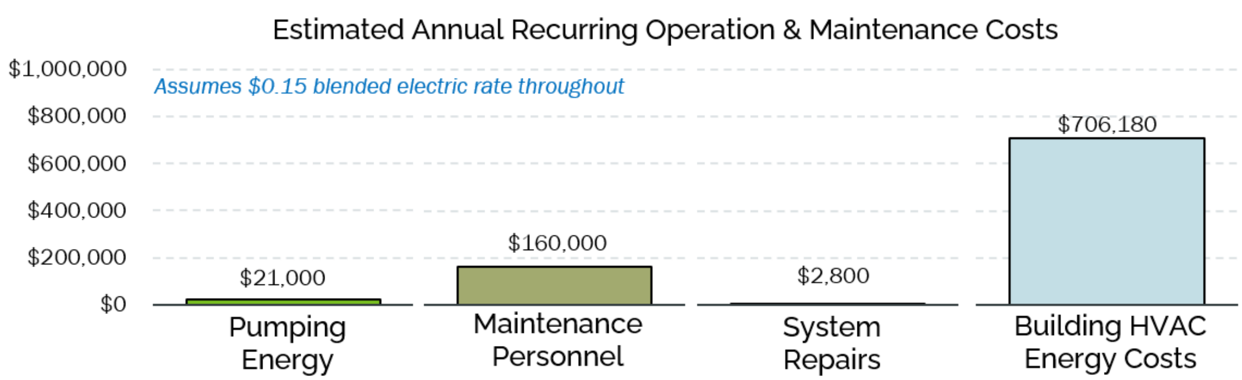


Figure 37: Rochester Site Estimated O&M Costs

SITE 2: NORWICH

BUILDINGS

The Norwich site consists of (12) non-residential and (29) residential buildings on a city block located in Norwich, NY. This site has a large grocery store, which has a large cooling load balancing out the loop. The grocery store parking lot is also very large and provides an opportunity for large borefields beneath the surface of the lot.

Table 5: Norwich Buildings

#	Building Name	SF	Classification
1	House 1	2,420	Residential
2	House 2	1,652	Residential
3	House 3	3,738	Residential
4	House 4	3,432	Residential
5	House 5	3,600	Residential
6	House 6	950	Residential
7	House 7	992	Residential
8	House 8	1,600	Residential
9	House 9	2,092	Residential
10	House 10	2,716	Residential
17	House 17	2,292	Residential
18	House 18	1,512	Residential
19	House 19	2,704	Residential
20	House 20	2,122	Residential
21	House 21	1,988	Residential
22	House 22	1,992	Residential
23	House 23	1,808	Residential
24	House 24	1,262	Residential
25	House 25	1,530	Residential
26	House 26	1,771	Residential
27	House 27	1,978	Residential
28	House 28	1,100	Residential
29	House 29	1,254	Residential
1	Community Shopping Plaza	8,215	Retail
3	Warehouse	39,197	Warehouse
4	Ontario Hotel	5,662	Residential
5	Bible Baptist Church	4,653	Religious Worship
6	Arrow Laundry and Dry Cleanning	3,864	Office
7	Norwich Clinical Research	4,176	Office
1	Tops Markets	58,653	Grocery Store
2	UHS Occupational Medicine	4,600	Office
3	Fashion Bug	8,000	Retail
4	Rent-a-Center	4,000	Office
5	Lucky Kitchen	1,200	Quick Service Restaurant
6	Dollar Tree	9,000	Retail

*Estimated Square Footages Based on Building Footprint

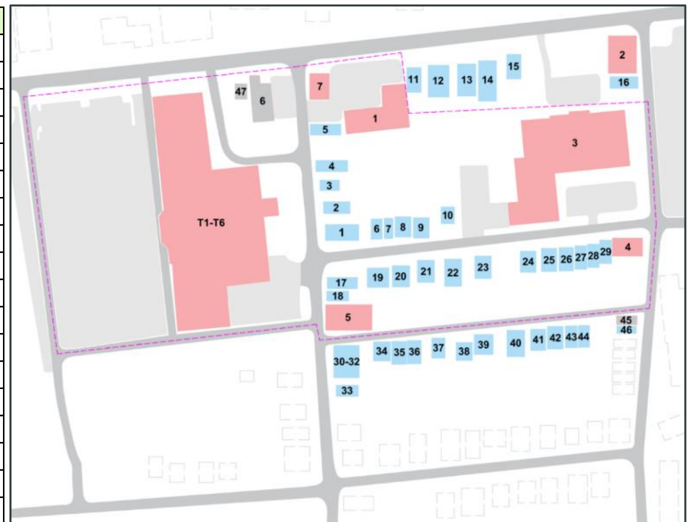


Figure 38: Norwich Site Map

LOAD PROFILES

Based on the buildings included in the scope and their square footages, load profiles were generated for every hour of the year for each building type to model the loop's heating and cooling loads as a whole. For each building type, load profiles from the NREL ComStock and ResStock Databases were generated and scaled based on square footages and expected peak thermal loads. [2, 3]

Load profiles were broken down by end use and further filtered into heating loads, cooling loads, refrigeration loads, and "other" non-thermal loads. The graphs below illustrate load profiles for a grocery store and a retail store to demonstrate the difference in peak hours for each. Existing natural gas profiles are shown for the month of January and electric profiles are shown for the month of July. Load profiles for all building types are included in Appendix B.

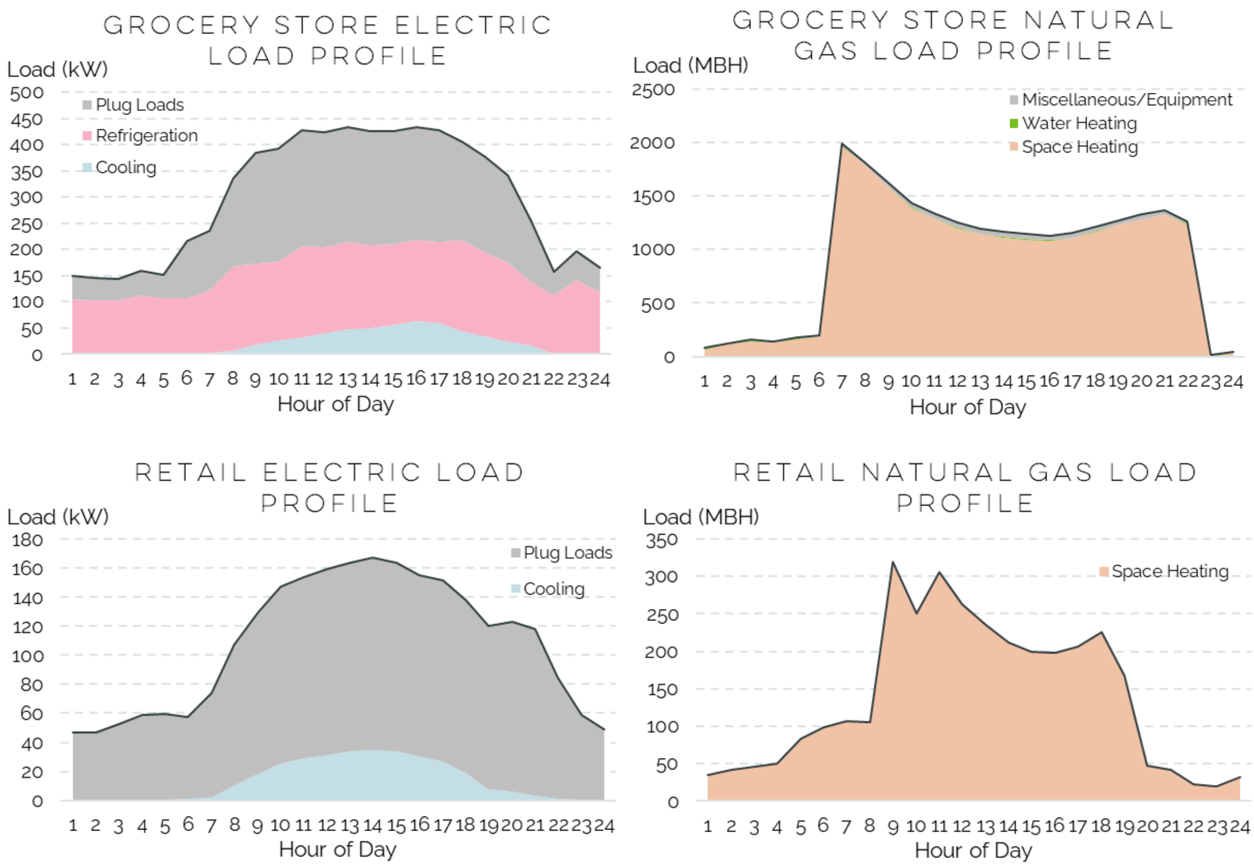


Figure 39: Norwich Site Electric (July) & Natural Gas (January) Load Profiles

Loop Design

Based on the combined thermal loads and site characteristics, a preliminary loop layout was developed, shown in Figure 40. A more detailed site layout is located in Appendix C.

The proposed thermal sources include vertical boreholes drilled to depths of approximately 500 feet beneath the Tops parking lot. Additional parking lots are available on the site if needed. As previously noted, the geology in the Norwich area would suggest that full-depth boreholes of 500 feet would be a cost-effective approach to use at this site. High static water levels have been recorded in water wells near this site which typically indicate good thermal properties for ground heat exchangers.

The preliminary proposed loop configuration is a single-pipe ambient temperature loop with 12" main piping. Small pumping buildings are located throughout the district to house circulation pumps above-ground. Note that the location of these buildings is flexible and can be changed.

Additional parking lots have been highlighted indicating other potential thermal resources to tap into. Future expansion for the loop can be accommodated in all directions along roadways as indicated by stub-outs in several locations.

Detail on the existing HVAC systems is not included in this scoping study. It is expected that the buildings currently use traditional gas-fired heating systems and will need to be converted to water-source heat pump systems.

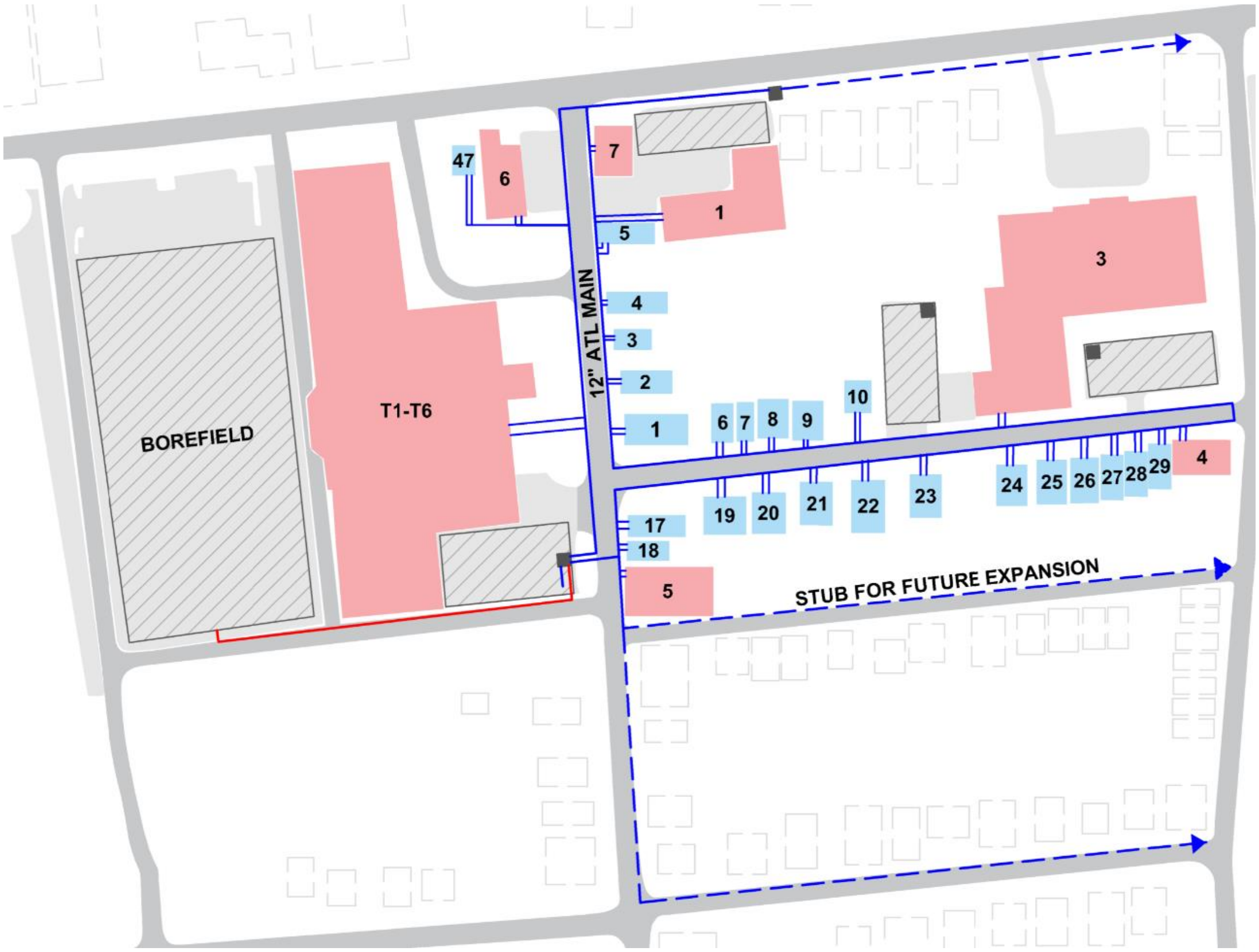


Figure 40: Norwich Preliminary Loop Layout

Energy & Carbon 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 converting the fossil fuel heating systems to electric.

Based on the projected increase in the peak electric load at the site, there is potential for co-location of PV and battery storage to offset strain on the surrounding electric infrastructure. This analysis is outside of the scope of this study but should be included as a part of the engineering design.

