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Brightcore

Somerville Networked Geothermal Feasibility Study

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1 Executive Summary

Within Massachusetts' buildings sector, heating and cooling demands account for over one-third of all end use energy consumption.[1] Natural gas is the primary fuel type that provides both space heating and domestic hot water heating to residential and commercial buildings across the state. While air-source heat pumps are becoming increasingly popular solutions to electrify heating in Massachusetts and across the United States, there is a risk that rising electrical demand for heating will shift annual peak loads to the winter months – creating increased strain across an aging electrical grid. Networked geothermal – a type of thermal energy network – is an emerging technology capable of improving the efficiency of electric powered heating and cooling systems by capitalizing on the reliability of consistent ambient heat from the ground.

To explore the potential for creating networked geothermal systems across the state, HEET, with support from the Massachusetts Clean Energy Center, created the Kickstart program – an initiative aimed at funding a new pipeline of "shovel-ready" networked geothermal demonstration projects across Massachusetts. The City of Somerville – one of the recipients of a Kickstart prize – is utilizing this funding to explore the viability of this technology within three of its neighborhoods: Central Hill, a neighborhood within the city that houses its City Hall, local high school, and public library, among a dense residential building stock; Ten Hills – a residential neighborhood bordering the Mystic River and several large housing complexes owned by the Somerville Housing Authority; and a strip of Central Somerville Avenue – a mixed-use neighborhood that features several opportunities for waste heat recovery as a means of providing thermal energy to nearby residential and commercial buildings.

Buro Happold, in collaboration with Brightcore, supported the City through several public engagement meetings and the preparation of a technical feasibility and economic viability analysis of three preliminary sites, looking at both the feasibility of the technology and the economics of an installation. As a part of this study, a review of local infrastructure networks that could introduce interference challenges were identified; a geological and hydrogeological review was conducted to determine an initial recommendation on drillability within each site; technical recommendations were made on how to approach test well drilling, permitting, and piping installation, and a rough order of magnitude cost

[1] Clean Energy Group. "Massachusetts Renewable Heating and Cooling." https://www.cleanegroup.org/wp-content/uploads/Meister-MA-renewable-thermal-study.pdf

estimate was developed for each site to understand the economic impacts for homeowners and businesses interested in connecting to the system.

It was found that while all studied sites were viable for a pilot networked geothermal system, but long-term thermal balance across each network will need to be thoughtfully considered during further stages of design. Based on the modelling results, which have been largely informed by simulated building stock information rather than real customer data, the Somerville housing stock tends to be more heating dominant, meaning more thermal energy is used in the winter than in the summer. As a result, relying on a full 100% geothermal network would result in ground temperature imbalance over time, with heat being consistently removed during the winter and not replenished in the summer. This results in lower network efficiencies and would require system design in the range of up to 80% heating capacity without further thermal resources. Additional thermal resources have been implemented for other networked geothermal systems, such as the system in Framingham, Massachusetts which includes auxiliary thermal resources, such as supplemental in-home heating systems.

In addition to the technical work done by the consulting team, two public engagement meetings were held with city residents to further educate the public on the technology and its long-term benefits to homeowners, businesses, and the City’s sustainability goals. Overall, for a future networked geothermal demonstration project to be successful in Somerville, thoughtfully developing a balanced network design, along with continuous stakeholder engagement, will be critical to showcasing the viability for geothermal energy systems to play a role in the City’s clean energy future.

2 Introduction

2.1 Motivation

Somerville, Massachusetts has long been a leader in sustainability and climate-conscious action. The city's community climate action plan, known as Climate Forward, aims for the city to reach net zero emissions by 2050 and has set aspirations for a carbon net-negative future.[2] Climate Forward outlines a plan to reduce contributions to climate change and to prepare the city for climate impacts, which includes adding new building standards that emphasize resilience, improving energy efficiency in existing buildings, and providing the ability to support fuel switching in the city's current building stock. However, recent work between the city and Buro Happold has highlighted that the city's existing electrical infrastructure may struggle to adapt to rapidly rising demand for electricity – both the result of new development and increasing levels of electrification.

These challenges are similarly felt on a broader scale at the state level. Massachusetts established an ambitious climate target of achieving net zero carbon emissions by 2050.[3] However, the state faces a significant challenge in meeting this goal as a large part of its buildings sector relies on fossil fuels for space heating and domestic hot water heating. While the building sector has made strides to improve the efficiency and electric-led performance of building-scale heating, ventilation, and air conditioning (HVAC) systems through air-source heat pumps (ASHPs) or ductless mini-split systems, there is still a risk that even this solution could result in overloading the electric grid beyond its current capacity.[4] New legislation and emerging business models evaluating the viability of networked geothermal systems may prove to be a scalable solution to meet the climate needs of the state while remaining thoughtful of the condition of Massachusetts' current energy infrastructure networks.

With funding from Massachusetts' Clean Energy Center (CEC), HEET developed the Kickstart program – an initiative aimed at establishing a pipeline of "shovel-ready" networked geothermal demonstration projects. With the buildout of more geothermal networks across Massachusetts, further insights related to the design, development, and operations of these

[2] City of Somerville, "Climate Forward."
[3] MA Climate Plan for 2050. https://www.mass.gov/info-details/massachusetts-clean-energy-and-climate-plan-for-2050
[4] J. Buonocore et al., (2022). "Inefficient building electrification will require massive buildout of renewable energy and seasonal energy storage." https://www.nature.com/articles/s41598-022-15628-2

systems can inform the cost and performance metrics that lead to further industry development at the state and national levels.

Since early 2024, Buro Happold has been working with the City of Somerville to understand the viability of implementing a networked geothermal system – especially considering its high level of density, grid infrastructure, modernization challenges, and aging building stock. The city is taking a major step forward in identifying an optimal site to demonstrate how this technology could be initially installed and later scaled across one of New England's most densely built environments. By completing this initial Kickstart feasibility study, the city will have better insight into approaching site selection, stakeholder engagement, and customer acquisition to develop a successful networked geothermal pilot project.

2.2 Report Structure

This report summarizes the findings from a networked geothermal feasibility study conducted in the Ten Hills, Central Hill, and Central Somerville Avenue neighborhoods in Somerville. The remainder of the report is structured as follows:

- Chapter 3 (Policy and Regulatory Review): This section discusses the key legislation supporting networked geothermal demonstration projects as well as engineering best practices needed to design and operate a system of this kind in Massachusetts.
- Chapter 4 (Site Selection): This section discusses the methodology utilized by the consultant team to identify optimal sites in Somerville for a networked geothermal pilot.
- Chapter 5 (Stakeholder Engagement and Response): This section discusses the progress-to-date related to stakeholder engagement as well as planned next steps.
- Chapter 6 (Techno-Economic Analysis): This section summarizes all key quantitative and qualitative results from the feasibility study, including economic, environmental, and social impacts of electrification and networked geothermal energy.
- Chapter 7 (Conclusions and Next Steps): This section summarizes all key findings from this study and provides recommendations on next steps towards implementation.

The report's appendix includes additional supporting information from the techno-economic analysis.

3 Policy and Regulatory Review

3.1 Gas-to-Geo Transition

The “gas-to-geo” transition refers to the emerging and rapidly progressing movement of switching building energy systems away from natural gas and fossil fuel-based systems to electrified, geothermal-based systems that utilize similar distribution infrastructure to a natural gas network.

In recent years, a regional disaster and academic studies have highlighted the risks of natural gas to human health and well-being. Natural gas is primarily composed of methane – a greenhouse gas with over 80 times the global warming impact of CO_2. Natural gas infrastructure is susceptible to leaks and explosions, which has become a prominent issue in the state of Massachusetts. In the fall of 2018, inadequate maintenance and operational procedures of gas lines in the Merrimack Valley region resulted in a series of gas explosions displacing several hundred residents.[5] Academic studies have demonstrated that cooking indoors with a gas range can negatively impact indoor air quality and contribute to asthma.[6] Thus, finding a solution to eliminate the dependence on gas-based heating systems, all while avoiding utility bill increases for customers is a key pathway to achieving many of the state’s sustainability, health, and equity goals. To address these issues, increasing numbers of networked geothermal systems are being evaluated and implemented across Massachusetts – the first utility-owned system was recently commissioned by Eversource in 2024.

Networked geothermal systems are a type of thermal energy network (TEN) that transfers the natural thermal energy from the ground to a group of buildings to provide space heating, cooling, and, in some cases, domestic hot water heating. Because the subsurface temperature remains roughly constant year-round, these systems can deliver consistent “ambient” temperatures (~55 °F) to buildings for both heating and cooling without vulnerability to extreme air temperatures in the winter or summer months. As shown in Figure 3-1, these systems typically include a borefield of geothermal wells which can extend beyond 1,000 feet, into which a loop of pipework is installed and grouted into place. Water mixed with a small percent of heat transfer fluid (i.e., glycol) is circulated through the closed loop of pipe where it is passively warmed or cooled depending on the temperature gradient

[5] Mass.gov. “Merrimack Valley Incident Report.” https://www.mass.gov/doc/merrimack-valley-incident-report/download
[6] Kashtan, Y., et al. (2024). “Nitrogen dioxide exposure, health outcomes, and associated demographic disparities due to gas and propane combustion by U.S. stoves.” *Science Advances*.

of the ground. The water is then pumped through the distribution network to individual buildings. Within the building, heat pumps utilize this constant temperature fluid to heat or cool the conditioned space.