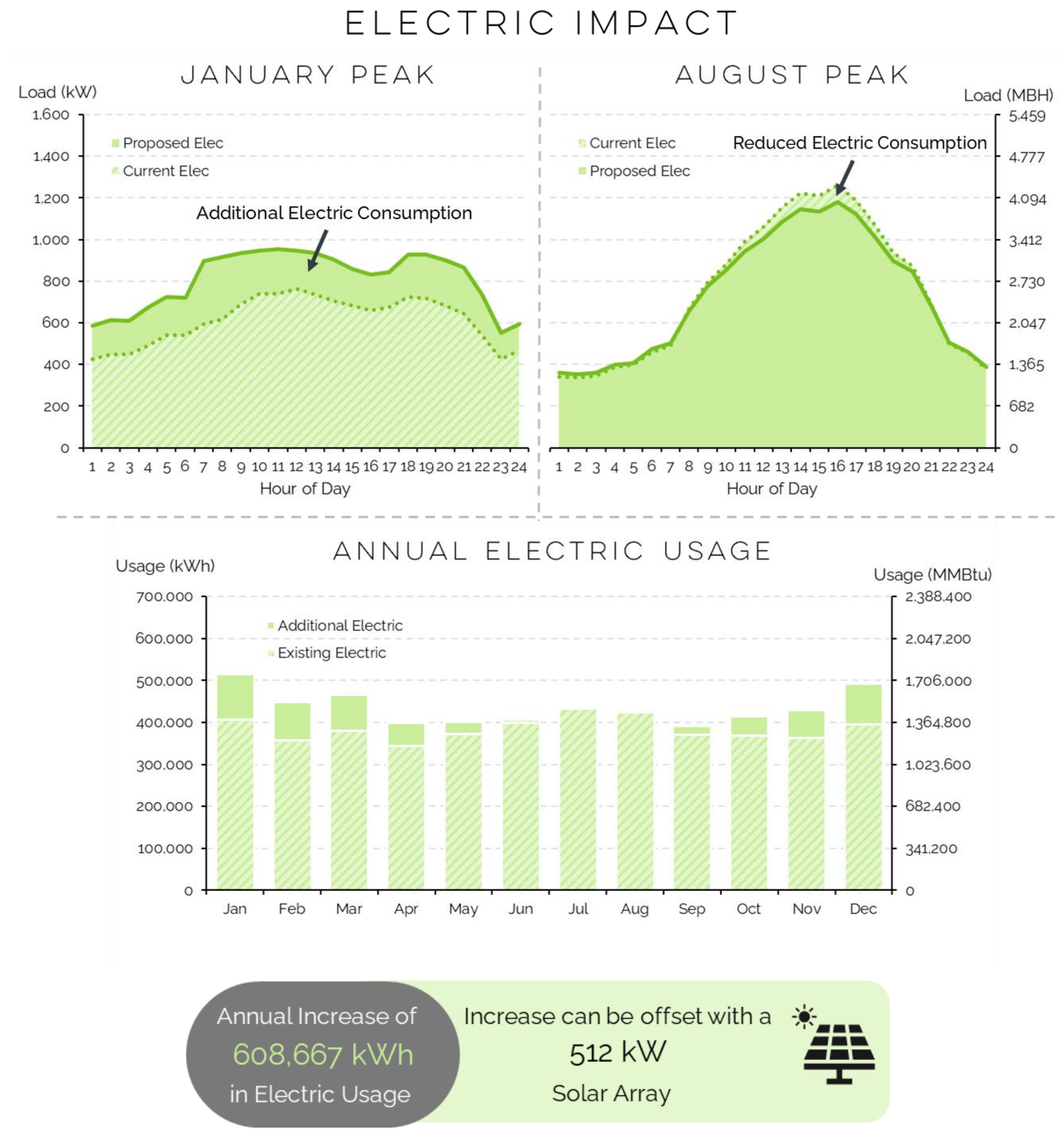


Figure 41: Estimated Electric Impacts at Norwich Site

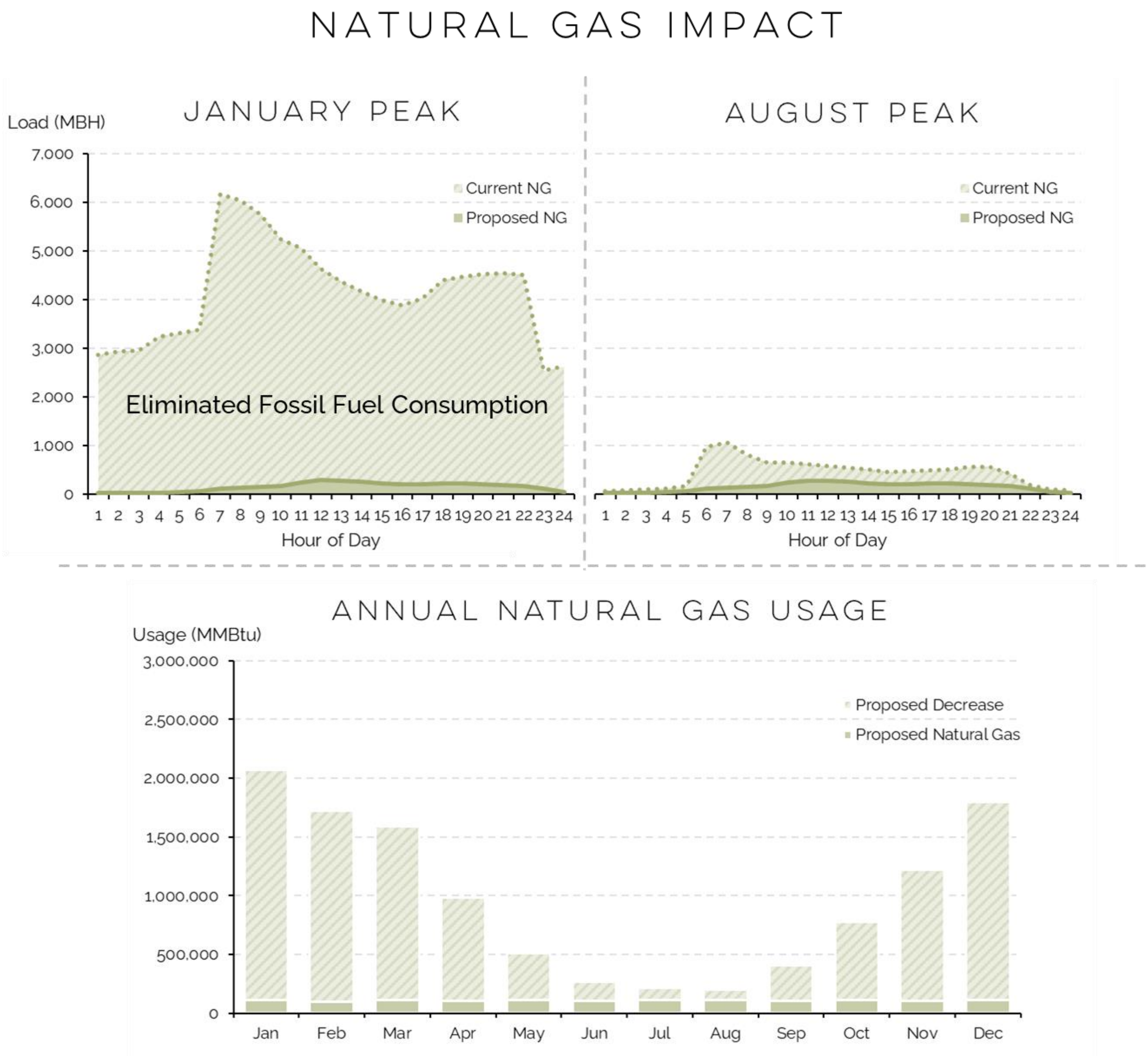


Figure 42: Estimated Natural Gas Impacts at Norwich Site

Based on the calculated annual energy savings the associated annual carbon savings are shown in the figure below. From the offsetting of fossil fuel heating to electric heating 291 metric tons of carbon emissions are estimated to be offset. The graphic below indicates equivalent emissions reductions based on US EPA emissions data.

Figure 43 Estimated Carbon Reduction at Norwich Site

Economic Analysis & Ownership Models

Using other district geothermal pilot projects as the only comparable price point on the market so far, the estimated cost per ton for a utility pilot system in the northeast is estimated to be $30,000 per ton of installed capacity. Understand that large commercial buildings with GSHP systems may come in more in the range of $10,000 per installed ton and the expectation is a broad geothermal utility would achieve economics more in this range after the design and installation becomes more routine. The tables and figures below illustrate the estimated installation costs broken down by major category, in addition to estimated system operation & maintenance costs based on other systems installed throughout the United States.

Norwich Site Estimated Pilot Project Cost

	Estimated Cost
Engineering Design & Permitting	$ 1,602,000
Drilling	$ 2,403,000
Horizontal Piping	$ 4,806,000
HVAC Conversions	$ 6,408,000
General Construction	$ 801,000
Total:	**$ 16,020,000**

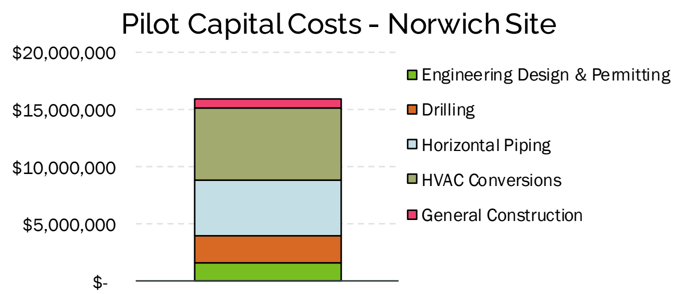


Figure 44: Norwich Site Estimated Capital Costs

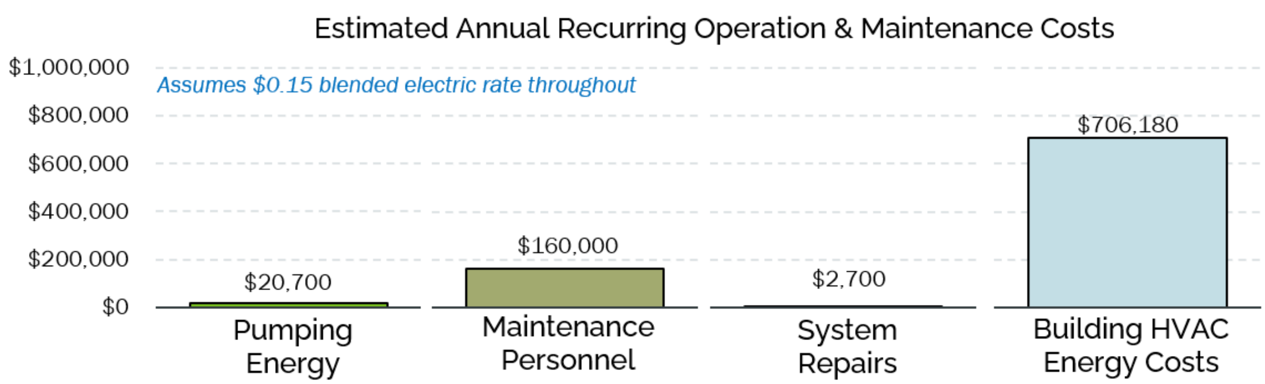


Figure 45: Norwich Site Estimated O&M Costs

SITE 3: ITHACA

BUILDINGS

The Ithaca site consists of (20) non-residential and (32) residential buildings on a city block located in Ithaca, NY. This site has a small grocery store, wastewater treatment plant, and several other small commercial buildings. The proposed thermal resources for this site include shallow boreholes less than 125 feet, wastewater heat recovery, and surface water heat exchanger in the Cayuga Inlet.

Table 6: Ithaca Buildings

#	Building Name	SF	Classification
1	House 1	1,380	Residential
2	House 2	1,138	Residential
3	House 3	1,068	Residential
4	House 4	1,791	Residential
5	House 5	1,774	Residential
6	House 6	1,968	Residential
7	House 7	1,232	Residential
8	House 8	1,784	Residential
9	House 9	1,208	Residential
10	House 10	1,920	Residential
11	House 11	2,110	Residential
12	House 12	5,096	Residential
13	House 13	1,552	Residential
14	House 14	1,480	Residential
15	House 15	2,520	Residential
16	House 16	2,520	Residential
17	House 17	1,480	Residential
18	House 18	1,152	Residential
19-32	House 19-House 32 (all similar to house 19)	31,752	Residential
1	Ithaca DMV	4,705	Office
2	L.A.P. Co., Inc.	3,300	Office
3	Hakacha Restaurant	3,427	Quick Service Restaurant
4	Cornerstone Veterinary Hospital	2,580	Office
5	Krispy Krunchy Chicken	2,150	Quick Service Restaurant
6	Quik Shoppe	2,820	Retail
7	B&W Restaurant Supply Co	10,000	Warehouse
8	Pleasant Valley Electric (Electric Contracting)	2,494	Office
9	Papa Johns	1,302	Quick Service Restaurant
10	Finger Lakes PT and Wellness Center	12,821	Office
11	210 Hancock Apartments	51,593	Midrise Apartment
12	Downtown Ithaca Children's Center	8,866	Office
13	Aldi	17,400	Grocery Store
14	Sciencenter	40,000	Primary School
15	Wastewater Treatment Plant	56,000	Wastewater Treatment
16	Cricket/Chiropractor/Wine Market	5,165	Retail
17	City of Ithaca Water & Sewer Division	8,392	Office
18	Warehouse 1	10,298	Warehouse
19	Warehouse 2	4,448	Warehouse
20	Warehouse 3	10,644	Warehouse

*Estimated Square Footages Based on Building Footprint

Figure 46: Ithaca Site Map

LOAD PROFILES

Based on the buildings included in the scope and their square footages, load profiles were generated for every hour of the year for each building type in order to model the loop's heating and cooling loads as a whole. For each building type, load profiles from the NREL ComStock and ResStock Databases were generated and scaled based on square footages and expected peak thermal loads per facility type. [2, 3]

Load profiles were broken down by end use and further filtered into heating loads, cooling loads, refrigeration loads, and "other" non-thermal loads. The graphs below illustrate load profiles for a restaurant and grocery store to demonstrate the difference in peak hours for each. Existing natural gas profiles are shown for the month of January and electric profiles are shown for the month of July. Load profiles for all building types are included in Appendix B.

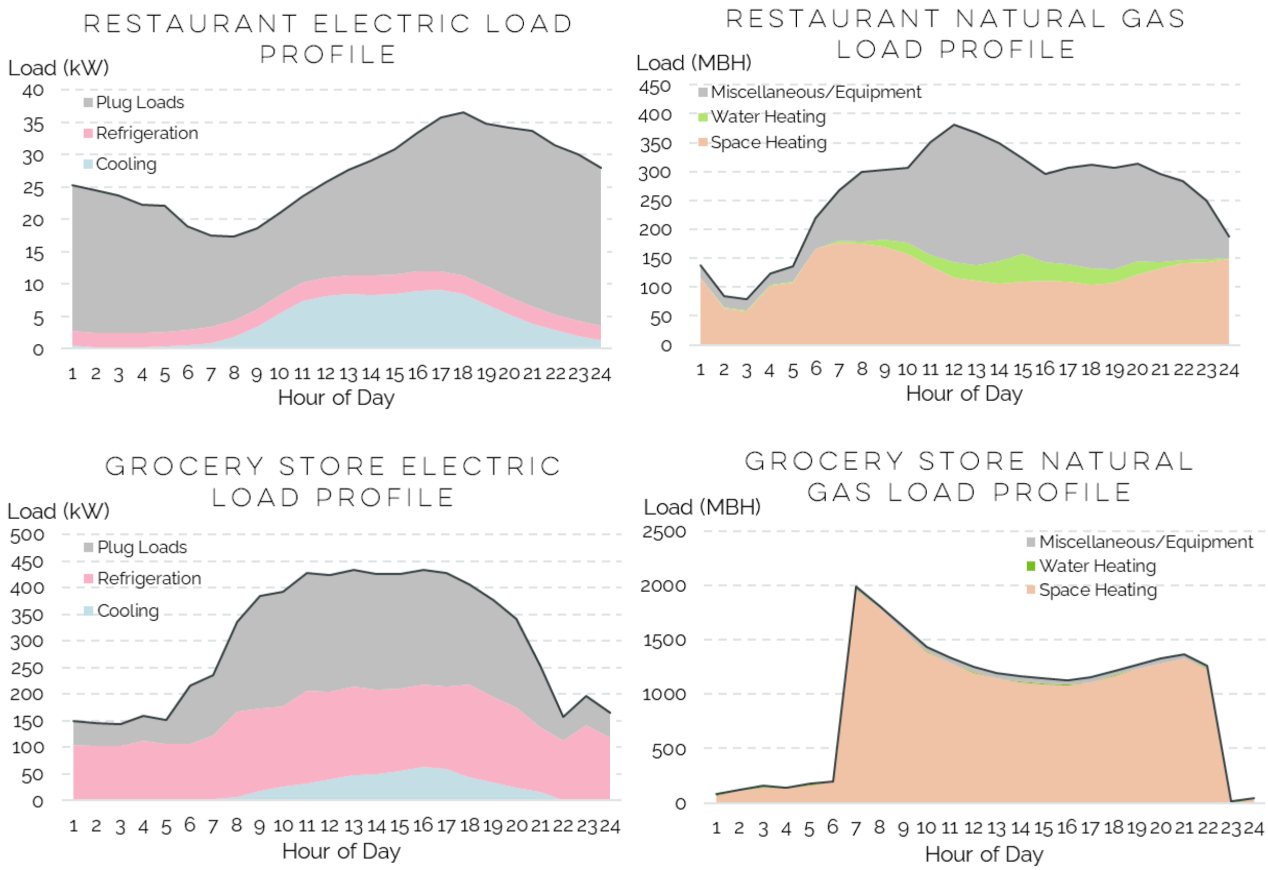


Figure 47: Ithaca Site Electric (July) & Natural Gas (January) Load Profiles

Loop Design

Based on the combined thermal loads and site characteristics, a preliminary loop layout was developed, shown in Figure 48. A more detailed site layout is located in Appendix C.

The proposed thermal sources include vertical boreholes drilled to depths of approximately 125 feet beneath the surface, wastewater heat recovery, and surface water heat recovery from the Cayuga Inlet.

As previously mentioned, the geology in the Ithaca region presents a unique challenge in using the ground as a heat exchanger. Drillers in the area noted that the flat areas in downtown Ithaca are similar to an old lake bottom – consisting of sand, gravel, and clay. Pressurized aquifers at depths of 125-170 feet present a unique challenge in water management and may result in limiting closed loop boreholes between 125 and 225 feet in depth. A networked groundwater system may be a more viable option in this instance to create an open-loop system. This option would require careful study to ensure the protection of ground water and will require collaboration with the City of Ithaca and the NYSDEC.

The preliminary proposed loop configuration is a single-pipe ambient temperature loop with 12" main piping. Small pumping buildings are located throughout the district to house circulation pumps above-ground. Note that the location of these buildings is flexible and can be changed.

Additional parking lots have been highlighted indicating other potential thermal resources to tap into. Future expansion for the loop can be accommodated in all directions along roadways as indicated by stub-outs in several locations.

Not included in this analysis is the nature of the existing HVAC systems at the buildings. It is expected that the buildings currently use traditional gas-fired heating systems and will need to be converted to water-source heat pump systems.

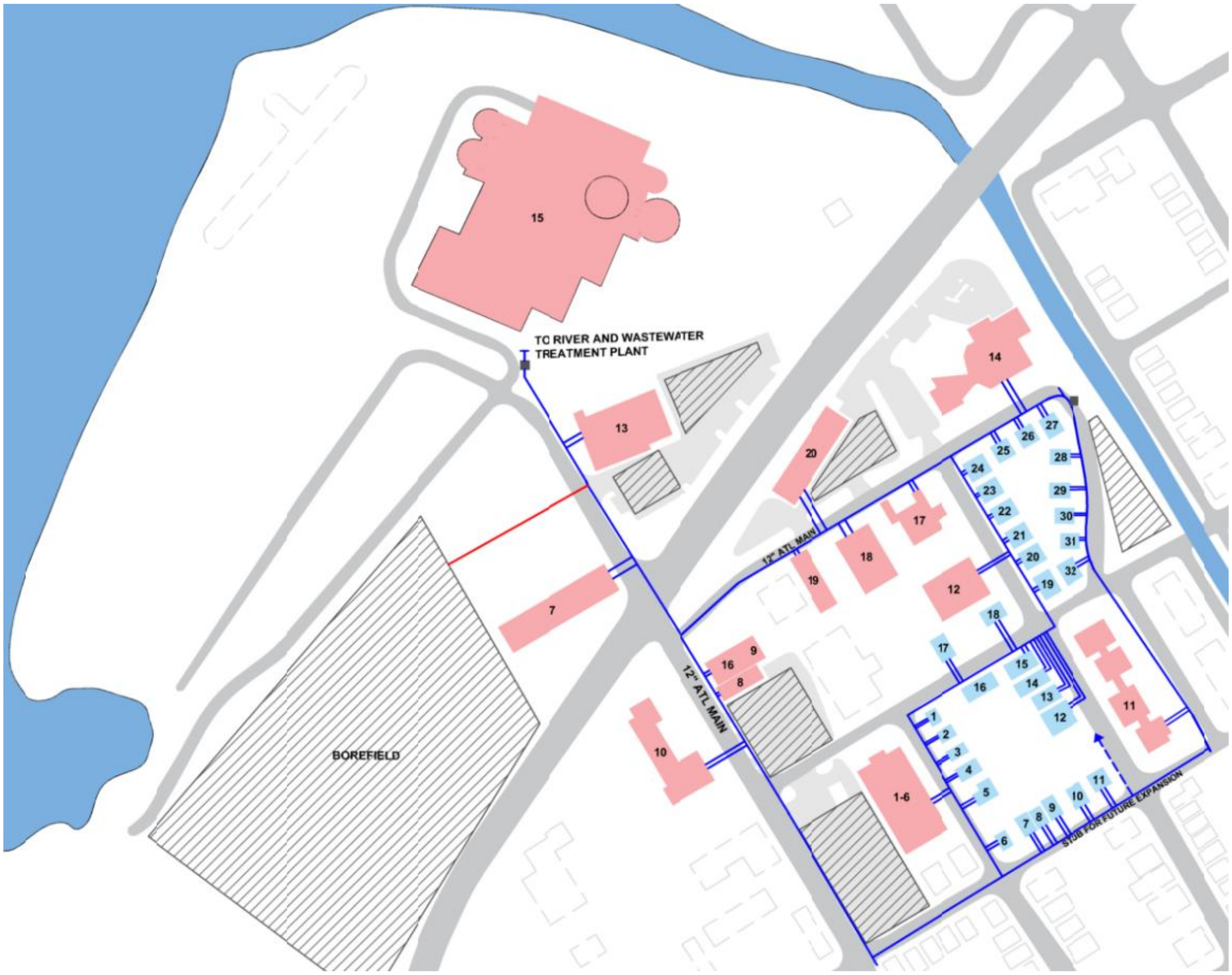


Figure 48: Ithaca Preliminary Loop Layout

ENERGY & CARBON 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 converting the fossil fuel heating systems to electric.

Based on the projected increase in the peak electric load at the site, there is potential for co-location of PV and battery storage to offset strain on the surrounding electric infrastructure. This analysis is outside of the scope of this study but should be included as a part of the engineering design.

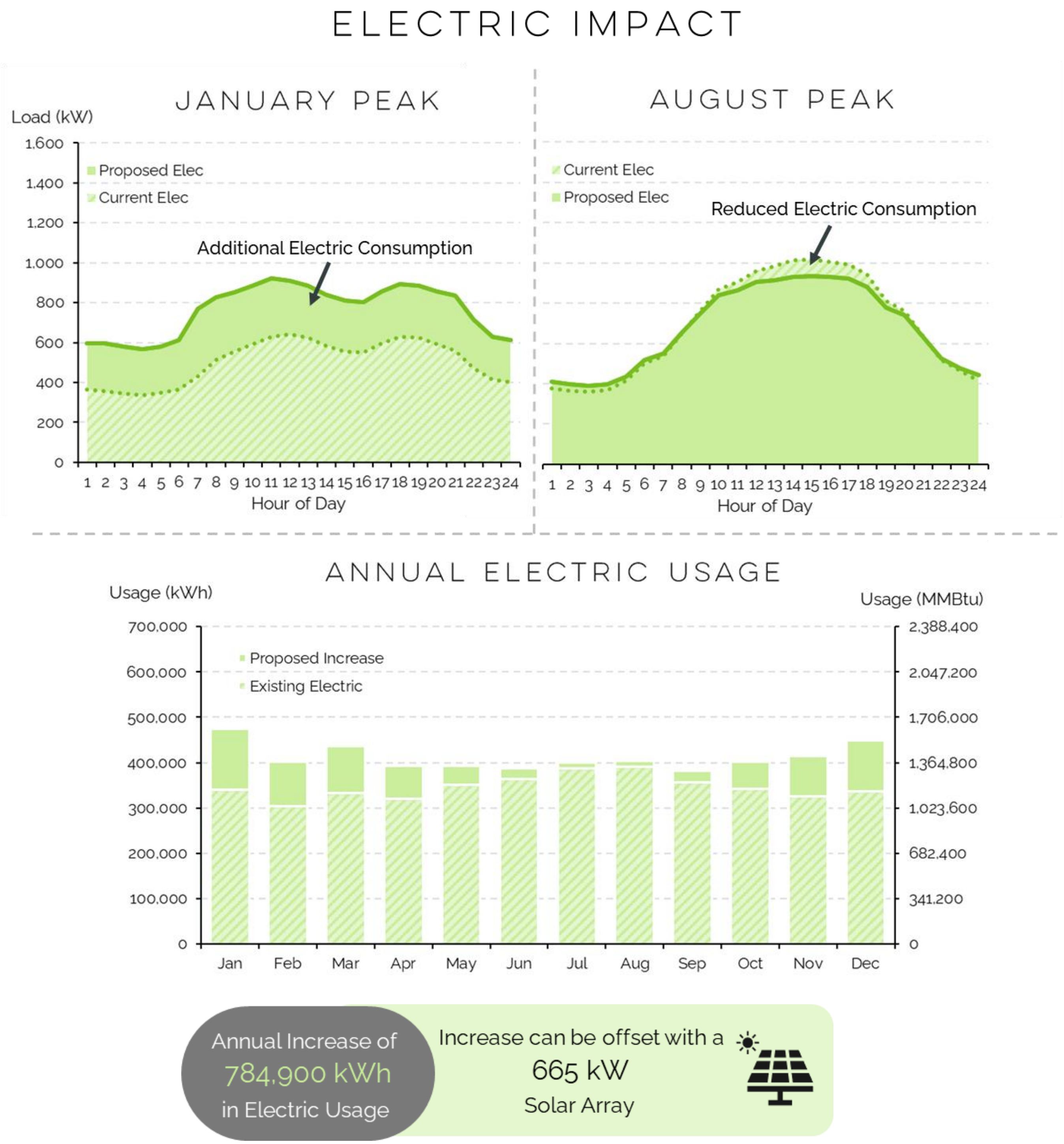


Figure 49: Estimated Electric Impacts at Ithaca Site

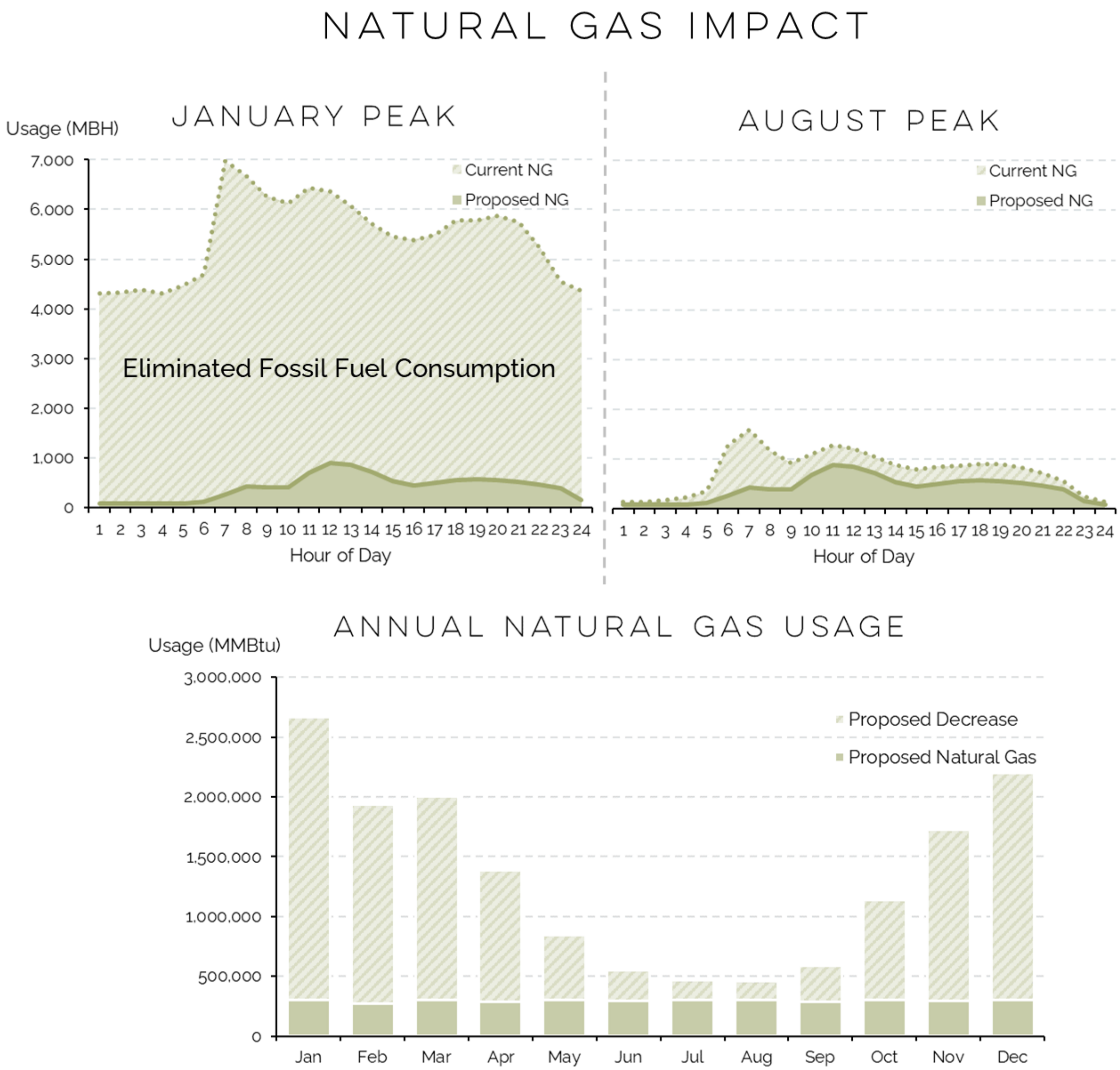


Figure 50: Estimated Natural Gas Impacts at Ithaca Site

Based on the calculated annual energy savings the associated annual carbon savings are shown in the figure below. From the offsetting of fossil fuel heating to electric heating 399 metric tons of carbon emissions are estimated to be offset. The graphic below indicates equivalent emissions reductions based on US EPA emissions data.

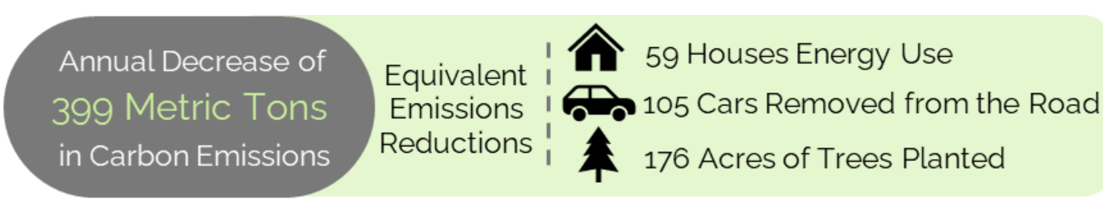


Figure 51: Estimated Carbon Reduction at Ithaca Site

Economic Analysis & Ownership Models

Using other district geothermal pilot projects as the only comparable price point on the market so far, the estimated cost per ton for a utility pilot system in the northeast is estimated to be $30,000 per ton of installed capacity. Understand that large commercial buildings with GSHP systems may come in more in the range of $10,000 per installed ton and the expectation is a broad geothermal utility would achieve economics more in this range after the design and installation becomes more routine. The tables and figures below illustrate the estimated installation costs broken down by major category, in addition to estimated system operation & maintenance costs based on other systems installed throughout the United States.

Ithaca Site Estimated Pilot Project Cost

	Estimated Cost
Engineering Design & Permitting	$ 1,599,000
Drilling	$ 2,398,500
Horizontal Piping	$ 4,797,000
HVAC Conversions	$ 6,396,000
General Construction	$ 799,500
Total:	**$ 15,990,000**

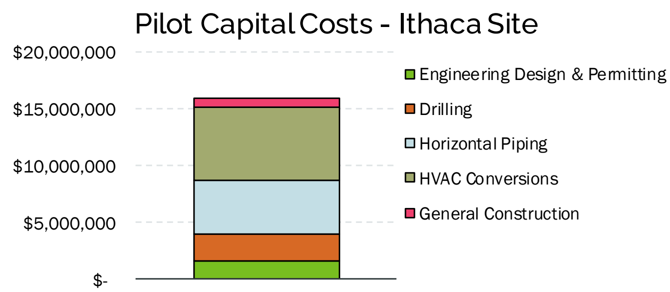


Figure 52: Ithaca Site Estimated Capital Costs

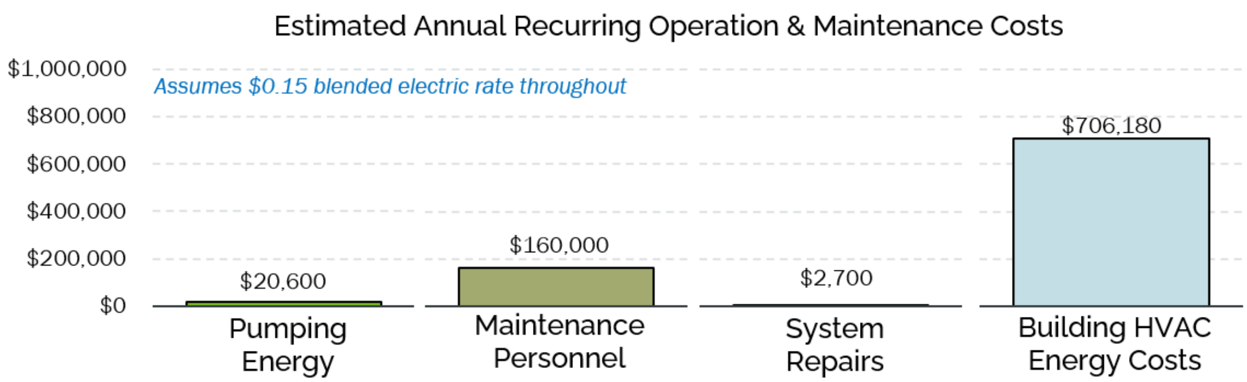


Figure 53: Ithaca Site Estimated O&M Costs

NEXT STEPS

Following the selection of pilot sites, the avenues to pursue the implementation of these systems would be either through the NYSERDA PON 4614 for Community Heat Pump Systems or through the traditional bid process for a detailed feasibility study, engineering design, and construction.

The NYSERDA PON 4614 for Community Heat Pump Systems includes funding for site-specific scoping studies (Category A, funding up to $100,000), site-specific design (Category B, funding up to $500,000), and project implementation (Category C, funding up to $4,000,000). These categories can be bid separately or progressively as projects move through the design process. Awards through NYSERDA under this program are competitive. The typical process for application entails the consultant developing the program application documentation with assistance from the project developer and site owners. [6]

If pursued outside of the NYSERDA avenues, a request for proposal can be issued for a detailed feasibility study, detailed engineering design, and construction. Depending on the procurement process this can be bid separately or together in the same RFP.

A request for proposal should consider including the following aspects:

- Detailed Site-Specific Feasibility Study
  - Characterization of Proposed Site
  - Assessment of Environmental Impacts
  - Preliminary Loop Layout & Design
  - Analysis of Building-Side Integration
  - Energy Modeling of Loop
  - Detailed Economic Modeling & Analysis
- Engineering Design:
  - Final Site and Schematic Review
  - Site Visits & Inspections
  - Geothermal Loop/Boring Design
  - Preliminary & Detailed Network Design
- Permitting
  - Environmental Permitting
  - Right-of-Way (ROW) Permitting / Department of Public Works (DPW) Permitting
  - Traffic Management Plans & Approvals
- Filings with DPS
- Stakeholder & Customer Engagement
- Bidding and Construction Administration
- System Operation Oversight and Technical Support

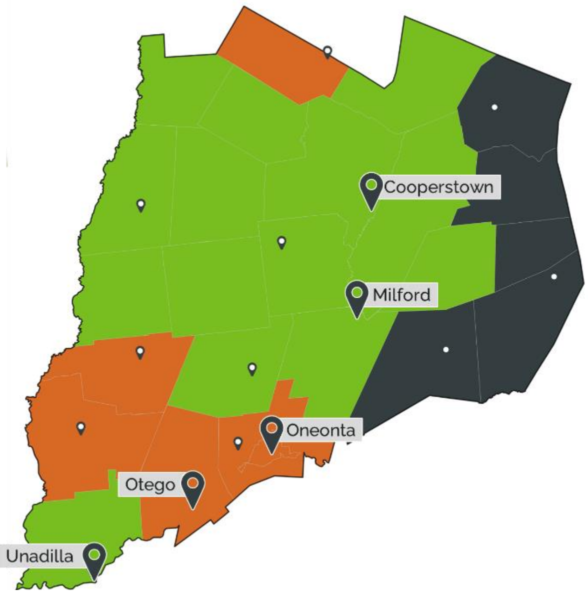
REFERENCES

1. Climate Leadership and Community Protection Act (CLCPA), NY State Senate Bill S6599 (July 18, 2019).
2. National Renewable Energy Laboratory. (2022). *ComStock Analysis Tool.* Retrieved from https://www.nrel.gov/buildings/comstock.html
3. National Renewable Energy Laboratory. (2022). *ResStock Analysis Tool.* Retrieved from https://www.nrel.gov/buildings/resstock.html
4. New York State Division of the Budget. (2022). New York State FY 2023 Executive Budget.
5. New York State Energy Research and Development Authority. (2016). *Utility Energy Registry*. Retrieved from https://utilityregistry.org/app/#/
6. New York State Energy Research and Development Authority. (2022). *Community Heat Pump Systems (PON 4614).* Retrieved from https://portal.nyserda.ny.gov/CORE_Solicitation_Detail_Page?SolicitationId=a0rt0000017lyygAAA
7. NYS Department of Environmental Conservation. (2021). *2021 NYS Greenhouse Gas Emissions Report.*
8. NYSEG and RG&E Joint Proposal, Rate Case 19-E-0378, 19-G-0379, 19-E-0380, 19-G-0381 (State of New York Public Service Commission April 1, 2020).
9. 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.
10. The New York State Museum. (1986). Surficial Geologic Map of New York. Albany, NY.
11. United States Census Bureau. (2010). *Explore Census Data*. Retrieved from https://data.census.gov/cedsci/
12. United States Geological Survey. (2022). Mineral Resources Online Spatial Data. Albany, NY.
13. US Department of Energy. (2022). *Geothermal Heat Pumps.* Retrieved from Energy Saver: https://www.energy.gov/energysaver/geothermal-heat-pumps
14. US Environmental Protection Agency. (2022). *Geothermal Heating and Cooling Technologies.* Retrieved from https://www.epa.gov/rhc/geothermal-heating-and-cooling-technologies
15. New York State Joint Utilities. (2022). *New York State Technical Resource Manual*.
16. Bret, C.E., Tepper, D.H., Goodman, W.M., LoDuca, S.T., ad Eckhert, Bea-Yeh. (1995). Revised Stratigraphy and correlations of the Niagaran Provincial Series (Medina, Clinton, and Lockport Groups) in the Type Area of Weatern New York. U.S. Geological Survey Bulletin 2086, p. 66
17. National Grid Joint Proposal. Rate Case 20-E-0380, 20-G-0381. (State of New York Public Service Commission April 1 2021)

APPENDIX A: SITE SELECTION DETAILED NARRATIVE

OTSEGO COUNTY EVALUATION

Town/City/Village			Candidate Sites	Population	Sq. Mi.	Pop. / Sq. Mi.
1	City of	Oneonta	Boys & Girls Club	13,901	4.4	3,188
2	Village of	Richfield Springs	RS Central Schools	1,264	1.0	1,251
3	Village of	Cooperstown	Price Chopper Plaza	1,852	1.6	1,129
4	Village of	Unadilla	Unitago Elementary	1,050	1.0	1,010
5	Village of	Otego	Otsego Christian Academy	1,010	1.2	871
6	Village of	Laurens		263	0.1	2,023
7	Village of	Milford		415	0.4	988
8	Village of	Cherry Valley		489	0.5	959
9	Village of	Morris		583	0.8	777
10	Village of	Butternuts		399	1.0	399
11	Town of	Oneonta		5,229	32.9	159
12	Town of	Unadilla		4,392	46.3	95
13	Town of	Richfield		2,388	30.9	77
14	Town of	Otsego		3,900	53.9	72
15	Town of	Otego		3,115	45.6	68
16	Town of	Milford		3,044	46.1	66
17	Town of	Laurens		2,424	42.0	58
18	Town of	Hartwick		2,110	40.1	53
19	Town of	Morris		1,878	39.1	48
20	Town of	Worcester		2,220	46.7	48
21	Town of	Edmeston		1,826	44.3	41
22	Town of	Maryland		1,897	52.4	36
23	Town of	Pittsfield		1,366	38.0	36
24	Town of	Middlefield		2,114	63.3	33
25	Town of	Butternuts		1,786	53.8	33
26	Town of	Springfield		1,358	42.9	32
27	Town of	Plainfield		915	29.5	31
28	Town of	Exeter		987	32.1	31
29	Town of	Cherry Valley		1,223	40.4	30
30	Town of	Westford		868	33.9	26
31	Town of	Burlington		1,140	44.9	25
32	Town of	New Lisbon		1,114	44.4	25
33	Town of	Roseboom		711	33.4	21
34	Town of	Decatur		353	20.6	17



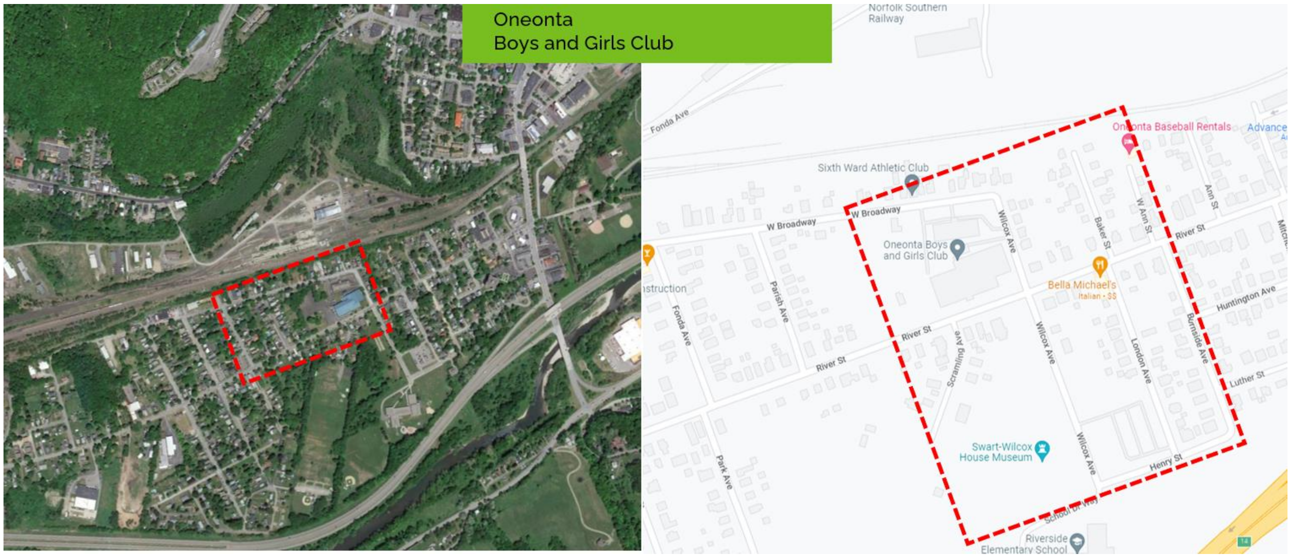
Otsego county includes 24 towns, 9 villages, and one city consisting of a total population of 62,259 according to the most recent census data. A list of the towns and their corresponding population density is listed above.