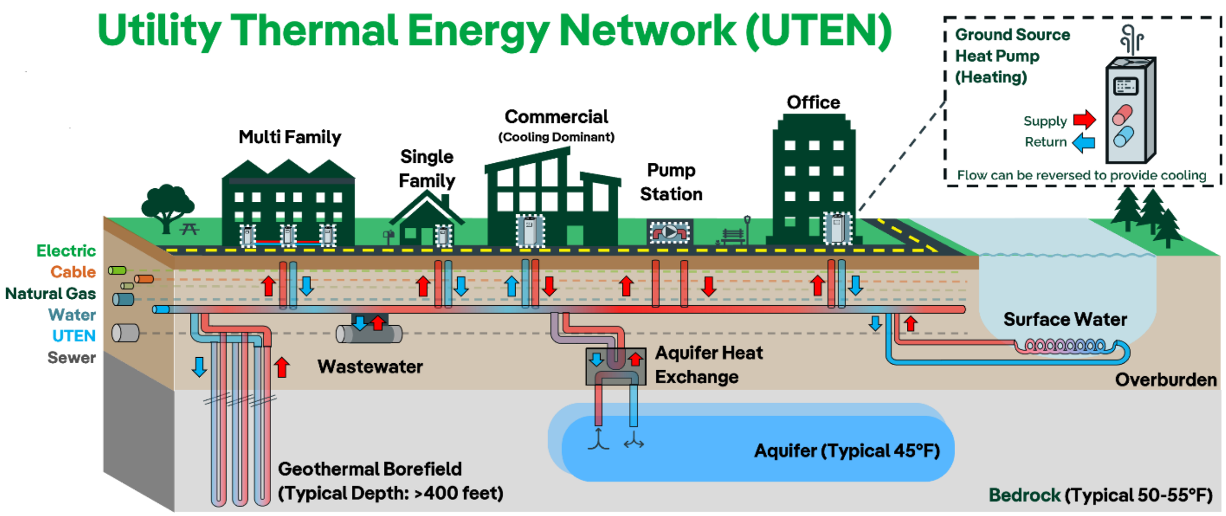

Figure 3-1. Concept diagram of a networked geothermal system.[7]

3.2 Legislation and Policy

In the last decade, geothermal networks have seen increasing legislative and policy-driven incentives associated with the development of clean energy technologies. Massachusetts has been a leader in supporting the development of new geothermal heating and cooling projects, both in response to the critical need to address a rapidly changing climate as well as the need to improve safety across the state's building stock.

In 2008, the State of Massachusetts passed the "Global Warming Solutions Act" – directing the Department of Energy Resources (DOER) and other state agencies to define economy-wide emissions reduction goals for the Commonwealth.[8] Updated most recently in 2021, the act has defined a legally-mandated state-wide goal of achieving a 50% reduction of greenhouse gas emissions compared to a 1990 baseline by 2030, a 75% reduction of greenhouse gas emissions compared to a 1990 baseline by 2040, and net-zero emissions by 2050. The foundational policy published by the commonwealth is known as the

[7] New York State Electric and Gas. "Utility Thermal Energy Networks. Bringing Clean Energy Solutions to our Customers and Communities through Shared Thermal Resources. (2025)." https://www.nyseg.com/smartenergy/innovation/utility-thermal-energy-network
[8] Mass.gov. "Global Warming Solutions Act." https://www.mass.gov/info-details/global-warming-solutions-act-background

Massachusetts Clean Energy and Climate Plan for 2050,[9] which has been amended to set near-term targets for 2025 and 2030. In December 2023, the state issued the Massachusetts Department of Public Utilities (DPU) Order 20-80, which sets forth a new strategy to guide the evolution of the natural gas distribution industry toward clean energy and decarbonization.[10]

In 2020, Massachusetts passed "An Act For Utility Transition to Using Renewable Energy", a bill outlining the transition plan for the state to move from natural gas to clean energy in alignment with the state's mandated GHG targets.[11] As a result of this bill, the DPU approved the initial utility-led pilot projects in Massachusetts: one led by Eversource in Framingham and the other by National Grid in Lowell. The state has also passed subsequent legislation further incentivizing the piloting of these systems. Section 22 of "An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy," passed in 2021 and allows gas utilities to install demonstration projects for networked geothermal and sell thermal energy in addition to their electricity and gas services to customers.[12] Section 57 of Bill H.5060 – "An Act Driving Clean Energy and Offshore Wind" authorizes pipe replacement funds to be redirected toward renewable energy infrastructure and incentivizes gas companies to make long-term repairs rather than expensive replacement of old pipes.[13] As a part of this bill, the state's electric utilities were mandated to develop Electric Sector Modernization Plans to provide a path toward modernizing and decarbonizing the electric grid – specifically focused on adding system capacity, supporting electrification programs, and decarbonizing their existing portfolios. This act has resulted in planned substation expansions, new projects for installing distributed energy resources, and pledges by National Grid and Eversource to reach net zero emissions by 2050 and 2030 respectively.[14,15]

To further support the development of geothermal networks, there are extensive funding opportunities available through various state departments and federal agencies, as summarized in Table 3-1.

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[9] Mass.gov. "Massachusetts Clean Energy and Climate Plan for 2050." https://www.mass.gov/info-details/massachusetts-clean-energy-and-climate-plan-for-2050

[10] Mass.gov. "Department of Public Utilities Order 20-80." https://www.mass.gov/news/department-of-public-utilities-issues-order-20-80

[11] MA Legislature. Bill S.2302. https://malegislature.gov/Bills/190/S2302

[12] MA Legislature. "An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy." https://malegislature.gov/Laws/SessionLaws/Acts/2021/Chapter8

[13] MA Legislature. Bill H.5060. https://malegislature.gov/Bills/192/H5060

[14] Eversource. "Electric Sector Modernization Plan." https://www.eversource.com/content/residential/about/sustainability/renewable-generation/electric-sector-modernization-plan

[15] National Grid. "Massachusetts Grid Modernization." https://www.nationalgridus.com/Our-Company/MA-Grid-Modernization

Table 3-1. Funding opportunities for networked geothermal systems.

Name	Agency/Funder	Description	Funding Deadline
Clean Electricity Investment Tax Credit	Internal Revenue Service (Federal)	Reduces Federal income liability for a percentage of the cost of a qualified clean energy system installed during that year	Open until 2032
IRC Section 25D: Residential Clean Energy Credit	Internal Revenue Service (Federal)	Tax credit based on amount invested in qualifying residential energy property	Open until 2032
Modified Accelerated Cost-Recovery System (MACRS)	Internal Revenue Service (Federal)	Cost recovery through depreciation deductions. Applicable for geothermal heat pumps.	Open until 2032
Energy-Efficient Commercial Buildings Tax Deduction (IRC Section 179D)	Internal Revenue Service (Federal)	Tax deduction for owners of commercial buildings who install systems to reduce total energy	Open until 2032
High Efficiency Electric Home Rebate Act (HEEHRA)	U.S. Department of Energy (Federal)	Point of sale rebates for qualified electrification projects include heat pump HVAC and water heaters	No deadline
NSF 24-534: Civic Innovation Challenge (CIVIC)	National Science Foundation (Federal)	Funding program for projects that pilot community-driven, innovative, and actionable research-centered approaches and technologies that focus on strengthening the resilience of a community and its economy to climate- and associated environmentally-related instability and disasters	Ongoing (annual funding rounds)

DOE Energy Efficiency Conservation Block Grant (EECBG) Competitive Program	U.S. Department of Energy (Federal)	DOE administration of $440 million in formula and competitive EECBG program funding appropriated by IIJA	Next application round closes May 2025
Mass Save Residential Rebates	Mass Save (State)	Rebates for energy efficiency technologies, including heat pumps and heat pump water heaters	No deadline
Alternative Energy Portfolio Standard[16]	Department of Energy Resources (State)	Incentives for homeowners and business to sell “Alternative Energy Certificates” in response to generating “naturally occurring temperature differences in ground, air or water”	No deadline

3.3 Regulations and Permitting

In addition to the incentives and policies promoting the development of networked geothermal, local and state regulations and permits should be noted during the creation of these systems. Table 3-2 summarizes the key information for permits required to facilitate geothermal drilling and installation in Somerville. Additional detail about the process of applying for these permits can be found in Section 6.8.

Table 3-2. Key permitting requirements for geothermal drilling and installation in Somerville, MA.