As apparent from this graph, the townships in Otsego County are sparsely populated and does not lend itself towards a district geothermal configuration.

Looking at more densely populated areas, Otsego County has a city and 9 villages. The 5 largest population centers that have the highest population density are the city of Oneonta, and 4 villages: Richfield Springs, Cooperstown, Unadilla, and Otego, as outlined in the figure above Each of these 5 densest population centers have locations deemed suitable for potential pilot sites.

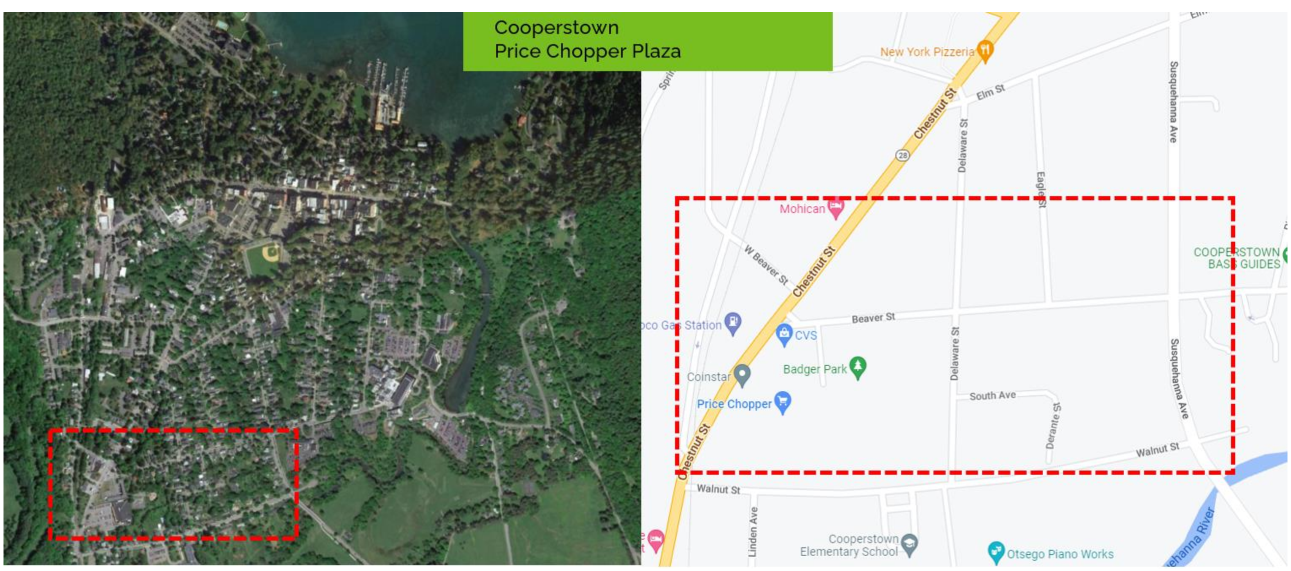
The **Oneonta Boys and Girls Club** was selected as one of the top 10 sites based on the following:

1. Needs air conditioning, but does not currently have it
2. Multiple large, paved lots for geothermal, solar thermal and solar PV renewable energy
3. Located next to railroad line with potential for high-capacity right-of-way solar PV
4. Surrounded by a mix of residential and non-residential buildings
5. Expandable in 180 degrees (2 directions)



The **Price Chopper Plaza** was selected as one of the top 10 sites because it has:

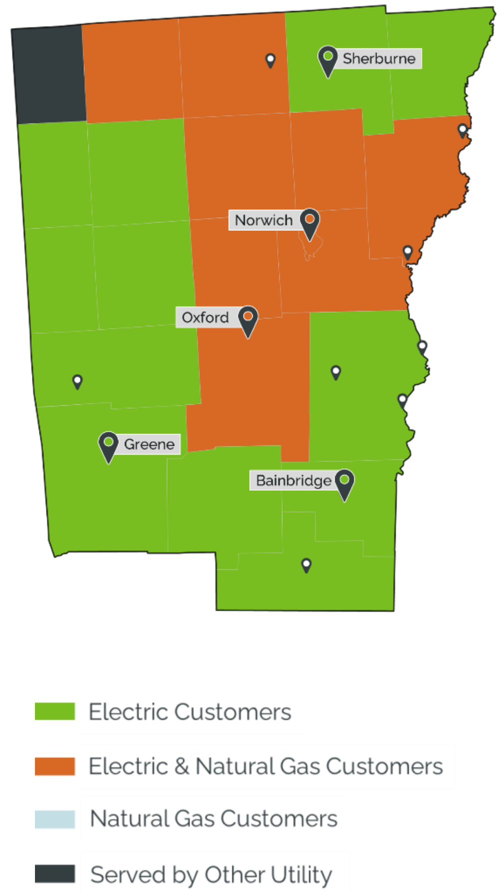
1. High heating and cooling load diversity
2. Several large, paved lots for geothermal, solar thermal and solar PV renewable energy
3. Among a cluster of small businesses and next to a large residential neighborhood
4. Expandable in 270 degrees (3 directions)
5. Highly replicable model for all similar cooling dominant large grocery store sites across the state



CHENANGO COUNTY EVALUATION

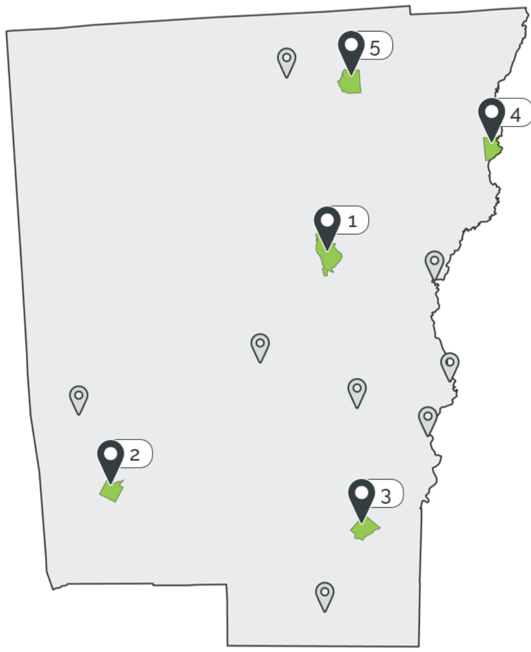
Chenango county includes 21 towns, 8 villages and the City of Norwich. The 5 most densely populated towns are highlighted in the figure below.

Town/City/Village			Candidate Sites	Population	Sq. Mi.	Pop. / Sq. Mi.
1	City of	Norwich	TOPS Plaza	13,901	4.4	3,188
2	Village of	Greene	Town Center	1,264	1.0	1,251
3	Village of	Bainbridge	Scoville-Meno Truck	1,852	1.6	1,129
4	Village of	New Berlin	New York Pizzeria	1,050	1.0	1,010
5	Village of	Sherburne	China King	1,010	1.2	871
6	Village of	Smyrna		263	0.1	2,023
7	Village of	Oxford		415	0.4	988
8	Village of	Earlville		489	0.5	959
9	Village of	Afton		583	0.8	777
10	Village of	Butternuts		399	1.0	399
11	Town of	Bainbridge		3,308	34.3	96
12	Town of	Norwich		3,998	42.0	95
13	Town of	Sherburne		4,048	43.6	93
14	Town of	Greene		5,604	75.1	75
15	Town of	Oxford		3,901	60.1	65
16	Town of	North Norwich		1,783	28.1	63
17	Town of	Afton		2,851	45.8	62
18	Town of	New Berlin		2,682	46.1	58
19	Town of	Guilford		2,922	61.7	47
20	Town of	Plymouth		1,804	42.2	43
21	Town of	Coventry		1,655	48.7	34
22	Town of	Smyrna		1,280	42.1	30
23	Town of	Preston		1,044	34.9	30
24	Town of	Pitcher		803	28.5	28
25	Town of	Otselic		1,054	38.0	28
26	Town of	Smithville		1,330	50.4	26
27	Town of	Columbus		975	37.4	26
28	Town of	McDonough		886	39.0	23
29	Town of	Pharsalia		593	38.8	15
30	Town of	Lincklaen		396	26.3	15
31	Town of	German		370	28.4	13



As apparent from this graph, the townships in Chenango County are sparsely populated and does not lend itself towards a district geothermal configuration.

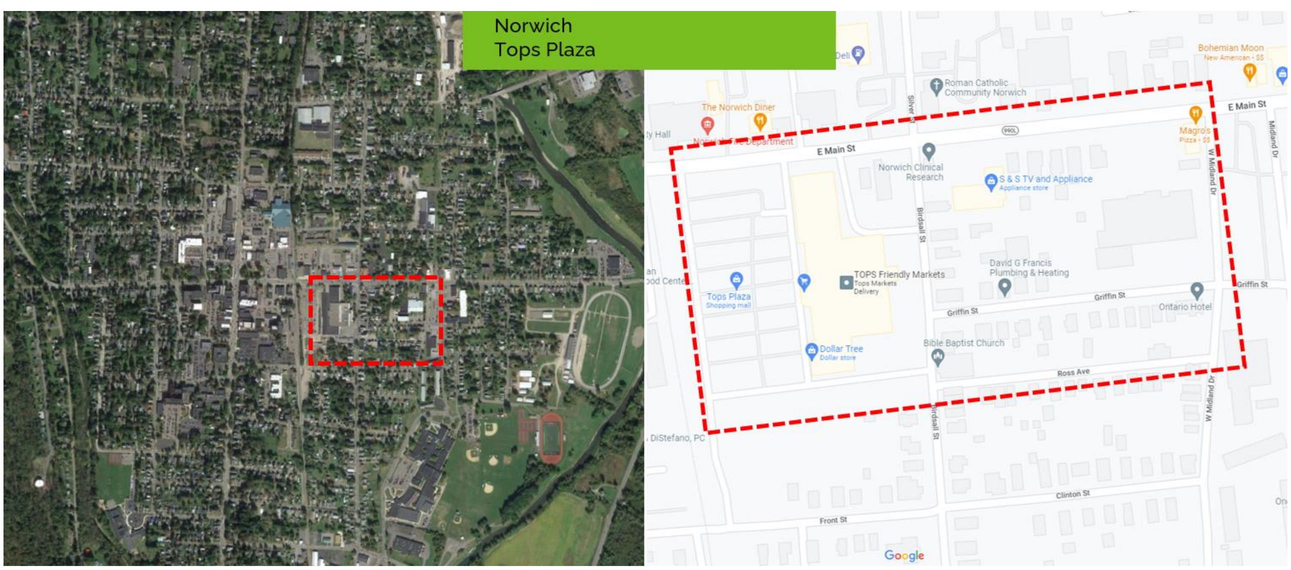
Looking at more densely populated areas, Chenango County has a city and 8 villages. The 5 densest population centers are the city of Norwich, and 4 villages: Greene, Bainbridge, New Berlin, and Sherburne, as outlined in the image above. Each of these 5 densest population centers have locations deemed suitable for potential pilot sites.



	City / Villages	Candidate Sites	Pop / Sq. Mile
1	City of Norwich	Tops Plaza	3,392
2	Greene	Town Center	1,477
3	Bainbridge	Scoville-Meno Truck	1,034
4	New Berlin	New York Pizzeria	961
5	Sherburne	China King	899

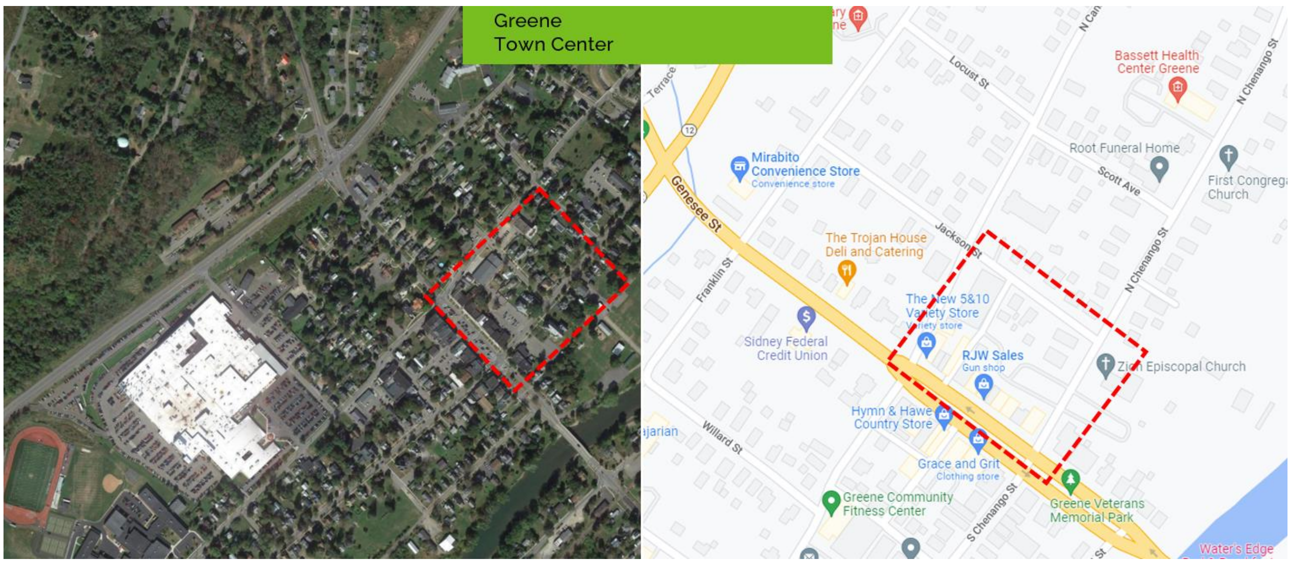
The **TOPS Plaza** was selected as one of the top 10 sites as a result of the following characteristics:

1. High heating and cooling load diversity
2. A 2 acre and several smaller paved lots for geothermal, solar thermal and solar PV renewable energy
3. Diverse mix of residential and non-residential buildings
4. Expandable in all directions
5. Highly replicable model for most cooling-dominant grocery stores throughout the state



The **Greene Town Center** was also selected as one of the top 10 sites. It includes:

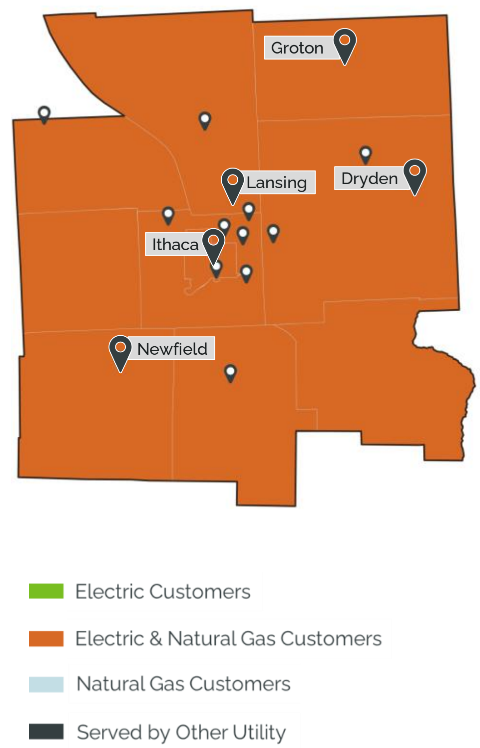
1. Mixed use commercial street adjacent to a residential area
2. Multiple paved lots with potential for geothermal, solar thermal and solar PV renewable energy
3. Chenango River as a supplemental thermal energy exchange source
4. Expandable in all directions,
5. Replicable model for small towns across the state



Tompkins County Evaluation

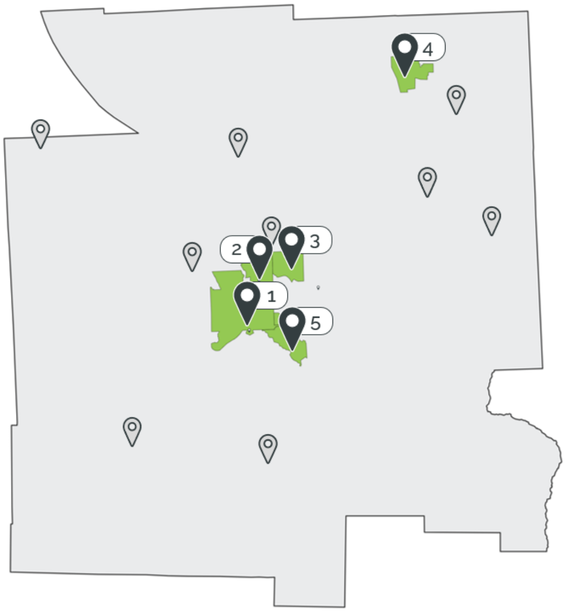
Tompkins county includes 9 towns, 9 villages, and the City of Ithaca – totaling a population of 101,5654 according to 2010 census data. The 5 densest population towns are highlighted in the figure below.