Activity	Permit	Jurisdiction	Cost
Moving 200+ cubic feet of soil	Site Construction Permit[17]	City of Somerville – City Engineer	$2,500
Water supply	Hydrant Permit[18]	City of Somerville – Water and Sewer Department	$200+

[16] Mass.gov. “APS Renewable Thermal Qualifications.” https://www.mass.gov/guides/aps-renewable-thermal-statement-of-qualification-application
[17] City of Somerville. “Engineering Site Permit Rules and Regulations.” https://s3.amazonaws.com/somervillema-live/s3fs-public/engineering-site-permit-rules-regs.pdf
[18] https://s3.amazonaws.com/somervillema-live/s3fs-public/permit-hydrant-meter-20250221.pdf

Dewatering (sanitary)	Temporary Construction Site Dewatering Permit[19]	Massachusetts Water Resources Authority (MWRA)	TBD
Dewatering (stormwater)	Notice of Intent (NOI) under NPDES General Permit for Dewatering and Remediation Activity Discharges in MA[20]	Massachusetts Department of Environmental Protection (DEP), US Environmental Protection Agency (EPA)	$20,000+

3.4 Best Practices for System Implementation

When developing and implementing a networked geothermal system, design, construction, and operation should aim to achieve optimal cost-effectiveness. The primary barrier to implementing networked geothermal at scale has historically been the cost implications of the system; however, through careful planning at each stage of the network's lifecycle, these concerns can be mitigated.

From a design perspective, a key opportunity to improve the cost-effectiveness of a networked geothermal system comes from their ability to leverage waste heat sources to further improve efficiency. Waste heat sources in Somerville include ice rinks, data centers, grocery stores, breweries, and other general manufacturing facilities. Heat is recoverable from various sources across the city, with sources categorized under one of the following:

- Heat recovery from flue gases – heat exchangers placed inside flues can heat ambient temperature water
- Wastewater heat recovery – residual heat from process wastewater is transferred through heat exchange
- Heat recovery from process cooling – industrial processes which require chilling can be targeted for heat recovery in the same way as data centers/refrigeration

As discovered during Eversource's development of their networked geothermal pilot in Framingham, the complexity and cost of building retrofits in relatively old building stock is a key challenge that needs to be addressed during the customer acquisition and construction phases. This challenge was similarly a driver that led to the cancelation of National Grid's pilot project in Lowell. It should be noted that each of these projects requires the utilities to

[19] MWRA. "Construction Site Dewatering Permit." https://www.mwra.com/media/file/construction-site-dewatering-discharge-permit-application
[20] EPA. "NPDES General Permit for Dewatering and Remediation." https://www3.epa.gov/region1/npdes/drgp/drgp-2022-permit-final.pdf

fund the building retrofits, so while it is not expected that a future networked geothermal system owner would need to fund these building-level upgrades, site selection and customer acquisition should strongly consider neighborhoods and customers that are more "network-ready."

To ensure the safe operation of networked geothermal systems, the Massachusetts DPU has introduced mandates requiring that system operators develop and follow an Emergency Response Plan and an Operator Qualification Plan to ensure that the systems operate safely. Operators are also expected to file annual reports with the DPU's Pipeline Safety Division, including performance and design-related information on the miles of service and number of customers.[21]

Finally, as shown in Eversource's initial utility-owned networked geothermal system, metering and system monitoring is essential to understanding and optimizing long-term performance. Eversource's metering and system monitoring was designed to account for all data necessary to calculate the synchronous and asynchronous load cancellation observed on hourly, daily, and seasonal scales.[22] In particular, this strategy included the installation of meters measuring BTUs along varying points of the network, pumping power, and temperature within the distribution network. It is expected that this system will provide ongoing monitoring for the first two years of operations. Table 3-3 summarizes the data collected in Framingham to measure system performance.

Table 3-3. Data collected as part of Framingham's networked geothermal demonstration project.

Data	Purpose	Method of Collection
Ground loop water supply temperature to buildings (seasonal variation)	Determine appropriate and acceptable seasonal variations in borefield temperatures given customer-side equipment requirements	BTU and temperature meters on ground-loop heat exchanger's supply and return connection (measured and logged throughout project lifetime)
Ground loop water supply temperature to buildings (annual variation)	Assess the need for supplemental heating and cooling equipment in order to maintain the effectiveness of the ground loop throughout its operational life	BTU and temperature meters on ground-loop heat exchanger's supply and return connection (measured and logged throughout project lifetime)

[21] Mass.gov. "DPU establishes networked geothermal guidelines." https://www.mass.gov/news/dpu-establishes-network-geothermal-guidelines
[22] Geothermal Data Repository, "Framingham Geothermal Network Monitoring and Metering Plan." https://gdr.openei.org/files/1672/Framingham%20Geothermal%20Network%20Monitoring%20and%20Metering%20Plan%20(1).pdf

Ground loop temperature difference between return and supply	Understand allowable tolerance for temperature delta based on customer's equipment ratings, performance, etc.	BTU and temperature meters on ground-loop heat exchanger supply and return connection (measured and logged throughout project lifetime)
Cost and time required for well recharge (replenishing heat within the boreholes)	Best practices for cost-effectively, sustainably charging the wellfield	Boiler trends (supply/return temperatures, fire rate, flow), measured and logged throughout project lifetime
Ground loop water flow (gpm)	Assess the flow requirements of the system during varying climate conditions, identify leaks	Flow meters on the ground-loop heat exchanger's supply and return connections
Addition of make-up water/glycol (gallons) over time (if required due to leaks, flushing, etc.)	Assess the typical volume and cost requirements of keeping the system full of working fluid	Consumption meter (gallons) on the make-up system; log of glycol purchases
Run-time and electricity consumption (hours and kWh) of central loop infrastructure	Better understand the operational load profile and cost of the central pumping system	Trends programmed for each central pump
Cost of customer building-side HVAC installation	Better understand cost to install or retrofit existing customer-side HVAC systems to function with a networked system	Log using invoiced cost for each customer's system
Cost of annual customer-side preventative maintenance and unscheduled repairs	Better understand customer-side maintenance and repair costs to be incurred when connecting to network	Log using invoiced cost for each customer's system
Amount of water quality impact / scale buildup	Understand tendency of scale to occur and whether condenser water should be provided directly to customers or via a heat exchanger	Monthly water quality tests (PPM, scale, etc.) in various parts of the network
Occupant comfort / space conditioning	Understand customers' satisfaction levels with the GSHP condenser water service	Surveys
Schedules and timeline for project phases	Better understand time requirements for customer acquisition, equipment and labor procurement, and construction activities across a range of installation types	Information logged during course of project management

4 Site Selection

As briefly discussed in Section 3.3, site selection is a critical component to ensure a successful networked geothermal project. Buro Happold has conducted an initial site selection analysis for three potential systems in the City of Somerville based on discussions with the City's project team. The three sites include the neighborhoods of Ten Hills, Central Hill, and a mixed-use corridor along Somerville Avenue.

4.1 Geospatial Review

Somerville is the densest city in New England,[23] and while urban density is an indicator for viability of cost-effective networked geothermal deployment, there are also challenges to constructing a new pipe network alongside critical infrastructure and other urban systems. Given the Kickstart program's emphasis on introducing these systems to underserved and energy burdened communities, it was essential to equally consider the technical and social factors that inform site selection.

Buro Happold's 2024 feasibility study utilized Geographic Information System (GIS) to map above- and below-ground obstructions to identify where piping, boreholes, and other central infrastructure could be sited to deliver thermal energy to buildings along the network. These mapping tools were used to determine if obstructions would be prohibitive at a given site. Figure 4-1 shows a map of Somerville overlaid with key obstructions used to screen the sites. This data included existing natural gas pipelines, electrical transmission lines, sewer gravity mains, water distribution lines, highways, and commuter rail lines.[24,25] In addition to the technical data pulled for this mapping exercise, additional data was sourced from HEET's existing "Learning from the Ground Up" (LeGUp) mapping tool, which includes information related to site selection criteria such as environmental justice communities, household income, energy cost burden, gas leaks, and asthma prevalence.[26]

Following the mapping exercise, facilities that had the potential to contribute waste heat sources were identified using Google Maps and included locations such as ice rinks, grocery stores, and manufacturing facilities, as well as thermal reservoirs like the Mystic River that

[23] Massachusetts Municipal Association. "Somerville." https://www.mma.org/community/somerville/
[24] U.S. EIA. "Natural gas interstate and intrastate pipelines." https://hifld-geoplatform.hub.arcgis.com/datasets/geoplatform::natural-gas-interstate-and-intrastate-pipelines/about
[25] U.S. EIA. "Transmission Lines." https://hifld-geoplatform.hub.arcgis.com/datasets/geoplatform::transmission-lines/about
[26] HEET. "Learning from the Ground Up." https://bucas.maps.arcgis.com/apps/instant/portfolio/index.html?appid=ff46ea51bfc243a0935c4b6d8f50535c

could provide additional network capacity. Building typologies were mapped across the city to evaluate neighborhoods with more diverse residential and commercial building composition to capitalize on thermal load diversity.

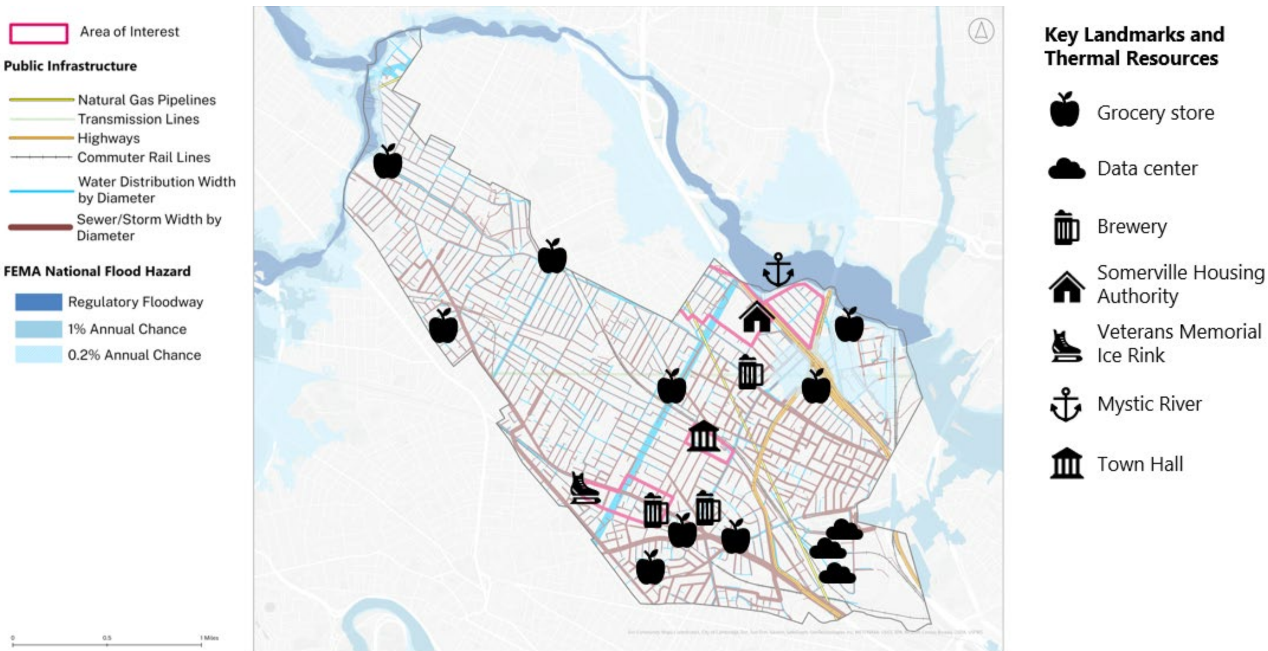


Figure 4-1. Public infrastructure interference and flood zone mapping in Somerville.

4.2 Ten Hills

Ten Hills – a neighborhood located north of the Interstate 93 freeway – is dominated by a large portion of residential buildings (Figure 4-2). Eleven more buildings owned by the Somerville Housing Authority located south of the freeway were incorporated into this site. The overall site contains open spaces well suited for borefield installation and central pump housing within the parcel areas of Somerville Housing Authority and within greenspaces bordering the Mystic River. The Mystic River could also be integrated into the system and used as a heat source.

Figure 4-2. Boundaries for the Ten Hills neighborhood.

4.3 Central Somerville Avenue

The Central Somerville Avenue site consists of about 350 buildings and has several opportunities to leverage waste heat as part of a network design (Figure 4-3). Buildings including Founders and Veterans Memorial ice rinks, Market Basket grocery store, Aeronaut Brewing Company, and several light industrial facilities associated with Greentown Labs. Surrounding these buildings are a blend of retail, restaurants, along with single- and multi-family housing.

Figure 4-3. Boundaries for the Central Somerville Avenue neighborhood.

4.4 Central Hill

Central Hill comprises a mix of 285 retail, office, single- and multi-family residential buildings, as well as key public facilities such as City Hall, Somerville High School, and Somerville Public Library. A local YMCA, which includes a large swimming pool and expects to undergo significant renovations in the near future is also located within this neighborhood.

As shown in Figure 4-4, there is a limited amount of greenspace and open parking lots surrounding the municipal buildings. The neighborhood is split by the Massachusetts Bay Transportation Authority (MBTA) Green Line, which could introduce potential challenges related to network routing, borehole drilling, or siting of a central pump house. Inclined drilling, similar to the approach used in Framingham, could be employed to minimize surface-level interference. If the geothermal borefield were extended to the north of the MBTA line to increase the thermal capacity of this system, additional permitting would be required to connect the northern borefield to the south.

Figure 4-4. Boundaries for the Central Hill neighborhood.

Further investigation of each site's existing infrastructure, geological conditions related to drillability, and borefield design are discussed in Section 6.

5 Stakeholder Engagement and Response

To date, the city engaged the public on the prospect of networked geothermal in two main ways: educating residents living in study areas about the prospect of networked geothermal and ways they can support the study, and engaging the broader Somerville community about networked geothermal; increasing awareness and interest. Due to the high turnover rates of Somerville's population, and the longer timelines associated with potential networked geothermal systems, engagement efforts were focused on citywide education and engagement.

To target residents living within the study areas, postcards and doorhangers of information about the technology were sent to residents (approximately 890 households). These print materials communicated information about networked geothermal and invited residents to two virtual town hall meetings.

To target all city residents, information about the initiative was distributed to the entire community through the city's main information channel as well as Somerville's Office of Sustainability and Environment community newsletter and social media channels.[27] Additional in-person engagement occurred at the onset of the project with tabling at the Somerville Winter Farmers Market. City staff engaged interested residents with an interactive diagram of networked geothermal systems in heating and cooling seasons; increasing knowledge and interest within the community at large.

All engagement efforts led to two virtual community town hall-style meetings. These were held December 9, 2024, and January 8, 2025, with approximately 100 community attendees total. Both virtual meetings covered an introduction to the project, "Networked Geothermal 101," current energy efficiency opportunities in Somerville, and ended with Q&A. Resident attendees had many questions showing interest and excitement at the prospect of networked geothermal.

An additional public engagement meeting took place on March 25, 2025, in which the results of the feasibility study was shared with the public for comment. This meeting was also advertised broadly to the public through electronic channels, through fliers posted around the city, and through a mailing to approximately 890 households within the study areas.

[27] City of Somerville. https://www.somervillema.gov/news/help-somerville-explore-new-clean-energy-technology-joining-upcoming-community-meetings

In addition to these meetings, the city also prepared a survey to gather information about the building stock of residents living in each study area, as existing building conditions can inform the level of complexity needed to retrofit a building to be compatible with a networked geothermal system. The survey to date has received approximately 220 responses from the Somerville community with approximately two dozen responses including specific household information responding to questions related to:

- Current heating fuel (space heating and domestic hot water)
- Existing HVAC systems (for both cooling and heating)
- Mass Save home energy assessment history
- Request to share utility data from Eversource or National Grid

The initiative of investigating the possibilities of networked geothermal in Somerville has been a major element of the city's recent messaging regarding environmental initiatives and was included in the Mayor's mid-term address as well as being included in citywide informational newsletters that were distributed broadly to the public.

6 Techno-Economic Analysis

6.1 Environmental Review

6.1.1 Geology and Hydrogeology

Geology in the Somerville area generally consists of the Cambridge Argillite formation which extends throughout Middlesex as well as Essex, Norfolk, Plymouth, and Suffolk counties. Argillite is a mudstone categorized as a metasedimentary rock. In addition to argillite, the formation also includes regions of quartzite, sandstone, and shale bedrock. Bedrock is typically covered by a layer of unconsolidated materials such as sand, clay, soil, and glacial till. This material is generally referred to as overburden and can range from a few feet to hundreds of feet in thickness in some areas.

Data was reviewed from test wells in the area, focusing mostly on those recorded within Somerville and the nearby town of Cambridge, MA. Because geology can be highly variable even across small distances, proximity of test wells to the site is important when considering the relevance of the reference data. Table 6-1 summarizes relevant lithological descriptions from well log data.

Table 6-1. Reference well log data, ordered by relative distance from Somerville.

Well Address	Location	Well Depth (ft)	Depth to Bedrock (ft)	Overburden	Bedrock	Depth to Water (ft)	Water Production
34 Richardson Street	Somerville	300	44	Till, clay	Shale	60	25 gpm @ 300 feet
30 Bryant Street	Cambridge	1,005	60	Gravel, clay	Argillite	30	3 gpm @1,005 feet
71 Washington Avenue	Cambridge	900	120	Unknown	Unknown	63	50 gpm @ 120 feet
8 Garden Street	Cambridge	1,500	81	Sand, gravel, till	Gabbro	Unknown	Unknown
105 Brattle Street	Cambridge	1,100	70	Unknown	Unknown	30	150 gpm @ 1,100 feet
14 Clinton Street	Cambridge	840	60	Till, clay	Shale, schist	23	3 gpm @ 37 feet
90 Mt. Auburn Street	Cambridge	450	55	Unknown	Unknown	50	150 gpm @ 450 feet

These reference well logs indicate a moderate amount of overburden (40-100 feet) primarily consisting of till and clay. Below the overburden, several types of bedrock were reported including shale, argillite, schist, and gabbro. These bedrock formations begin at depths ranging from 44 to 120 feet and continue to depth. This has positive implications for drilling costs; less overburden means that less steel casing is needed to maintain borehole integrity. Steel casing is discussed further in the next section.

There is potential for water production in this geology. The reference well logs report static water levels at 30-60 feet below the surface and production rates ranging from 3 to 150 gallons per minute (gpm) at depth.