	Town/City/Village		Candidate Sites	Population	Sq. Mi.	Pop. / Sq. Mi.
1	City of	Ithaca	Southside Ithaca	30,014	5	5,568
2			South Meadow Square			
3			Dept Motor Vehicles			
4			Purity Ice Cream Area			
5	Village of	Cayuga Heights	First Congresional Church	3,729	2	2,107
6	Village of	Northeast Ithaca	TST BOCES/ Northest Elementary	2,655	2	1,770
7	Village of	Groton	Groton Elementary	2,363	2	1,358
8	Village of	East Ithaca	East Hill Plaza	2,231	2	1,312
9	Village of	Trumansburg		1,797	1	1,293
10	Village of	South Hill	Ithaca College	6,673	6	1,131
11	Town of	Dryden		1,890	2	1,074
12	Town of	Lansing	Shops at Ithaca	3,529	5	766
13	Town of	Ithaca	Northwest Ithaca	1,115	3	384
14	Town of	Newfield	Newfield	759	1	633
15	Town of	Ithaca	Forest Home	572	0	1,907
16	Town of	Dryden	Freeville	520	1	491
17	Town of	Ithaca		19,930	29	689
18	Town of	Lansing		11,033	60	182
19	Town of	Dryden		14,435	94	154
20	Town of	Ulysses		4,900	33	149
21	Town of	Groton		5,950	49	120
22	Town of	Enfield		3,512	37	96
23	Town of	Newfield		5,179	59	88
24	Town of	Danby		3,329	54	62
25	Town of	Caroline		3,282	55	60



Consistent with the other counties, the villages in Tompkins County are less densely populated and do not lend themselves well to district geothermal configurations.

Looking at more densely populated areas, Tompkins County has a city and 9 villages. The 5 densest population centers are the city of Ithaca, and 4 villages: Cayuga Heights, Northeast Ithaca, Groton, and East Ithaca, as outlined in the figure above. Each of these 5 densest population centers have locations deemed suitable for potential pilot sites., including Ithaca that has four potential pilot sites.

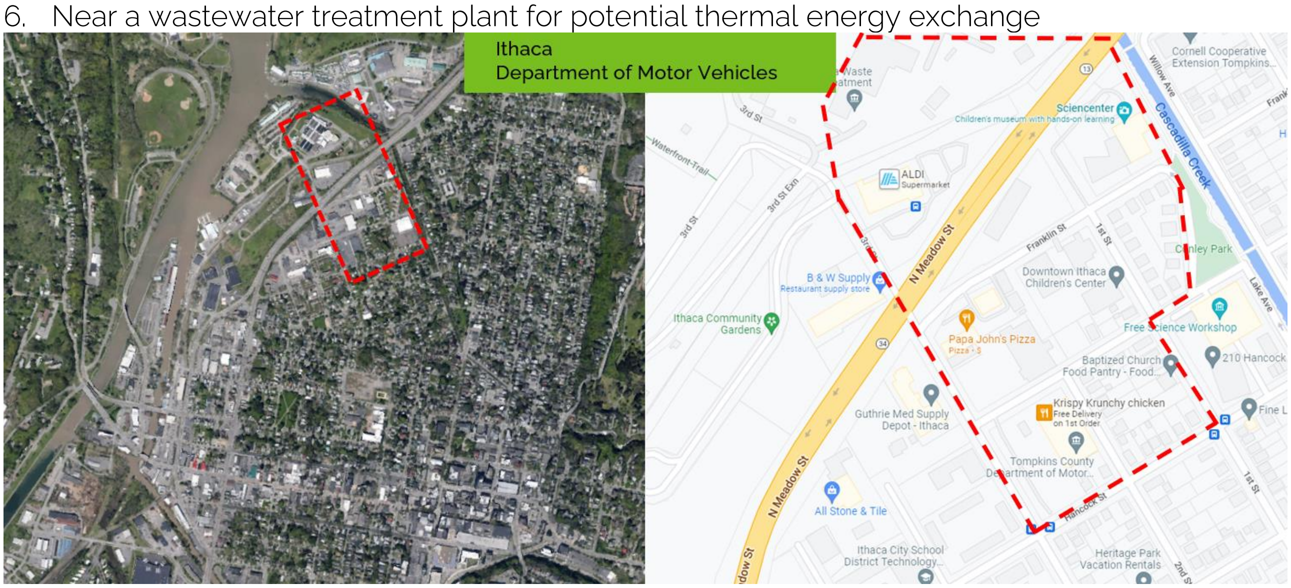


	City / Villages	Candidate Sites	Pop / Sq. Mile
1	City of Ithaca	Southside Ithaca	5,568
1	City of Ithaca	South Meadow Square	
1	City of Ithaca	Dept. Motor Vehicles	
1	City of Ithaca	Purity Ice Cream Area	
2	Cayuga Heights	First Congressional Church	2,107
3	Northeast Ithaca	TST BOCES / Northeast Elementary	1,770
4	Groton	Groton Elementary	1,358
5	East Ithaca	East Hill Plaza	1,312

Eight locations deemed suitable for geothermal district systems were identified as listed in the figure above.

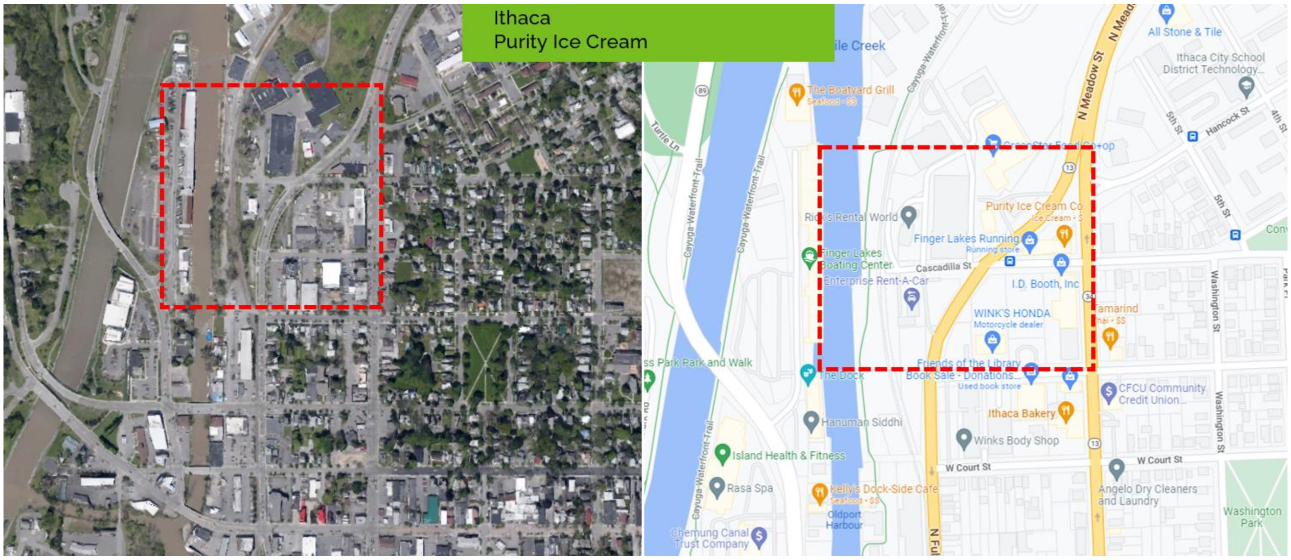
The **Department of Motor Vehicles** area was selected as one of the top 10 sites based on the following:

1. High heating and cooling load diversity
2. Five distributed paved lots for geothermal, solar thermal and solar PV renewable energy
3. Diverse mix of residential and non-residential buildings
4. Expandable in three directions
5. Highly replicable model for all similar cooling dominant large grocery store sites across the state
6. Near a wastewater treatment plant for potential thermal energy exchange



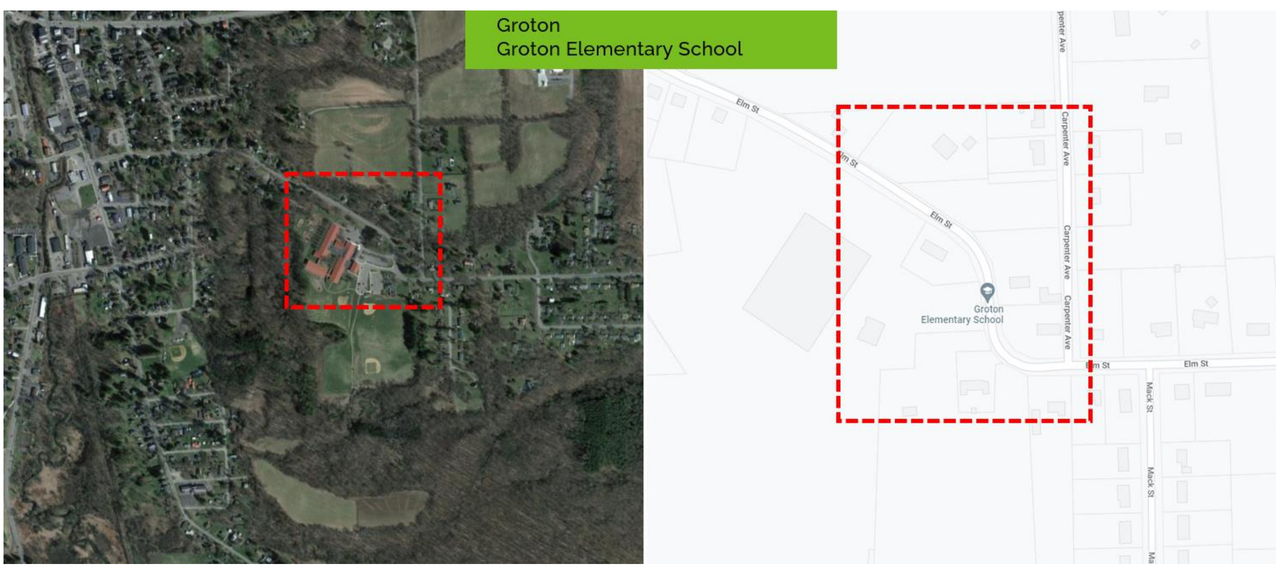
The **Purity Ice Cream** area was also selected as one of the top 10 sites. It includes:

1. Mixed use commercial area adjacent to a residential area
2. High heating and cooling load diversity
3. Multiple distributed paved lots for geothermal, solar thermal and solar PV renewable energy
4. Six Mile Creek as a potential supplemental thermal energy exchange source
5. Expandable in three directions



Groton Elementary School was selected as one of the top 10 sites due to the following:

1. Includes multiple inter-connected school wings adjacent to residential community it serves
2. Multiple large, paved lots for geothermal, solar thermal and solar PV renewable energy
3. Many of the residential buildings have south-facing rooftops for supplemental PV
4. Replicable example of rural community elementary schools

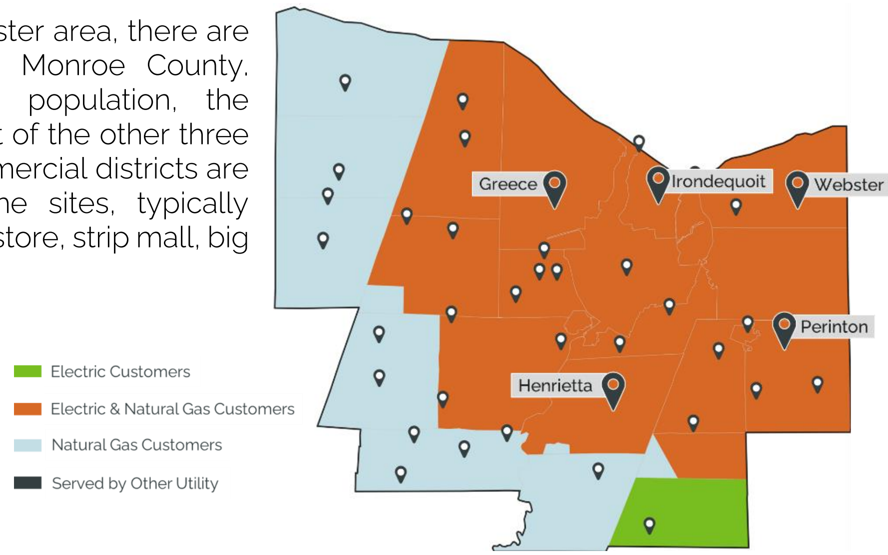


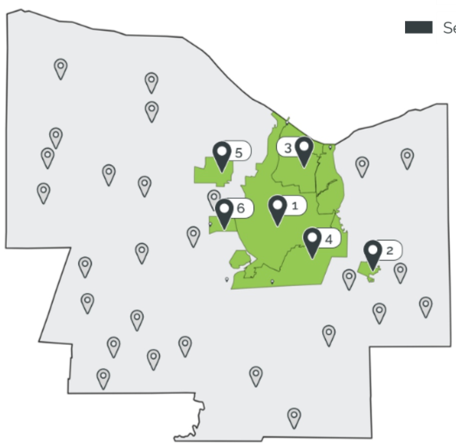
Monroe County Towns Evaluation

Monroe county with a population of approximately 760,000 is unique among the 4 counties in this study. The city of Rochester is the 3rd largest city in New York State with a population of about 210,000. Only Buffalo (250,000) and New York City (greater than 8 million) are larger. Twenty towns make up the remaining 550,000 population. The 5 densest population towns are highlighted in the figure below.

	Town/City/Village	Candidate Sites	Population	Sq. Mi.	Pop. / Sq. Mi.
1	Town of East Rochester	Hollycake House/Public Library	6,587	1	4,971
2	Town of Irondequoit	East Irondeqouit - Wegman's	51,692	15	3,446
3	Town of Brighton	Brighton Metro Park, MCC, Rustic Village, Gray's Iceplex	36,609	15	2,375
4	Town of Greece	Mall at Greece Ridge			
5	Town of Greece	Lowes Plaza	96,095	48	2,022
6	Town of Gates	Wegmans	28,400	15	1,868
7	Town of Perinton	Rochester Ice Center			
8	Town of Perinton	Wegmans	46,462	34	1,359
9	Town of Webster	Xerox Campus	42,641	34	1,272
10	Town of Pittsford	Wegmans	29,405	23	1,268
11	Town of Henrietta	Marketplace Mall			
12	Town of Henrietta	The Dome Arena	42,581	35	1,205
13	Town of Henrietta	Crane Elementary School	42,581	35	1,205
14	Town of Penfield	Wegmans/Target Plaza	36,242	37	974
15	Town of Chili	Wegmans Corporate Office	28,625	39	725
16	Town of Ogden	BOCES	19,856	36	544
17	Town of Sweden	Brockport Corners Mall	14,175	34	421
18	Town of Parma	Tops Markets	15,633	42	372
19	Town of Mendon		9,152	39	232
20	Town of Hamlin	Tops/Krony's Pizza	9,045	43	208
21	Town of Clarkson		6,736	33	203
22	Town of Riga		5,590	35	160
23	Town of Wheatland	Cooper Vision - Scottsville	4,775	30	157
24	Town of Rush		3,478	30	115

Due to the size of the Rochester area, there are many feasible sites across Monroe County. Despite the much higher population, the population density is like that of the other three counties. Concentrated commercial districts are at the core of most of the sites, typically anchored by a large grocery store, strip mall, big box store, or mall.

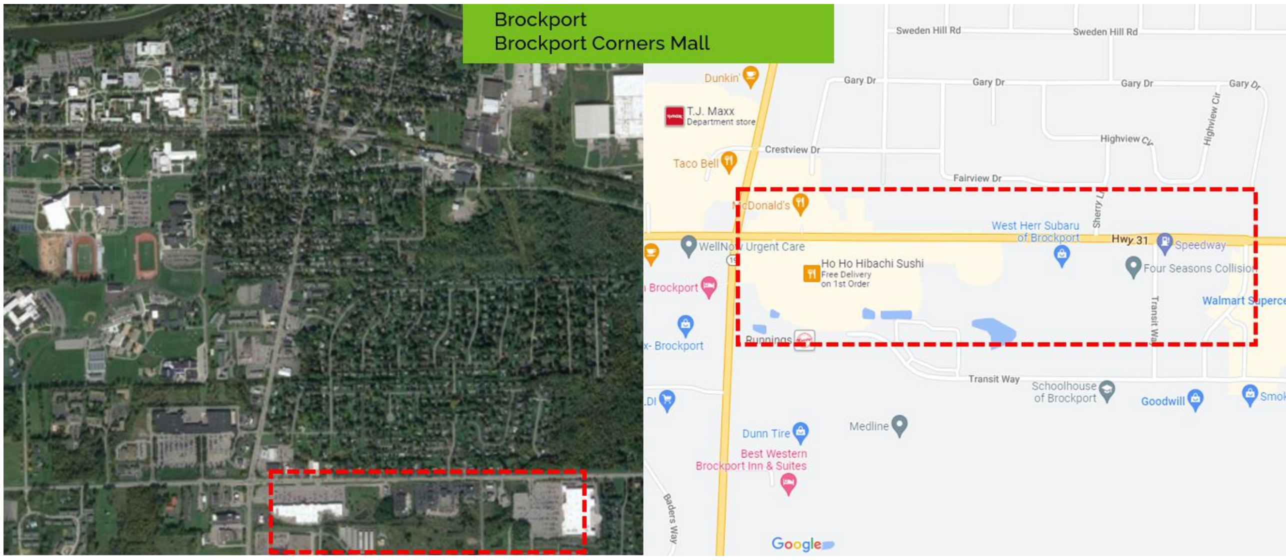




	Town / City / Villages	Candidate Sites	Population	Pop / Sq. Mile	Sq Mile
1	City of Rochester	-	210,565	5,885	35.78
2	Town of East Richester	Hollycake House/Public Library	6,587	4,971	1.33
3	Town of Irondequoit	East Irondequoit - Wegman's	51,692	3,446	15.00
4	Town of Brighton	Brighton Metro Park, MCC, Rustic Village, Gray's Iceplex	36,609	2,375	15.42
5	Town of Greece	Wegmans/ Mall at Greece Ridge	96,095	2,000	48.00
6	Town of Gates	Wegmans			

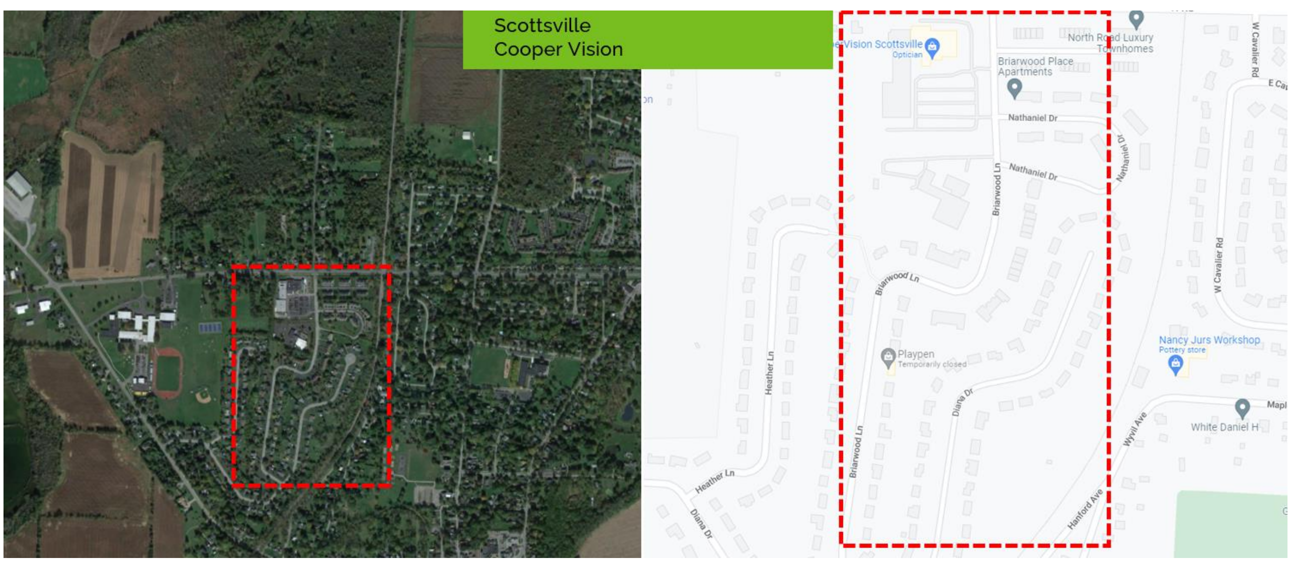
The **Brockport Corners Mall** area in Sweden was selected as one of the top 10 sites because it has:

1. Several commercial buildings next to a residential community
2. A larger group of commercial buildings across the street
3. Multiple distributed paved lots for geothermal, solar thermal and solar PV renewable energy
4. A diverse mix of residential and non-residential buildings
5. Can be expanded in all directions
6. Is a replicable model for small mixed-use communities



The **CooperVision** area in Scottsville was selected as one of the top 10 sites because it:

1. Has two manufacturing sites: CooperVision that makes contact lens, and Heavy Industries that makes ceramics products
2. One large and two smaller paved lots for geothermal, solar thermal and solar PV renewable energy
3. Part of a community consisting of single-family homes and multiple apartment complexes
4. Can be expanded in all directions
5. Is a replicable model for similar rural mixed-use communities



Monroe County City of Rochester Evaluation

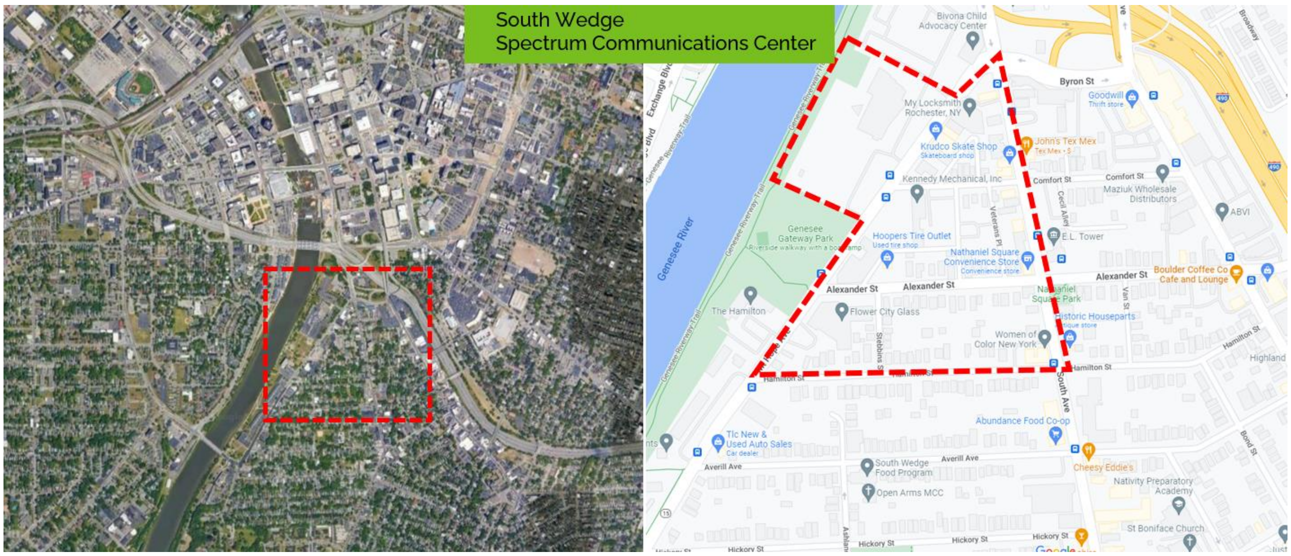
All ten downtown Rochester neighborhoods are deemed suitable for geothermal district systems. The combination of dense commercial buildings with numerous cooling dominant high-rises combined with a high ratio of paved lots to buildings makes this possible. While a few of the neighborhoods might not have quite enough geothermal energy potential, adjacent neighborhoods will have enough to share.

Twelve neighborhoods surrounding the downtown area were evaluated and deemed feasible for geothermal district systems. While it may not be feasible to do 100% of each neighborhood, in most cases there is sufficient commercial / residential mix and space for geothermal energy access to support converting greater than 50 to 75% of the buildings. Due to the large cooling loads associated with the high-rise buildings, the focus for the pilot projects was turned towards sites that had a diverse portfolio of buildings that fit within the target pilot project budget.

#	County	Towns	City / Neighborhoods	Population	Pop / Sq Mi	SqMi
	Monroe	City of Rochester		210,565	5,885	35.78
1	Monroe	Rochester - DT	Saint Paul Quarters	729	13,755	0.053
2	Monroe	Rochester - DT	Convention	176	6,769	0.026
3	Monroe	Rochester - DT	Manhattan Square	200	6,667	0.03
4	Monroe	Rochester - DT	Four Corners	817	5,713	0.143
5	Monroe	Rochester - DT	Grove Place	287	5,627	0.051
6	Monroe	Rochester - DT	Cascade	359	5,439	0.066
7	Monroe	Rochester - DT	East End	610	5,259	0.116
8	Monroe	Rochester - DT	St. Joseph's Park	117	3,900	0.03
9	Monroe	Rochester - DT	Washington Square	300	3,659	0.082
10	Monroe	Rochester - DT	Midtown	150	3,000	0.05
1	Monroe	Rochester	Beechwood	10,189	16,982	0.6
2	Monroe	Rochester	Neighborhood of the Arts	3,497	11,281	0.31
3	Monroe	Rochester	Group 14621	38,693	9,437	4.1
4	Monroe	Rochester	South Wedge	3,406	7,671	0.444
5	Monroe	Rochester	Marketview Heights	4,131	7,351	0.562
6	Monroe	Rochester	Corn Hill	2,460	7,288	0.34
7	Monroe	Rochester	19th Ward	18,093	7,237	2.5
8	Monroe	Rochester	Lyell-Otis	12,694	6,752	1.88
9	Monroe	Rochester	Upper Falls	6,838	5,946	1.15
10	Monroe	Rochester	Edgerton	7,051	5,876	1.2
11	Monroe	Rochester	Southwedge	3,406	5,805	0.59
12	Monroe	Rochester	Maplewood (10th Ward)	17,663	4,813	3.67

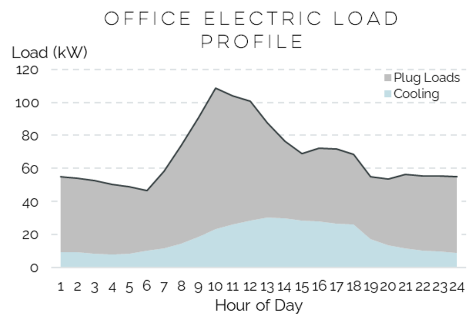
The **Spectrum Communications Center** area in the top portion of the South Wedge neighborhood triangle was selected as one of the top 10 sites because it has:

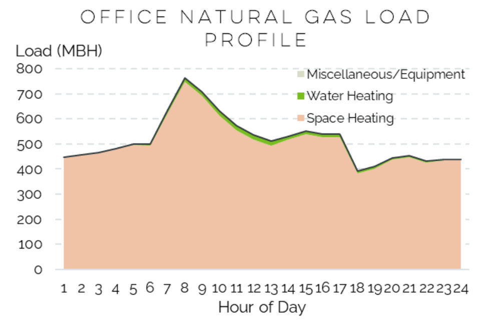
1. High heating and cooling load diversity
2. Three significant size paved lots for geothermal, solar thermal and solar PV renewable energy
3. A diverse mix of residential and non-residential buildings
4. Access to the Genesee River as a source of thermal energy exchange
5. Can be expanded in three directions
6. Is a replicable model for a riverside community

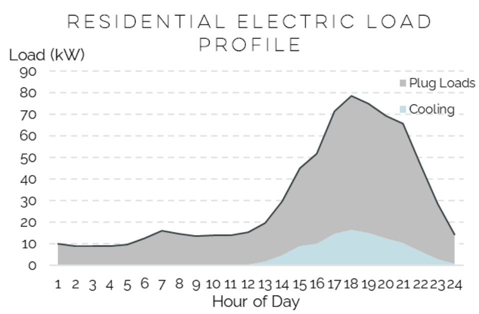


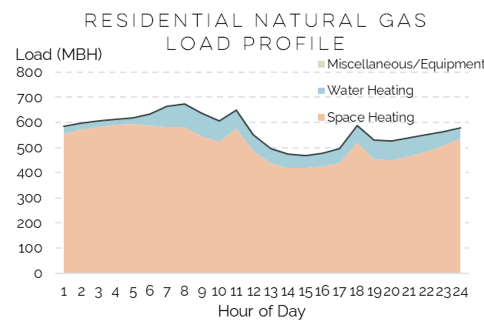
APPENDIX B: BUILDING LOAD PROFILES

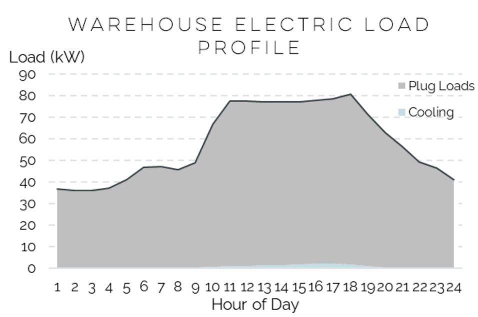
The following graphs indicate electric and natural gas load profiles used for modeling of existing buildings. 8760 data for each building classification from the NREL ComStock and ResStock Analysis Databases. End uses were separated into space heating, water heating, space cooling and "other" for the purpose of this analysis. Load profiles shown below are averages for the month of January for natural gas (heating) and for the month of July for electric (cooling). [2, 3]

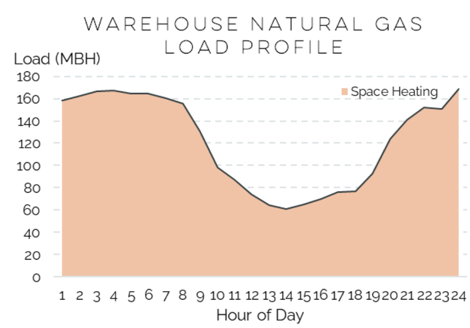


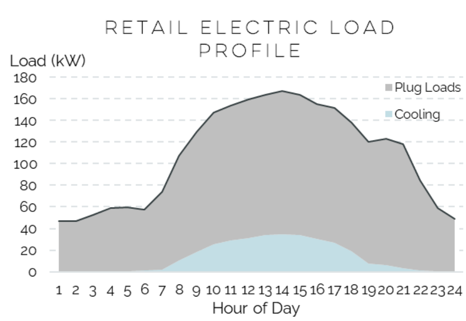


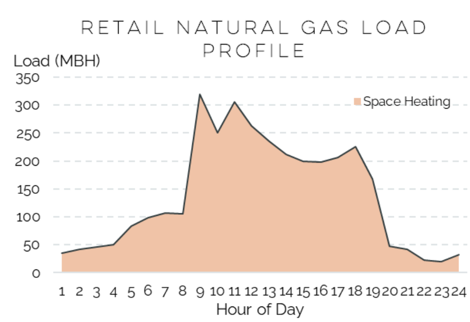


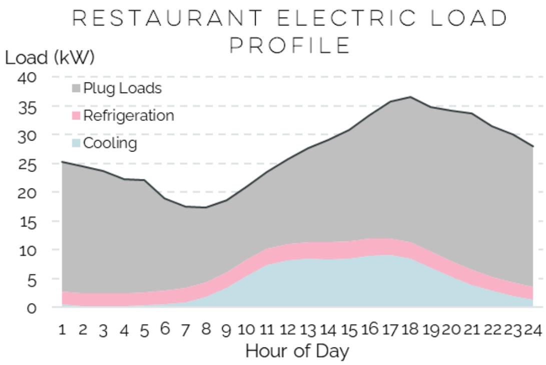


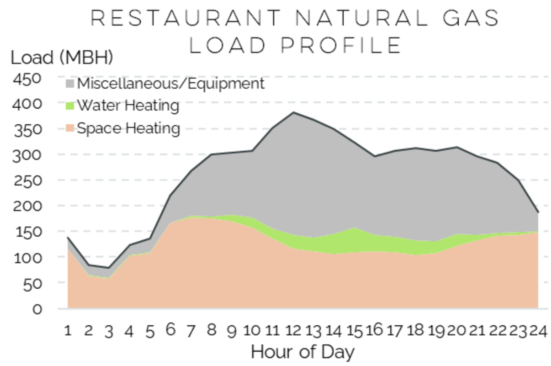


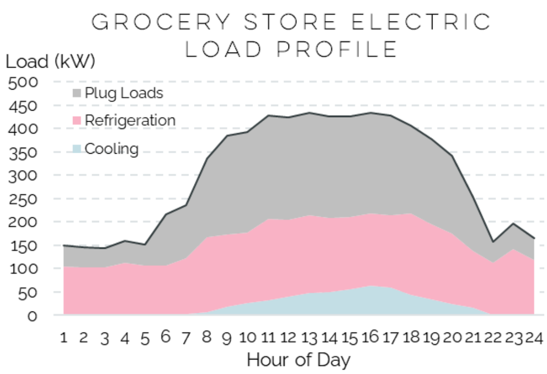


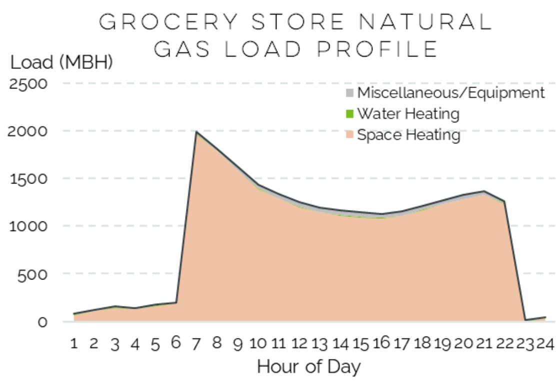


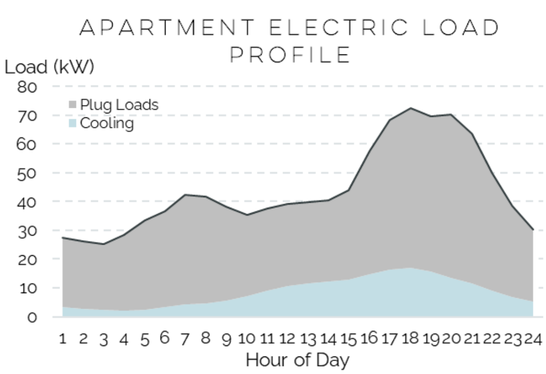


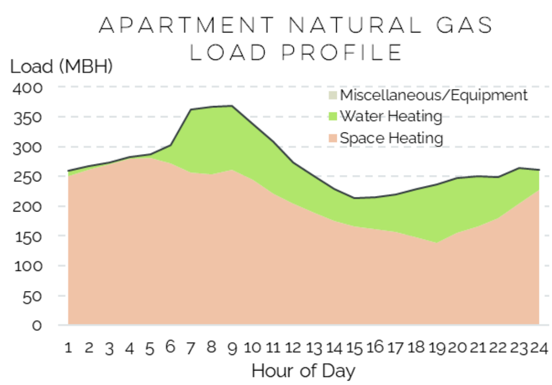

RESTAURANT ELECTRIC LOAD PROFILE
Load (kW)
Plug Loads
Refrigeration
Cooling
Hour of Day

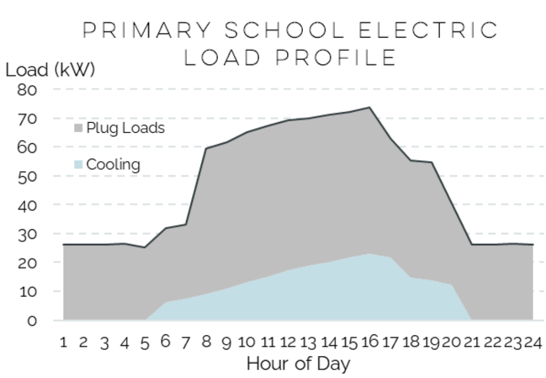

RESTAURANT NATURAL GAS LOAD PROFILE
Load (MBH)
Miscellaneous/Equipment
Water Heating
Space Heating
Hour of Day

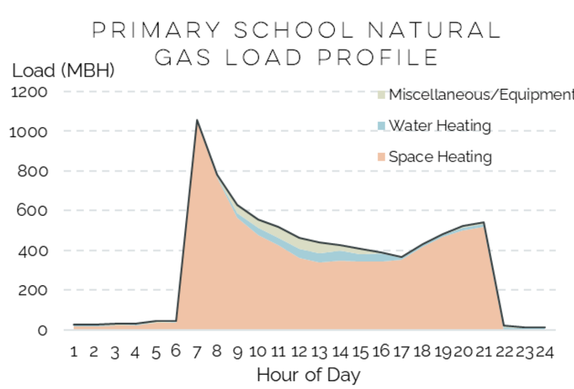

GROCERY STORE ELECTRIC LOAD PROFILE
Load (kW)
Plug Loads
Refrigeration
Cooling
Hour of Day


GROCERY STORE NATURAL GAS LOAD PROFILE
Load (MBH)
Miscellaneous/Equipment
Water Heating
Space Heating
Hour of Day