6.1.2 Implications for Drilling

Mud rotary drilling would likely be utilized in the overburden as it is the most common and effective approach when drilling through till and clay. Steel casing is typically installed from the top of the borehole until bedrock is reached to maintain hole integrity. After encountering bedrock, the drilling process is switched from mud to air drilling, which is the most common method when drilling in bedrock. In cases where the top layer of bedrock is less competent due to weathering, additional steel casing can also be used to keep the borehole open until harder, more competent rock is reached.

In water bearing formations, air drilling must be accompanied with a dewatering system to manage the produced water that surfaces with the drill cuttings. The water and cuttings are then pumped from the drill rig to a roll-off container where larger solids are allowed to settle out of the water before transferring the water to a weir tank to allow further settling of fine sediments. From there, it is common to run the water through a dual hose bag filter to reduce suspended particles to 50 microns or less.

After the water has been treated, it can be discharged to a sewer or storm drain at the site. Discharge permitting is required to utilize the public sewage system, which specifies requirements for treatment and water quality prior to discharge.

6.2 Infrastructure Review

6.2.1 Water Tunnel Clearance

Ten Hills

The Ten Hills area does not have any water tunnels running through it, so no areas will need to be avoided for drilling due to water tunnel setbacks.

Central Somerville Avenue

The Central Somerville Avenue location has two water tunnels running in the proposed area, one just north of Somerville Avenue and the other along Laurel Street and below Aeronaut Brewing Company. The State of Massachusetts restricts drilling within 50 feet of a water tunnel. This 50-foot setback does not cross into any of the areas considered for drilling, so there are no concerns related to water tunnels with drilling in the area. Figure 6-1 shows the location of the water tunnels relative to the Central Somerville Avenue area.

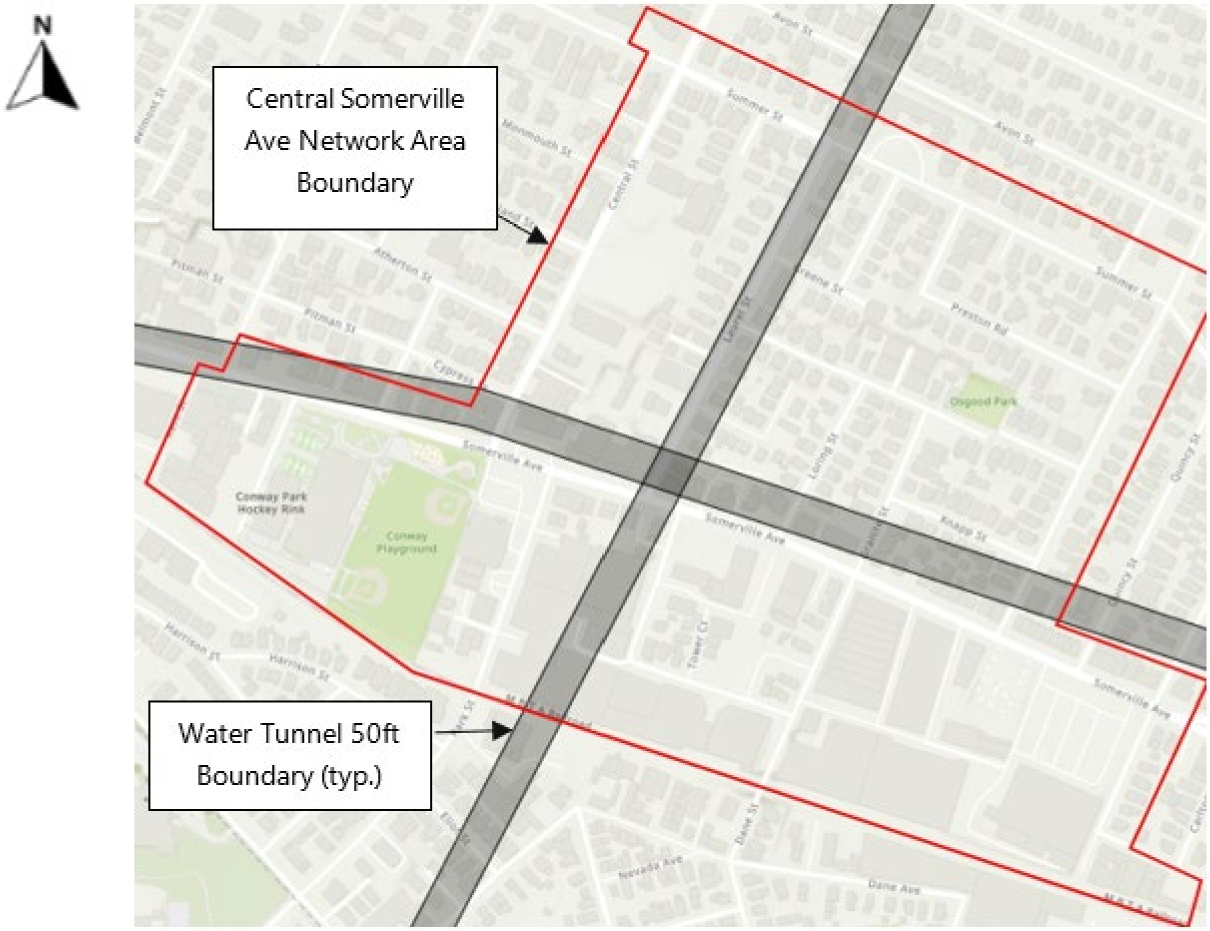


Figure 6-1. Central Hill water tunnel setbacks.

Central Hill

A water tunnel runs through southeastern Central Hill near the Somerville Public Library. The 50-foot setback around the water tunnel prohibits drilling boreholes in the green space south of the library. A second water tunnel runs along Sycamore Street; this area did not have any drillable areas identified, so there are no concerns with water tunnel interference. Figure 6-2 shows the location of the water tunnels relative to the Central Hill area.

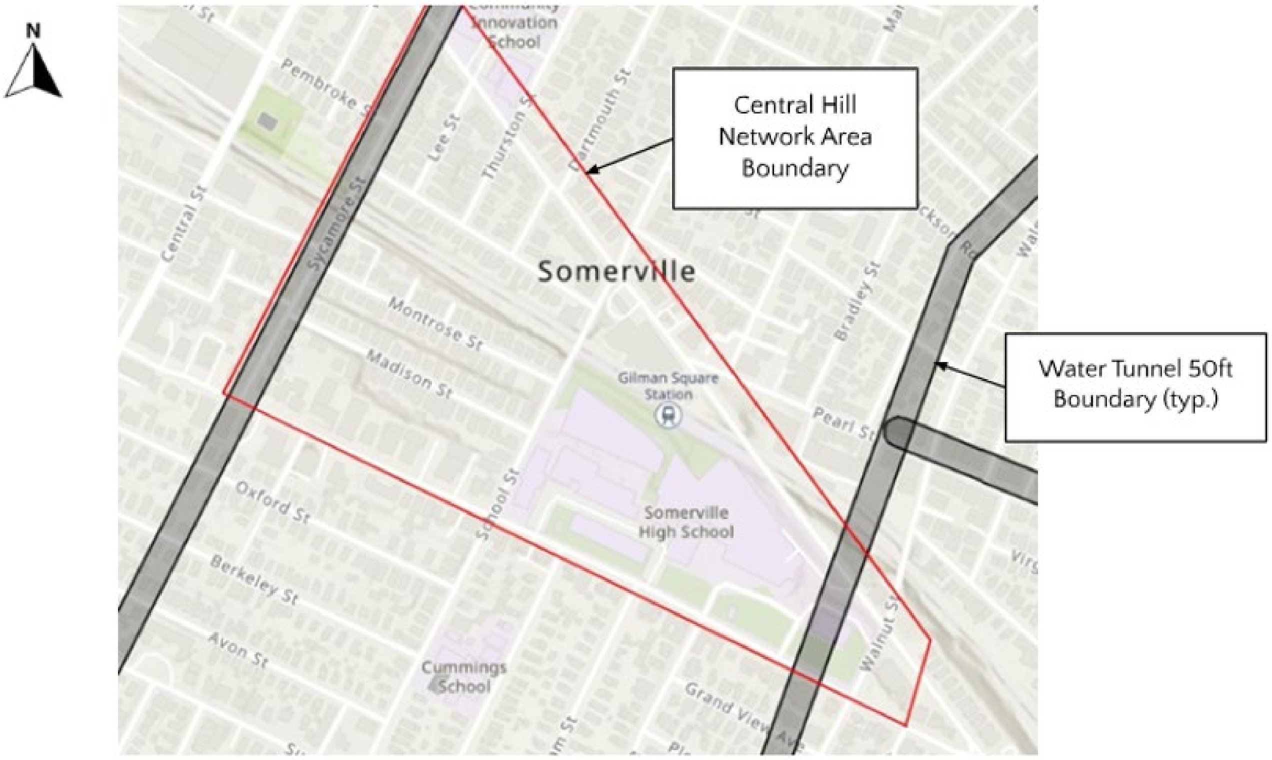


Figure 6-2. Central Hill water tunnel setbacks.