APARTMENT ELECTRIC LOAD PROFILE
Load (kW)
Plug Loads
Cooling
Hour of Day

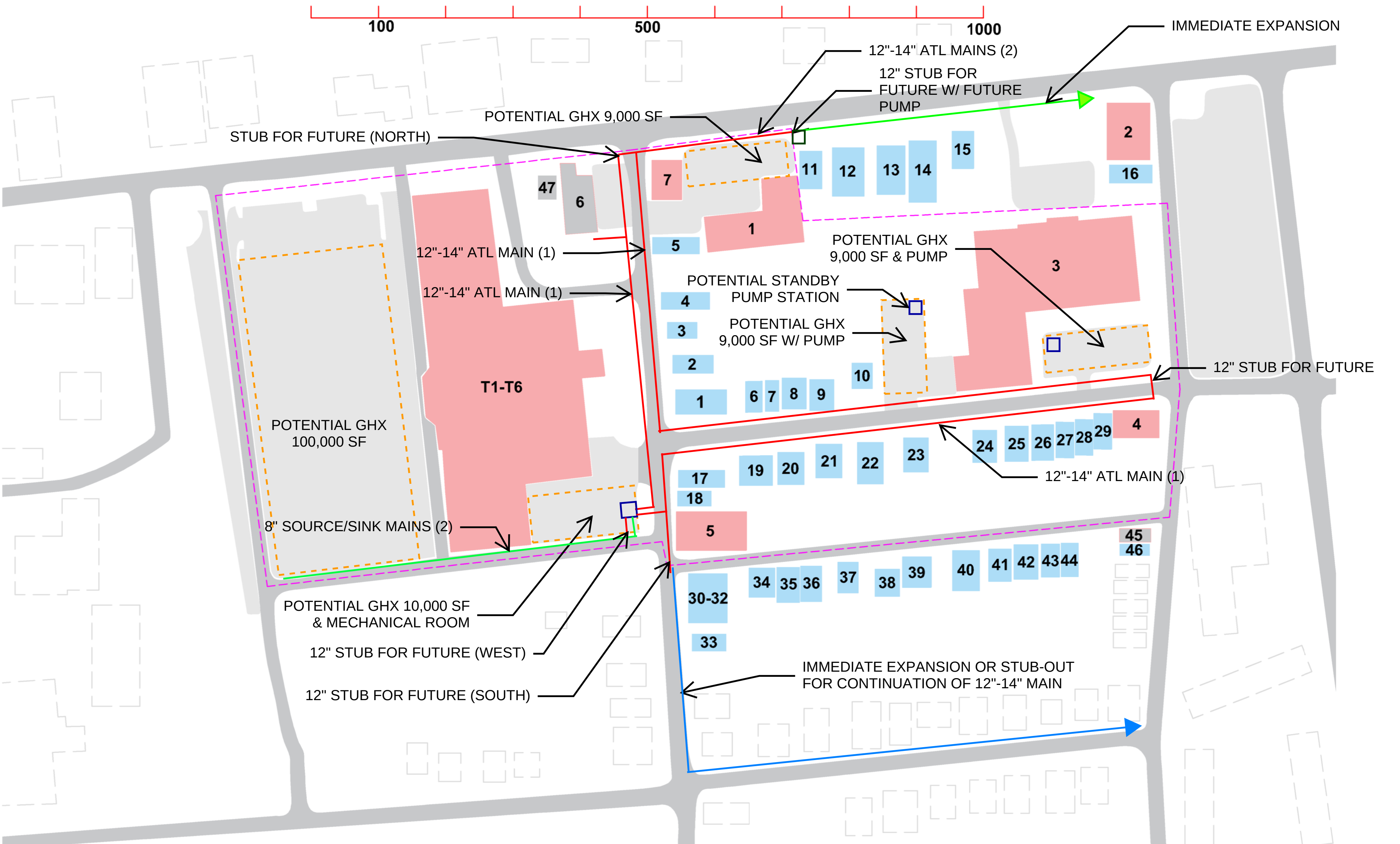

APARTMENT NATURAL GAS LOAD PROFILE
Load (MBH)
Miscellaneous/Equipment
Water Heating
Space Heating
Hour of Day


PRIMARY SCHOOL ELECTRIC LOAD PROFILE
Load (kW)
Plug Loads
Cooling
Hour of Day


PRIMARY SCHOOL NATURAL GAS LOAD PROFILE
Load (MBH)
Miscellaneous/Equipment
Water Heating
Space Heating
Hour of Day

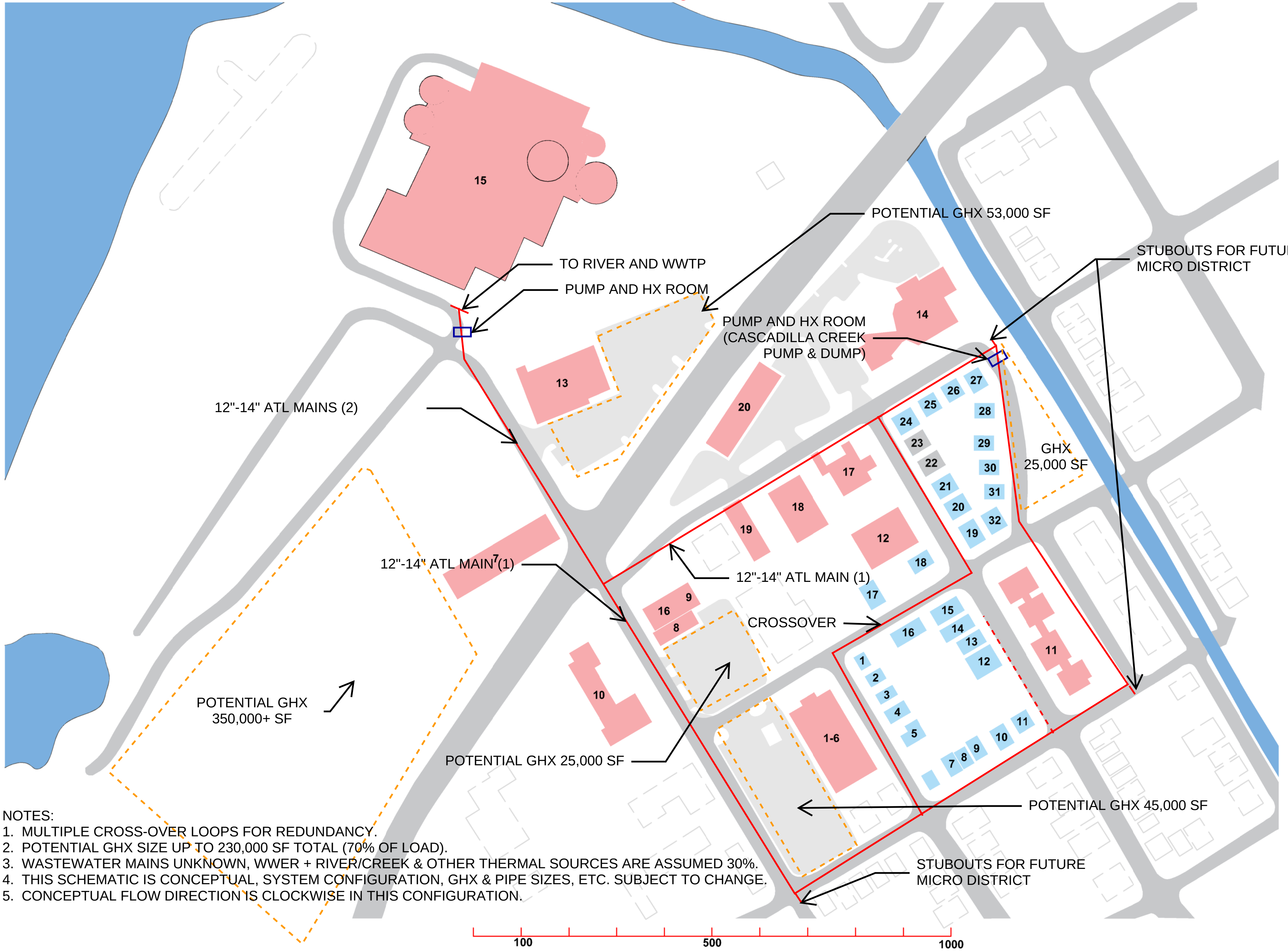
APPENDIX C: DETAILED SITE LAYOUTS

TOPS Site; Norwich, NY
Peak Cooling Load: 534 Tons
Peak Heating Load: 707 Tons



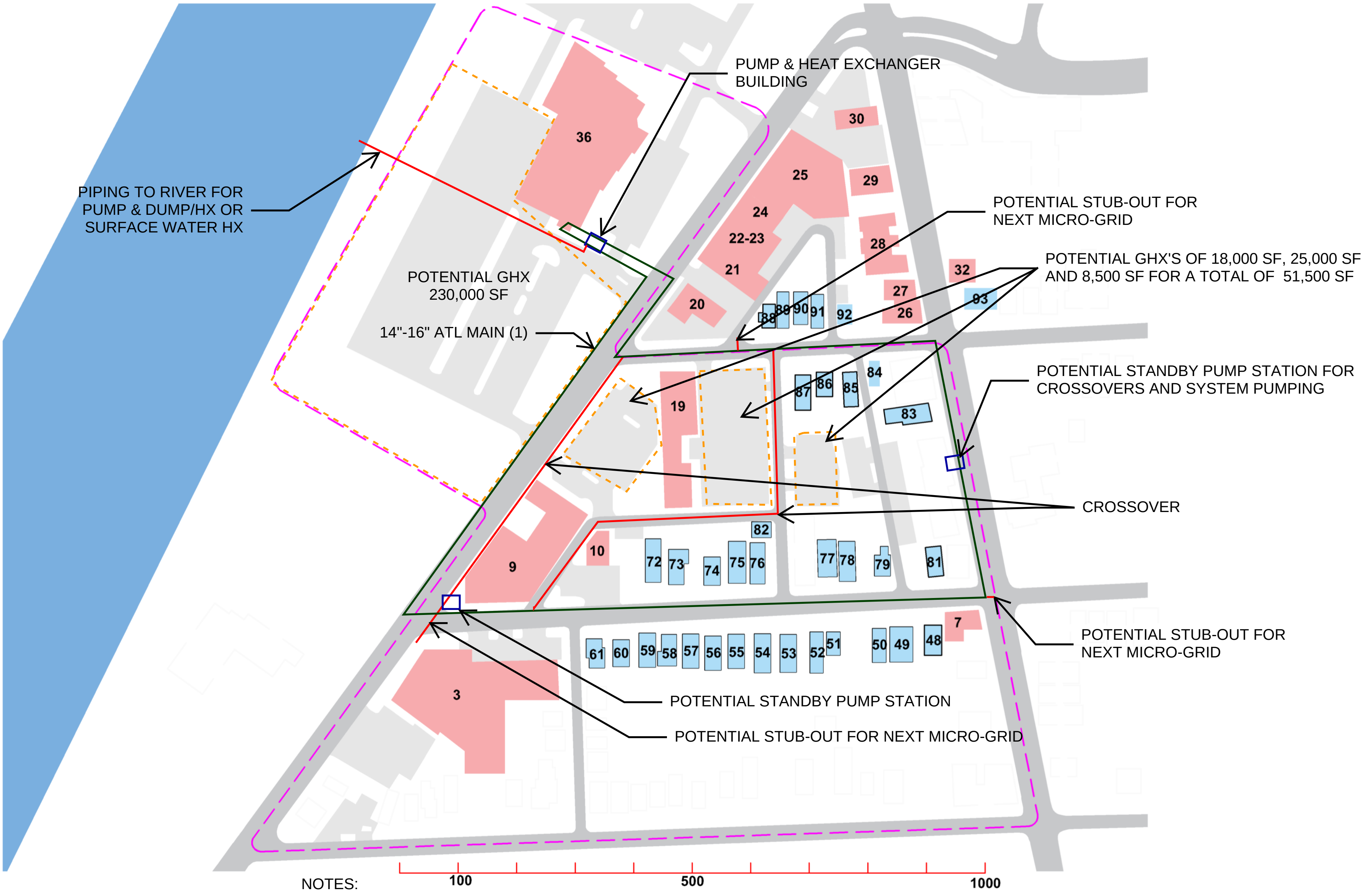
NOTES:
1. MULTIPLE CROSS-OVER LOOPS FOR REDUNDANCY NOT SHOWN,
2. POTENTIAL GHX SIZE 70,000 - 100,000 SF TOTAL (70% OF LOAD). 137,000 SF SHOWN AVAILABLE.
3. WASTEWATER MAINS UNKNOWN, WWER + OTHER THERMAL SOURCES ARE ASSUMED 30%.
4. THIS SCHEMATIC IS CONCEPTUAL, SYSTEM CONFIGURATION, GHX & PIPE SIZES, ETC. SUBJECT TO CHANGE.
5. CONCEPTUAL FLOW DIRECTION IS CLOCKWISE IN THIS CONFIGURATION.

DMV Site; Ithaca, NY
Peak Cooling Load: 533 Tons
Peak Heating Load: 699 Tons



NOTES:
1. MULTIPLE CROSS-OVER LOOPS FOR REDUNDANCY.
2. POTENTIAL GHX SIZE UP TO 230,000 SF TOTAL (70% OF LOAD).
3. WASTEWATER MAINS UNKNOWN, WWER + RIVER/CREEK & OTHER THERMAL SOURCES ARE ASSUMED 30%.
4. THIS SCHEMATIC IS CONCEPTUAL, SYSTEM CONFIGURATION, GHX & PIPE SIZES, ETC. SUBJECT TO CHANGE.
5. CONCEPTUAL FLOW DIRECTION IS CLOCKWISE IN THIS CONFIGURATION.

Spectrum Comm Center Site; Rochester, NY
Peak Cooling Load: 543 Tons
Peak Heating Load: 1,319 Tons



NOTES:
1. MULTIPLE CROSS-OVER LOOPS FOR REDUNDANCY.
2. POTENTIAL GHX SIZE 230,000+ SF TOTAL.
3. WASTEWATER MAINS UNKNOWN, WWER, AND RIVER ARE ASSUMED 30%.
4. THIS SCHEMATIC IS CONCEPTUAL, SYSTEM CONFIGURATION, GHX & PIPE SIZES, ETC. SUBJECT TO CHANGE.
5. CONCEPTUAL FLOW DIRECTION IS CLOCKWISE IN THIS CONFIGURATION.

APPENDIX D: SAMPLE DETAILED DESIGN

Page 1
BACKGROUND

Demographics from Utah Site

Current Land	606		A	100%
Canals	5.3		A	
Road Frontage	4.5		A	
Gross Developable	596.2	25,970,472	SF	
Roads and Civil Infrastructure	121.2		A	20%
Open Land	151.5		A	25%
Net Developable Land Area	333.3	14,518,548	A	55%

Non-Residential Uses	Acreage	SF	FAR	Parking	Total GFA	%NDLA	%GFA	Notes
Commercial Office	140	6,098,400	0.9	21,954	5,488,560	42%		
Innovation Office	0							
Institutional/Anchor Tenant	0							
Retail/Food & Beverage	11.5	500,000	0.6	600	300,000	3.4%	2.03%	
Civic	0							
Hotel	4.8	207,429	0.6	250	125,000	1.4%		250 Keys
Mixed Use	0							
	156.3			22,804	5,913,560	46.8%	40%	

Residential Land Uses

	Acreage	Units/AC	Units	GFA/Unit	Parking	Total GFA	%NDLA	%GFA	Notes
Single Family Detached	20.8	12	250	1,600	500	400,000	6.3%		For Sale
Workforce Attached	0	0	500	1,600	500		0%		For Sale
Attached Town Homes	56	18	1,100	1,600	1100	1,760,000	16.8%		For Sale
Condominium	30	45	1,450	1,600	725	2,320,000	9%		For Sale
Multi-Family Apartment	70	57.5	4,400	1,000	2200	4,400,000	21%		Rental
	176.8		7,700		5025	8,880,000	53.1%	60%	
					Total GFA:	14,793,560			

Water Use Estimates

Total Residential bodies @ density	2.1	16,170	Bodies			
Total Gallons/day Water (151 - 200)	80					
Average water:		1,293,600	gpd			
(does not include Irrigation)		53,900	gph			
		898.33	gpm	4,491,666.67		
Hot water per day:	20	323,400	gpd	13,475		
S.F. per HVAC Ton	500	SF/T				
		29,587	Tons	$ 81,364,580.00	$ 3,661,406.10	

5488560

14,793,560.00

LOAD ESTIMATES

	% of Load	Tons	Max GPM	Main Piping	PD - FOH @ 11.5 FPS
The Canal District	0.142857143	4,226.73	12,500	24"	1.23
Wasatch District	0.142857143	4,226.73	12,500	24"	1.23
The Ridge District	0.142857143	4,226.73	12,500	24"	1.23
The East River District	0.142857143	4,226.73	12,500	24"	1.23
West River District	0.142857143	4,226.73	12,500	24"	1.23
The Hub	0.285714286	8,453.46	20,000	30"	0.99
	1.0000000000	29,587.12			

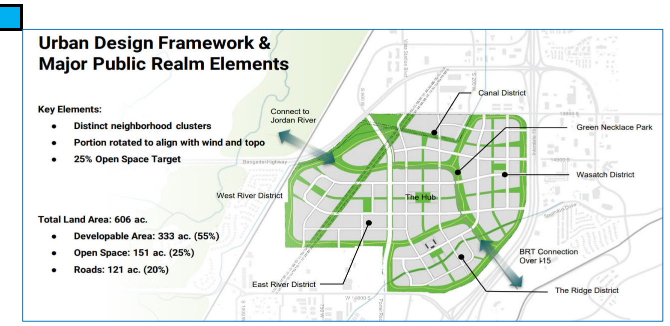
Load Distribution	Heating	Cooling	Primary Job	
Diversity	30%	30%	Both	
Borehole	40%	40%	Both	
Wastewater	5%	5%	Both	
Potable Water	2%	2%	Both	0.77
Geothermal	17%		Heating	
Irrigation	7%	10%	Cooling	
DHW Heating				
Towers		13%		
	102%	100%		

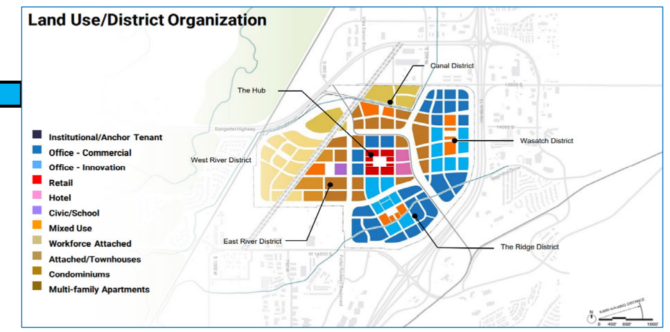
Water Calculator

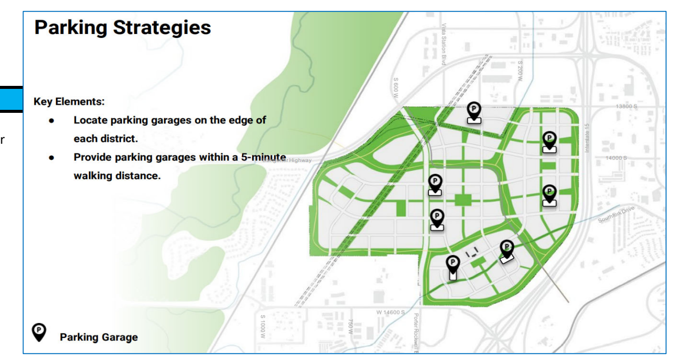
Well Output			Potable Water
Well Temp:	185		
Well Output:	1000	gpm	
Degree used F:	123		
	8340	pounds	
	1025820	BTU/m	
	61,549,200	BTU/h	
	5,129.10	Tons	