6.2.2 Underground Utilities

Further research into the locations of other utilities, such as sewer, water, electric, and gas lines will be required and identified in the field to avoid during drilling. It is standard to perform a ground-penetrating radar (GPR) test and survey during the design phase of a project to confirm the accuracy of existing drawings and confirm underground utility locations prior to drilling. A GPR test utilizes ground-penetrating radar to non-intrusively survey any infrastructure or utilities buried beneath the ground. Brightcore performs GPR tests on a majority of its drilling projects and has extensive experience with interpreting the test results to identify and avoid underground infrastructure during drilling.

6.2.3 Additional Infrastructure Considerations

Ten Hills – Interstate 93 Clearance

Interstate 93 runs through the center of the Ten Hills area. Because this portion of I-93 is an elevated highway, there are no concerns with impacting its use during drilling. However, if the lot beneath the highway were to be used for drilling, the United States Department of Transportation (USDOT) would need to be contacted in advance to confirm the area could be used. Drilling near the supports for the highway in this area is likely restricted; a 10-foot setback has been maintained from all support elements during borefield design. Additionally, vibration monitoring may be required during drilling to confirm there is no impact on the highway above. Brightcore has implemented vibration monitoring on projects in the past and does not anticipate any concerns with vibration impact on existing infrastructure.

Central Somerville Avenue

The Central Somerville Avenue location does not have any additional infrastructure that would impact drilling in the area.

Central Hill – MBTA Railway

The Massachusetts Bay Transportation Authority (MBTA) Green Line and Lowell commuter rail line both run through the Central Hill area to the north of Somerville High School. The MBTA requires a permit if work is performed within 30 feet of their property line (designated as the MBTA Zone of Influence). This permit requires construction documents to be provided to the MBTA for a review of the proposed work to ensure there will be no impact on their infrastructure. During borefield design, a 50-foot setback from the railway was added to avoid any potential for interference.

6.3 Drilling Logistics

6.3.1 Drill Rig

The GTD GT35 (shown in Figure 6-3) or Comacchio GEO 600 drill rigs are ideal for drilling throughout the Somerville area. These track mounted drill rigs are capable of both mud rotary and percussive air rotary drilling, both of which will be necessary for geothermal well installation in this area.

Figure 6-3. GTD GT 35 drill rig.

6.3.2 Drillable Areas

Ten Hills

Ten Hills does not have any large green spaces within its area for substantial drilling. However, the City of Somerville is considering engaging with the U.S. Department of Transportation about drilling beneath the raised highway I-93 nearby. If this is possible, there is a large area beneath the highway that could be used for drilling. To the east of the raised highway there is also a public right of way that could be used for additional drilling but would require removal and future replanting of the trees in that right of way. Additionally, there is space for drilling in the parking lots and courtyards of the Somerville Housing Authority complex. Utilizing inclined drilling techniques could allow for a significant amount of load to be captured from these areas.

Central Somerville Avenue

There are several areas throughout Central Somerville Avenue that could be used as drillable areas. The parking lot to the west of Founders Memorial Rink and the small parking areas to the south and east of Veterans Memorial Rink could be used for drilling. Drilling within nearby Conway Field was not considered as it was previously a brownfield site with potential contaminants, as well as stormwater collection being located beneath the field. The parking lot for St. Anthony's Church in the center of the area also provides ample area for drilling to contribute to the network's available thermal energy. Additionally, the Market

Basket grocery store along Somerville Avenue has a large parking lot that could be used as a drilling location and provide significant capacity to the network. It should be noted that St. Anthony's Church and the Market Basket grocery store are private property while the ice rinks are owned by the state. Gaining rights to use underground areas of the property will require engaging the property owners to come to an agreement.

Finally, it is possible to extract waste heat from the nearby Veterans Memorial Rink complex, Aeronaut Brewing Company, and Market Basket grocery store due to their high heat production from brewing and refrigeration. This waste heat can be utilized to better balance the load profile of the area, allowing the geothermal system to satisfy more of the network's heating and cooling loads. This waste heat is normally rejected to the air, so overall system efficiency and capacity can be increased if waste heat is utilized.

Central Hill

Central Hill has several moderately sized green spaces in front of City Hall, Somerville High School, the Public Library, and the 1895 Building; these areas are not viable for drilling due to monuments being installed in those green spaces. However, there are parking areas and walkways surrounding these green spaces that could be used for drilling, particularly in front of the 1895 Building and Somerville High School. Inclined drilling techniques could be used in these paved areas and allow for thermal energy to be extracted from the ground beneath these green spaces and the surrounding buildings.

To the north of Somerville High School, there is a large open lot that could also be used as a drillable area. The lot's proximity to MBTA train lines to the south and Medford Street to the north does not allow for inclined drilling to be used in this area, but the lot's large open area does allow for additional vertical bores to be installed, increasing the capacity of the system.

6.3.3 Accessibility

The GT35 and GEO 600 drill rigs that would be used for geothermal installation in the outdoor areas of this site measure at approximately 32-45 feet long, 8.5 feet wide, and 14 feet of overhead space is generally recommended during mobilization. During drilling, approximately 40 feet of overhead space is required.

Ten Hills

The parking lots of the Somerville Housing Authority buildings are easily accessible from Mystic Avenue, Temple Street, and Memorial Road, making it easy for the drill rig to drive into these areas. The courtyards of these buildings are also easily accessible from the surrounding roads and parking lots. Each of the courtyards have removable barriers preventing vehicles from driving into the space which could be quickly removed to allow the drill rig access. None of these areas have any overhead obstructions that would need to be avoided, and the spaces are open enough to allow the drill rig to maneuver from hole to hole with minimal concerns.

The area beneath highway I-93 is fenced off, but there are two gates that allow access – one on Temple Street beneath the highway and the other on Mystic Avenue near Grant Street – both of which the drill rig could drive through to reach the drillable area. Beneath the highway, the maximum clearance in some areas is as low as 12 feet, meaning the GT35 and GEO 600 drill rigs will not fit for mobilization or drilling. Brightcore's mini drill rig – the Comacchio MC 5D – would need to be used for drilling in this area. The mini drill rig requires only 9 feet of overhead space while drilling, allowing the full area beneath the highway to be used, as the area is open enough for there to be no concerns about maneuvering the rig during the drilling process.

Central Somerville Avenue

The lots near Founders Memorial Rink and Veterans Memorial Rink are easily accessible from Somerville Avenue. The parking lot to the west of Founders Memorial Rink has no overhead obstructions that would need to be avoided. The parking areas to the south and east of Veteran's Memorial Rink are small, and the lot to the south has a power line running through its center that would need to be avoided during mobilization and while moving the drill rig between boreholes. It is likely that Brightcore's mini drill rig – the Comacchio MC 5D – would be used for drilling in this area due to space constraints. The St. Anthony's Church parking lot is easily accessible from Tyler Street, as well as Somerville Avenue if a small fence were to be removed. The lot has no overhead obstructions that would need to be avoided during drilling. Finally, the Market Basket parking lot is easily accessible from Somerville Avenue with no overhead obstructions that would need to be avoided. The entrances to the parking lot are wide enough for the drill rig to drive into the lot easily.

Central Hill

Each of the outdoor drilling locations near City Hall and Somerville High School lie directly next to Highland Avenue, making it easy to drive a drill rig onto the proposed areas from the street or nearby parking lots. The open lot north of the high school lies along Medford Street, also allowing for easy access for the drill rig. There are no overhead obstructions in these areas that would need to be avoided during mobilization. Additionally, each of the proposed areas are open enough that there are no concerns about maneuvering the drill rig during the drilling process.

6.3.4 Water Sources and Wastewater Management

During drilling, water may be required at up to 100 gpm to operate mud rotary drilling equipment. Water can be sourced from a nearby fire hydrant or building water connection and must be connected to a pump staged near the drill rig. After being used for drilling, water that was used and produced mixes with the pulverized bedrock and becomes a slurry, which then must be settled and filtered prior to discharged. At the drill rig, a diverter is used to discharge slurry away from the drilling area via hose. Due to the pressures created during drilling, the slurry may flow directly to the dewatering area or may require a small booster pump to reach the dewatering area. Dewatering is accomplished with several pieces of water management equipment, typically consisting of several large weir tanks, a centrifuge, and filters used to separate sediment from the water. This equipment is typically staged near the drilling area. There are no concerns with flooding related to this water production, as the water is stored in these tanks and other pieces of equipment. The water discharge can be managed as necessary to avoid overloading the drainage system or transported off site if needed.

Once all sediments have been removed from the drilling water, it is discharged to the sewage or stormwater systems. Prior to discharge to any of these systems, appropriate permits would be obtained. Somerville has stormwater protection requirements for further treatment and testing to verify compliance with water quality criteria prior to discharge.[28] This may mean that water will need to be held onsite in the weir tank for an extended period prior to discharge. In a situation with high water production and strict filtration/testing criteria for discharge, multiple weir tanks may be required. Drill cuttings that are settled prior to water discharge may be repurposed onsite during the restoration process. Alternatively, if cuttings are required to be disposed off-site, a suite of analytical testing will be completed to characterize and document the waste prior to disposal at a licensed facility.