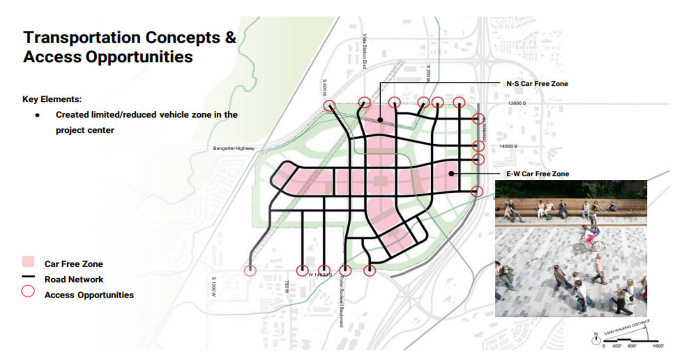
Potable Output Calculator:		
H2O Temp:	75	
H2o Use	13,475	gph
Degree used F:	75	
	112,381.50	pounds/h
		BTU/m
	8,428,613	BTU/h
	702.38	Tons

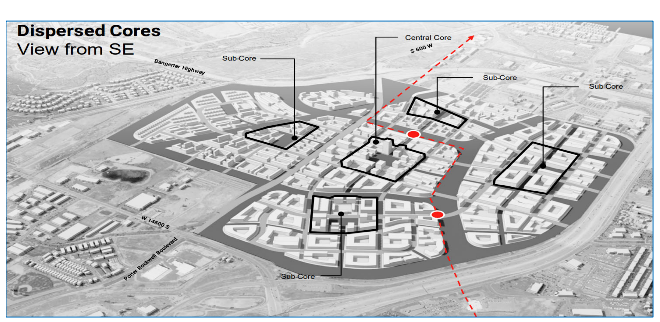
Borehole Estimate @ $/ft.	$ 20.00							
feet/ton Heat/Cool	130		174					
	Length	Cost		Cost	Sq. Feet	Acres	% of Total Land	% of open area
40%	1,538,530	$ 30,770,605	2,059,264	$ 41,185,271	3,217,599.30	73.89	12%	49%
50%	1,923,163	$ 38,463,256	2,574,079	$ 51,481,589	4,021,999.13	92.36	15%	61%
60%	2,307,795	$ 46,155,907	3,088,895	$ 61,777,907	4,826,398.95	110.84	18%	73%
70%	2,692,428	$ 53,848,558	3,603,711	$ 72,074,224	5,630,798.78	129.31	21%	85%



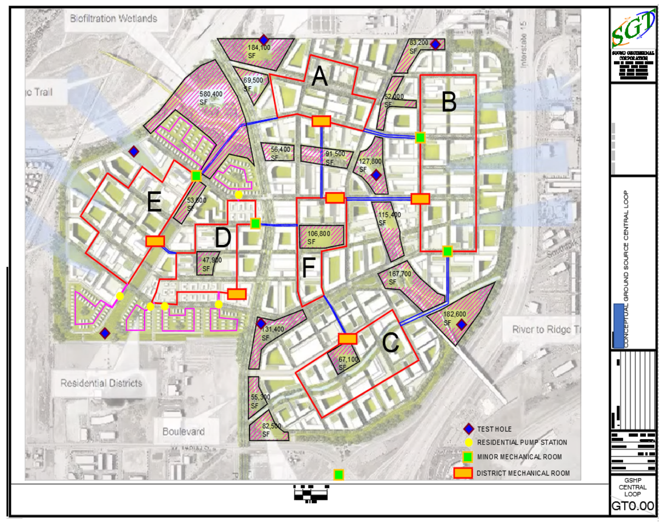


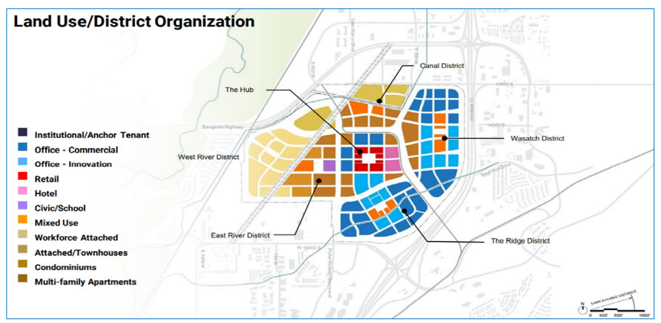






EXPENSE AND REVENUE CALCULATIONS
Page 3





Thermal Highway

		% of Load	Tons	Max GPM	Main Piping	PD - FOH @ 11.5 FPS	Length	Cost/Ft	Total Cost
A	The Canal District	0.142857143	4,227	12,500	24"	1.23	3508	$ 250.00	$ 877,000
B	Wasatch District	0.142857143	4,227	12,500	24"	1.23	4780	$ 250.00	$ 1,195,000
C	The Ridge District	0.142857143	4,227	12,500	24"	1.23	3593	$ 250.00	$ 898,250
D	The East River Distric	0.142857143	4,227	12,500	24"	1.23	4321	$ 250.00	$ 1,080,250
E	West River District	0.142857143	4,227	12,500	24"	1.23	4298	$ 250.00	$ 1,074,500
F	The Hub	0.285714286	8,453	20,000	30"	0.99	3137	$ 350.00	$ 1,097,950
			29,587						$ 6,222,950

Transfer Latterals

	Max GPM	Main Piping	PD	Length	Cost/Ft	Total Cost
A - B	4,000	12"	43.6293	1287	$ 150.00	$ 193,050
A-F	4,000	12"	52.7145	1555	$ 150.00	$ 233,250
B-C	4,000	14"	35.8344	1659	$ 175.00	$ 290,325
B-F	4,000	14"	47.3688	2193	$ 175.00	$ 383,775
C-F	4,000	12"	34.7814	1026	$ 150.00	$ 153,900
D-E	4,000	10"	43.1548	559	$ 135.00	$ 75,465
D-F	4,000	12"	31.7982	938	$ 150.00	$ 140,700
E-A	4,000	14"	50.2848	2328	$ 150.00	$ 349,200
						$ 1,819,665

Residential Loops

	Tons	Max GPM	Main Piping	Length	Cost/Ft	Total Cost
1	84	250	6"	1367	$ 100.00	$ 136,700.00
2	84	250	6"	1344	$ 100.00	$ 134,400.00
3	84	250	6"	1380	$ 100.00	$ 138,000.00
4	84	250	6"	800	$ 100.00	$ 80,000.00
5	84	250	6"	1918	$ 100.00	$ 191,800.00
6	150	450	8"	2341	$ 125.00	$ 292,625.00
						$ 973,525.00

Building & Equipment

District Mechanical R	7		$ 500,000.00	$ 3,500,000.00
Minor Mechanical Rc	4		$ 125,000.00	$ 500,000.00
Blackwater Station	2		$ 500,000.00	$ 1,000,000.00
Irrigation Station	10	2000	$ 40,000.00	$ 400,000.00
Residential Transfer I	5		$ 25,000.00	$ 125,000.00
				$ 5,525,000.00

Testing

		Depth	Drill	TC Test	
Test Hole	7	400 to 600	$ 12,000	8000	$ 140,000
High Temp Test Hole	2	800	$ 80,000		$ 160,000
Slinky Test	2			$ 6,000.00	$ 12,000
					$ 312,000

Total $ 14,853,140.00

Drilling Loops

Borehole Estimate @ $/ $ 20.00 — Total Tons: 29,587.12
feet/ton Heat/Cool 130 — 174

	Length x Tons	Cost	Length x Tons	Cost	Sq. Feet	Acres	% of Total Land	% of open area
40%	1,538,530	$ 30,770,605	2,059,264	$ 41,185,271	3,217,599.30	73.89	12%	49%
50%	1,923,163	$ 38,463,256	2,574,079	$ 51,481,589	4,021,999.13	92.36	15%	61%
60%	2,307,795	$ 46,155,907	3,088,895	$ 61,777,907	4,826,398.95	110.84	18%	73%
70%	2,692,428	$ 53,848,558	3,603,711	$ 72,074,224	5,630,798.78	129.31	21%	85%

Total Cost for Thermal Highway

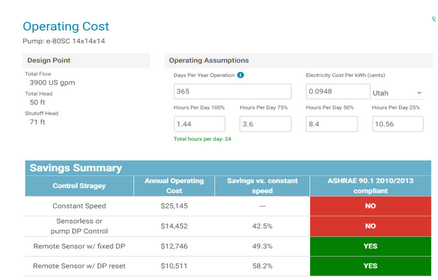
	Laterals	Loopfield	Cont.	Engineering	10% Contingency	TOTAL
40%	$ 14,853,140	$ 41,185,271	10%	$ 2,521,728	$ 5,603,841	$ 64,163,981
50%	$ 14,853,140	$ 51,481,589	10%	$ 2,985,063	$ 6,633,473	$ 75,953,264
60%	$ 14,853,140	$ 61,777,907	10%	$ 3,448,397	$ 7,663,105	$ 87,742,548
70%	$ 14,853,140	$ 72,074,224	10%	$ 3,911,731	$ 8,692,736	$ 99,531,832

Constants

Gallons per ton:	3 gpm	8,760	Hours per year
Tons:	29,587	3,000	gpm / pump
Gallons at Peak:	88,761 gpm		
Gallons per hour:	5,325,682 gph		
Gallons per day:	127,816,358 gpd		

Pumping Costs for Central Loop

% of Load	Pumping Time	Hours	System Tons	GPM	GPH	Total Gallons Pumped per year	Pumps/60 Hp	HP	Operating Cost / Pump	100%	Annualized
100%	6%	526	29,587	88,761	5,325,682	2,799,178,249	29.58712	60	$ 25,145	$ 743,968.13	$ 44,638.09
75%	15%	1,314	22,190	66,571	3,994,261	5,248,459,217	22.19034	25.3	$ 10,602.81		318,084
50%	35%	3,066	14,794	44,381	2,662,841	8,164,269,893	14.79356	7.5	$ 7,454.05		$ 223,622
25%	44%	3,854	7,397	22,190	1,331,420	5,131,826,790	7.39678	1	$ 3,352.67		$ 100,580
		8,760				21,343,734,148					$ 686,923.88



Operating Cost for Distribution

Expences	Gross Number		Peroids	
Pump Power + 15%				$ 789,962
Billing Cost Paper	$ 14,000	1.5	12	$ 252,000
Tax			9%	$ 22,680
Employees	$ 80,000	5		$ 400,000
Repairs	$ 150,000	1		$ 150,000
				$ 1,614,642
Contingency			10%	$ 161,464
				$ 1,776,107

Revenue and Fuel Cost (from AP Economics): GROSS SAVINGS

	Conventional	Geothermal
Gas Heating	$ 9,343,628	$ 4,317,077
A/S Cooling	$ 3,512,021	$ 1,873,078
HotWater	$ 446,619	$ 445,425
Total Conventional Fuel Cost	$ 13,302,268	$ 6,635,580
Operating Cost	$ 4,216,165	$ 1,849,195
Total Fuel and O&M Cost:	$ 17,518,433	$ 8,484,775
Distribution Cost of Operations:		$ 1,776,107
Total Energy and Operating Margin:		$ 9,033,658

Energy Check-Sum

	Energy Cost
Total Tons:	29,587
$$ per ton per yr	$ 450
	$ 13,314,204

Simple Return Matrix

System Cost	10 Year Simple Return	15 Year Simple Return
$ 64,163,981	$ 6,416,398	$ 4,277,599
		$ -
$ 75,953,264	$ 7,595,326	$ 5,063,551
$ 87,742,548	$ 8,774,255	$ 5,849,503
$ 99,531,832	$ 9,953,183	$ 6,635,455

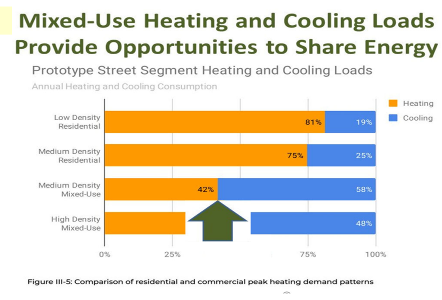
Operations Revenue - Rate per Gallon with Taxes

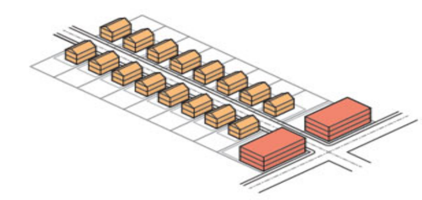
Pumping Time	Total Gallons Pumped per year		
6%	2,799,178,249	$ 0.000431	$ 1,206,446
15%	5,248,459,217	$ 0.000431	$ 2,262,086
35%	8,164,269,893	$ 0.000431	$ 3,518,800
44%	5,131,826,790	$ 0.000431	$ 2,211,817
			$ 9,199,149

Incentive

	Tax Credit	MACRS	State	Utility	Net Cost	179 d
	10%	20%				$0.60/sq ft
$ 64,163,981	$ 6,416,398	$ 11,549,517	$ 50,000	$ 250,000	$ 45,898,066	
$ 75,953,264	$ 7,595,326	$ 13,671,588	$ 50,000	$ 250,000	$ 54,386,350	
$ 87,742,548	$ 8,774,255	$ 15,793,659	$ 50,000	$ 250,000	$ 62,874,635	
$ 99,531,832	$ 9,953,183	$ 17,915,730	$ 50,000	$ 250,000	$ 71,362,919	

SOUND GEOTHERMAL CORPORATION
Ultra-high Efficiency Annual Operating Cost Economics
The Point - SLC, UT
1/23/2022
Furnace/DX vs GX Heat Pumps
100% Water Heating





Heating Calculations

F= HL x 24 x DD / E x P x T.D.

Tons:	29,587.12	Base Load:	29,587.12
		Bin Temp:	100%
City:	Salt Lake City	Used:	65 F

355,045,440	HL - Design heating load in BTU
6,052	DD - Degree Days
0.70	E - Seasonal Efficiency Gas
0.92	E - Seasonal Efficiency Propane
0.80	E - Seasonal Efficiency Fuel Oil
2.20	E - Seasonal Efficiency Electricity ASHP
5.50	E - Seasonal Efficiency HP (COP)
70	Winter Setpoint (Deg. F)
0	Winter Design Temperature
70	T.D. - Design Temp. difference

Annual Fuel Consumption

1,026,772,325.92	Gas(cubic feet)
8,751,593.54	Propane (gal)
6,673,090.07	Fuel Oil (gal)
98,115,380.21	Electricity (kWh)
39,246,152.08	GSHP (kWh)

NOTE: HL, DD, and TD are all relative to each other. Each must be adjusted to reflect the conditions at the setpoint. e.g. If DT decreases then HL and DD will also decrease. Savings usually will decrese with less total fuel used.

P - Heating value of Fuel

1,025	Gas - BTU/cubic Foot
91,500	Propane - gallon
138,000	Fuel Oil - gallon
3,413	Electricity - BTU/kWh

Annual Cost		Fuel Cost	
$ 9,343,628.17	Gas	$ 0.910	Therm
$ 17,503,187.07	Propane	$ 2.000	gal.
$ 16,682,725.18	Fuel Oil	$ 2.500	gal.
$ 10,792,691.82	Electricity	$ 0.110	kWh
$ 4,317,076.73	GSHP		

Cooling Calculations

Cooling kW/year= CLH*QC / 1000*SEER

Tons:	17,752.27		60%
City:	Salt Lake City	55 F bin	

Cooling kWh/year=	31,927,461
GSHP Cooling kWh/yr=	17,027,979
$$/year=	$ 3,512,021
GSHP $$/Year=	$ 1,873,078

213,027,264	QC - Design Cooling Load
2,398	CLH - Cooling Degree Days
16.00	SEER - Seasonal Efficiency - ASHP
30.00	SEER - Seasonal Efficiency of GSHP
y	Heat Pump (y or n)

DHW - Water Calculations

BTU/gal 608.82

52	EWDHW - Entering Potable water
125	DT - Desired Temperature DHW
73	DC - Degree change
323,400	WU - water use per day
5.2	HP - COP

	DIRECT HEAT			GS HEAT PUMP	
	$$/gal water	$$/day	$$/year	$$/day	$$/year
Electricity	$ 0.0196	$ 6,345.78	$ 2,316,211.36	$ 1,220.34	$ 445,425
Propane	$ 0.0122	$ 3,959.37	$ 1,445,168.61		
Gas	$ 0.0038	$ 1,223.61	$ 446,619.17		
Fuel oil	$ 0.0088	$ 2,853.51	$ 1,041,532.20		

High Temperature DWH

54	EWDHW - Entering Potable water
120	DT - Desired Temperature DHW
66	DC - Degree change
140	Desired Final Temperature
20	Deg. Additional Needed
0	WU - water use per day
4.1	HP - COP

BTU/gal	550.44
Additional BTU/gal	166.8

(CONVENTIONAL FUEL ONLY ADDITIONAL HEAT 120 F to 140F)

		$$/day	$$/year
$$/gal - electricity	$ 0.0054	$ -	$ -
$$/gal - propane	$ 0.0034	$ -	$ -
$$/gal - gas	$ 0.0010	$ -	$ -
$$/gal - fuel oil	$ 0.0024	$ -	$ -

	Total Cost/Year Conventional Only	Total Cost/Year with GS HEAT PUMP
Electricity	$ 2,316,211	$ 445,425.26
Propane	$ 1,445,169	$ 445,425.26
Gas	$ 446,619	$ 445,425.26
Fuel oil	$ 1,041,532	$ 445,425.26

TOTAL ESTIMATED BUILDING FUEL COST

HVAC Fuel	Conventional	GSHP	Savings
Electricity	$ 16,620,924	$ 6,635,580	
Propane + Electricity	$ 22,460,376	$ 6,635,580	
Gas + Electricity	$ 13,302,268	$ 6,635,580	$ 6,666,688
Fuel oil + Electricity	$ 21,236,278	$ 6,635,580	

O & M CALCULATIONS

Total sq. ft.: 14,793,560

0 $ -

Estimated Boiler/DX cost sq/ft:	$ 0.285	$ 4,216,165	
Estimated Ground source cost sq/ft:	$ 0.125	$ (1,849,195)	
Projected O & M Savings:			$ 2,366,970
Total Projected Savings:			$ 9,033,658