Ten Hills

There is a fire hydrant along the northeast side of Mystic Avenue that would be ideal for supplying water to any drilling performed underneath I-93. Alternatively, there are

[28] Somerville, MA. "Managing adverse impacts of stormwater runoff." https://library.municode.com/ma/somerville/codes/code_of_ordinances?nodeId=PTIICOOR_CH11PUWO_ARTVIDIEN_S11-146MAADIMSTRU

additional hydrants along the northeast side of Bailey Road on the other side of the highway that could be used as water supplies, but these would require piping to cross the road, which adds additional logistics. There are storm drains along the northeast side of Mystic Avenue, the southeast side of Temple Street, and the southwest side of Bailey Road, all of which could be used to discharge water.

The Somerville Housing Authority area has several fire hydrants throughout, including in the Mystic Activity Center parking lot, along Memorial Road, and within some of the buildings' courtyards, all of which could be used to supply water for drilling. Some of the drillable areas would require piping to be run across the street, which requires additional logistics such as trenching the street, but is still feasible to supply those areas with water. The Mystic Activity Center and many of the Somerville Housing Authority parking lots, as well as the southwest side of Mystic Avenue have plenty of storm drains that could be used for water discharge after the dewatering process.

Central Somerville Avenue

In the lot west of Founders Memorial Rink there is a fire hydrant that could be used to supply water for all drilling in that area. There are storm drains throughout the lot as well as along Somerville Avenue that could be used to water discharge.

For the lots east and south of Veteran's Memorial Rink, a fire hydrant near the green space in front of the rink along Somerville Avenue could be used as a water supply. There is a storm drain on the south side of Somerville Avenue near Conway Park that would be ideal for water discharge.

In the St. Anthony's parking lot, a fire hydrant along Somerville Avenue could be used to supply water to the drill rig. Storm drains located throughout the parking lot as well as just outside the lot on Somerville Avenue could be used for clean water discharge.

At the Market Basket location, there is a fire hydrant on the corner of Somerville Avenue and Church Street that would be ideal for supplying water to the drill rig. Additionally, there is a storm drain at the east entrance to the parking lot and another on the west side of Church Street, both of which could be used for discharging water during drilling.

Central Hill

Along the north side of Highland Avenue there are several fire hydrants that are close to each of the potential drilling areas along that street that could be used. There are also several hydrants in the nearby parking lots that could supply water. Fire hydrants are also located along the north side of Medford Street which could be used to supply water to the empty lot near the street. Alternatively, water could be supplied from a connection point on one of the nearby city buildings. An initial site assessment did not identify any direct water supplies from the municipal buildings, but these could be investigated in the future.

Each of the parking lots along Highland Avenue have storm drainage that could be used for clean water discharge, as well as storm drains along Highland Avenue itself. There are also several storm drains and sewer connections along Medford Street that could be used for clean water discharge from the empty lot.

6.3.5 Loop and Grout

Following the drilling of each borehole, a factory assembled 1-1/4" diameter high-density polyethylene (HDPE) geothermal U-bend pipe will be installed to the bottom of the borehole which could extend to 500 feet or beyond. The annulus between the loop and interior of the borehole will be filled with thermally enhanced grout utilizing tremie grouting techniques. The purpose of the grout is to promote heat exchange between the heat transfer fluid within the loop and the surrounding geology within the borehole.

6.3.6 Lateral Piping Installation

Following the installation of the downhole loops, the HDPE pipes are connected to the lateral piping circuit at the surface. These circuits are typically installed by trenching portions of the street and parking areas, installing the lateral piping beneath the frost line, and restoring the street above them.

6.3.7 Manifold

All lateral piping is connected at a geothermal manifold located adjacent to the borefield or within the mechanical space. For this project, the manifold could be located within any of the city owned buildings in the area, or within a new structure constructed to house the manifold and other pump equipment. All geothermal piping will be filled with heat transfer fluid, which would be either water or a water/propylene glycol mix to allow the system to function below freezing temperatures. From the manifold, larger pipes are connected into the mechanical system to allow the heat transfer fluid to be used for heating and cooling applications. For individual residences with heat pumps, the geothermal piping connects directly to the residence's heat pumps or heat exchangers.

6.4 Borefield Design

6.4.1 Drilling Depth

Based on Brightcore's previous drilling experience in this area, the optimal drilling depth is 500 feet below the surface. Thus, the borefield design was limited to 500 feet below ground surface. Both the GTD GT35 and Comacchio GEO 600 drill rigs are capable of inclined drilling, which allows for thermal capacity to be accessed from areas which are not drillable from the surface. This technique can be utilized in many of the drillable areas at each of the three considered locations, allowing for thermal capacity below surrounding buildings and green spaces to be captured. This concept is illustrated in Figure 6-4.

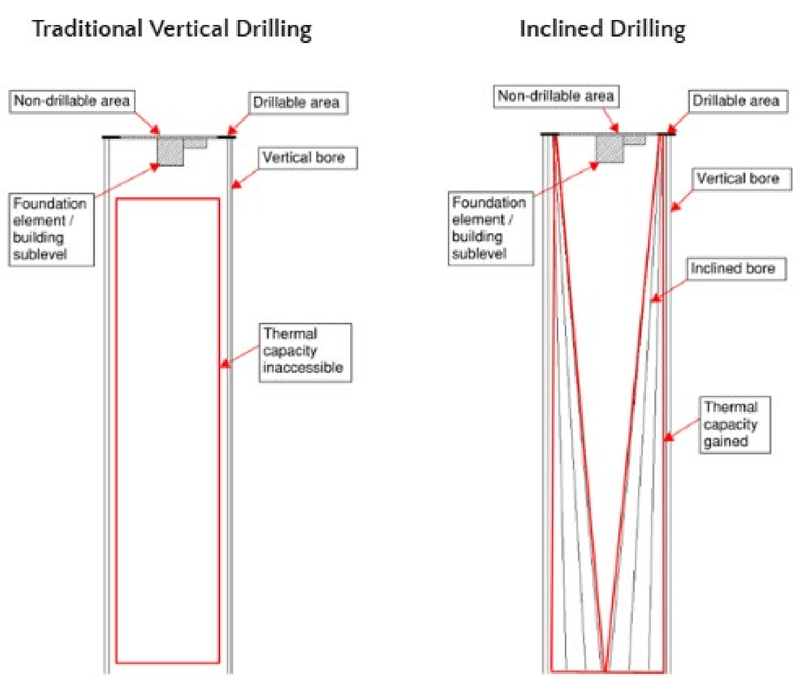


Figure 6-4. Concept diagram of inclined drilling.

6.4.2 Preliminary Borefield Layout

Brightcore analyzed each of the drillable areas identified at each proposed site and attempted to maximize the number of boreholes that could be installed within those areas. To avoid thermal interference between boreholes, vertically installed boreholes were spaced a minimum of 20 feet apart. Inclined boreholes were given a minimum spacing of 5 feet, though typically they were spaced 10 feet apart to minimize interference with nearby boreholes.

Ten Hills

In the Ten Hills area, it was determined that 421 boreholes can be located throughout the Somerville Housing Authority complex, utilizing drilling in both courtyard and parking lot areas. This configuration includes a combination of vertical and inclined boreholes. Additionally, it was determined that 95 vertical boreholes could be drilled beneath the I-93 raised highway. This means that a total of 516 boreholes could be fit within the area. A preliminary layout of the borefield can be found in Appendix 8.2 at the end of this document. The number of boreholes in each location is also summarized in Table 6-2.

Table 6-2. Ten Hills borehole count by drillable area.

Drillable Area	Drillable Boreholes
Somerville Housing Authority complex	421
Beneath I-93 highway	95
Total	516

Central Somerville Avenue

It was determined that a total of 884 boreholes can be located throughout the Central Somerville Avenue network area. This includes 178 boreholes in the Founders Memorial Rink lot, 84 in the Veterans Memorial Rink lot, 178 in the St. Anthony’s Church lot, and 444 throughout the Market Basket parking lots. Each of these areas contain a combination of vertical and inclined boreholes. The preliminary layout of the borefield can be found in Appendix 8.2 at the end of this document. The number of boreholes in each location is also summarized in Table 6-3.

Table 6-3. Central Somerville Avenue borehole count by drillable area.

Drillable Area	Drillable Boreholes
Founders Memorial Rink lot	178
Veterans Memorial Rink lot	84
St. Anthony's Church lot	178
Market Basket front lot	325
Market Basket side lot	119
Total	884

Central Hill

A total of 240 boreholes were able to be located within the drillable areas in front of Somerville High School, City Hall, and the 1895 Building. This borefield configuration includes a combination of vertical and inclined boreholes. Additionally, it was determined that 72 vertical boreholes can be located within the open lot to the north of Somerville High School. This means that a total of 312 boreholes could be fit within the drillable areas at Central Hill. The preliminary layout of this borefield can be found in Appendix 8.2 at the end of this document. The number of boreholes in each location is also summarized in Table 6-4.

Table 6-4. Central Hill borehole count for each drillable area.

Drillable Area	Drillable Boreholes
Parking areas in front of Somerville High School, City Hall, and 1895 Building	240
Open lot on Medford Street	72
Total	312

6.5 Geothermal Capacity Model

6.5.1 System Loads

To develop an initial network design, building stock models from NREL's ComStock and ResStock datasets were used to develop preliminary estimates of building heating and cooling loads throughout each of the three study areas.[29][30] These datasets utilize traditional bottom-up, physics-based energy modelling tools and survey data on typical characteristics of the building stock in Somerville. As a result, these initial load estimates are not necessarily reflective of the true human interaction with building heating and cooling systems, which may vary between buildings and smooth out the differences in cumulative thermal loads. Additionally, these loads do not account for the expected rise in cooling demand that would result from a warming climate in the City of Somerville.

Ten Hills

The heating and cooling loads expected for the full Ten Hills area are summarized in Table 6-5 and shown graphically in Figure 6-5. These initial estimates indicate that the load profile for the area is highly heating dominant, having an annual heating usage approximately two times larger than the annual cooling usage.

Table 6-5. Ten Hills total heating and cooling loads.

	Total Load
Total Heating (kBTU)	31,978,581
Peak Heating (kBTU/hr)	21,963
Total Cooling (kBTU)	14,055,803
Peak Cooling (kBTU/hr)	9,567

[29], NREL. ComStock. https://comstock.nrel.gov/
[30] NREL. ResStock. https://resstock.nrel.gov/

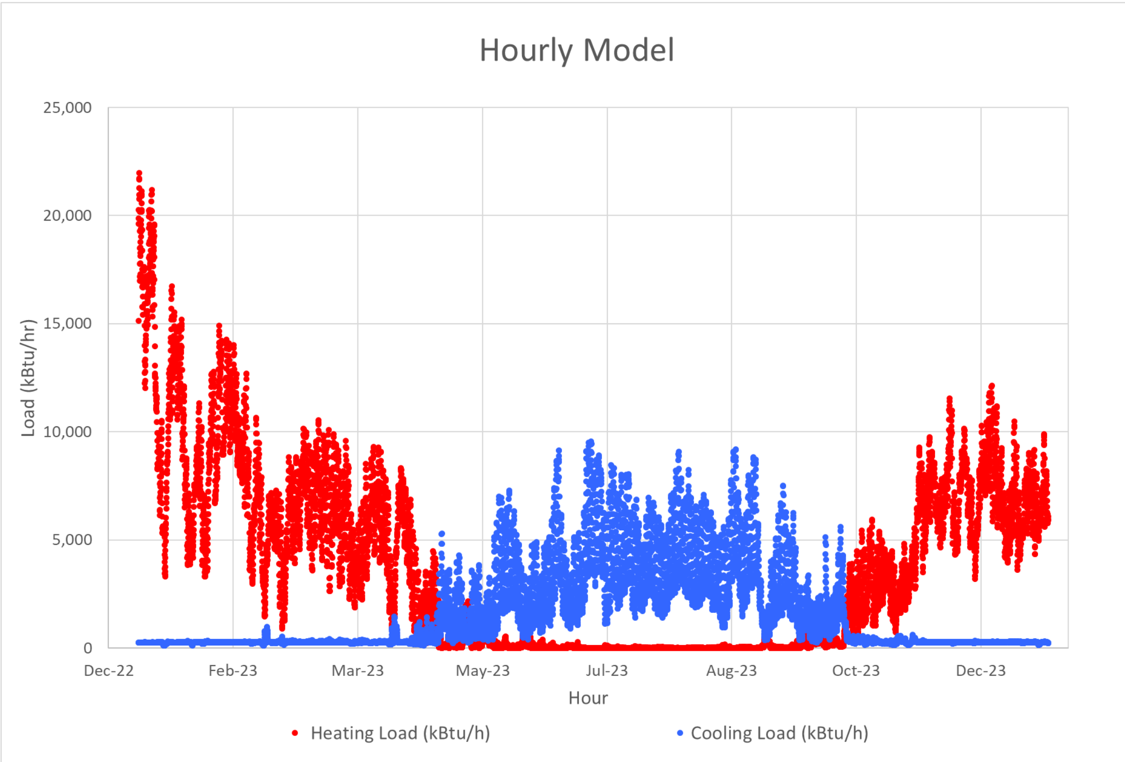


Figure 6-5. Ten Hills full load profile.

Central Somerville Avenue

The heating and cooling loads expected for the Central Somerville Avenue area are summarized in Table 6-6 and shown graphically in Figure 6-6. These results indicate that the load profile for the area is highly heating dominant, having an annual heating usage approximately 3 times larger than the annual cooling usage.

Table 6-6. Central Somerville Ave total heating and cooling loads.

	Total Load
Total Heating (kBTU)	72,701,486
Peak Heating (kBTU/hr)	50,455
Total Cooling (kBTU)	24,174,328
Peak Cooling (kBTU/hr)	15,957

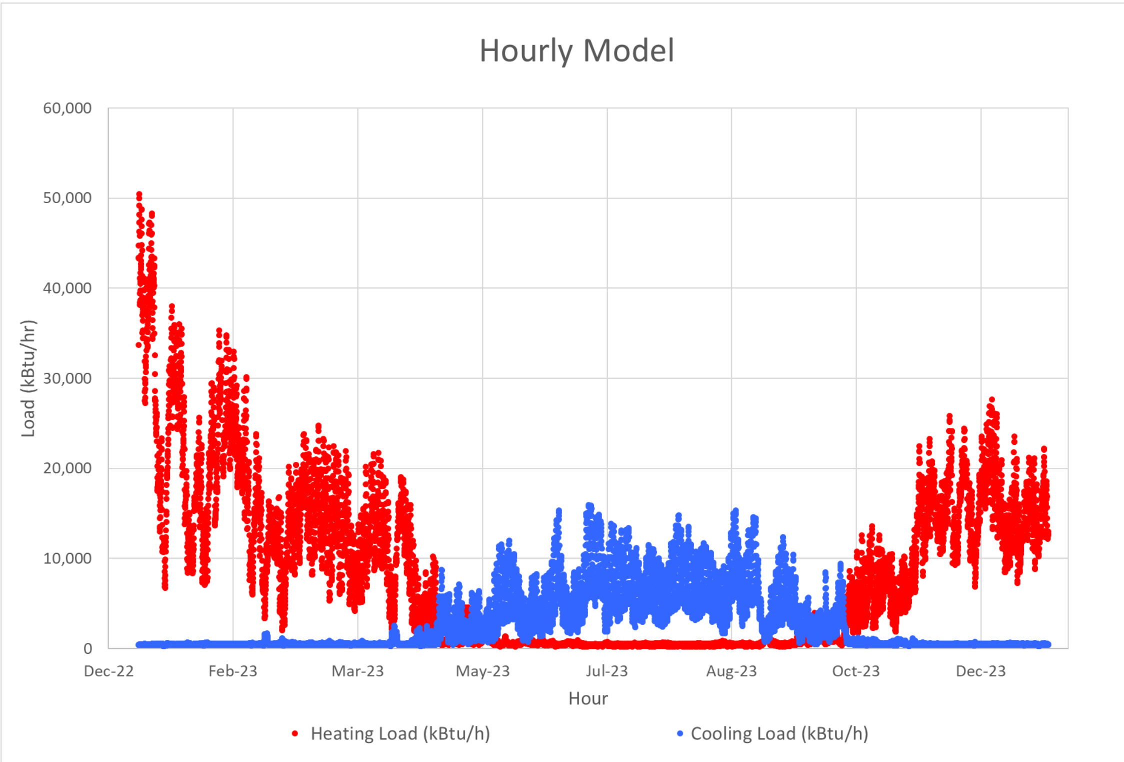


Figure 6-6. Central Somerville Ave full load profile.

The Central Somerville Avenue load profile also included waste heat extraction opportunities from the two ice rinks, the Market Basket grocery store, and the Aeronaut Brewing Company. These buildings produce a significant amount of waste heat due to their refrigeration requirements and the heat generated through the brewing process, which could be extracted to better balance the geothermal system and provide additional heating. The ice rinks and grocery store were modeled as operating 24/7 and maintaining an operating temperature of -17°C (1.4°F) with a 90% heat recovery efficiency. The brewery was modeled exhausting heat at 32°C (89.6°F) during operating hours (9AM – 5PM Monday through Friday) through a heat exchanger with a flow rate of 3,600 gallons per minute. The amount of waste heat available from each source is summarized in Table 6-7. The value for waste heat recovered from the brewery can vary significantly based on the flow rate and full load profile of the system; the maximum amount of waste heat extracted in the simulations discussed in this report is the value reported in Table 6-7, but could potentially be increased if different variables were adjusted.

Table 6-7. Central Somerville Avenue waste heat summary.

Location	Annual Waste Heat Available (kBTU)
Ice Rinks	11,075,738
Market Basket Grocery Store	2,710,937
Aeronaut Brewing Company	34,916,949

Central Hill

The heating and cooling loads expected for the full Central Hill area are summarized in Table 6-8 and shown graphically in Figure 6-7. These results indicate that the load profile for the area is highly heating dominant, having an annual heating usage almost 5 times larger than the annual cooling usage.

Table 6-8. Central Hill total heating and cooling loads.

	Total Load
Total Heating (kBTU)	107,492,489
Peak Heating (kBTU/hr)	81,704
Total Cooling (kBTU)	22,953,232
Peak Cooling (kBTU/hr)	17,059

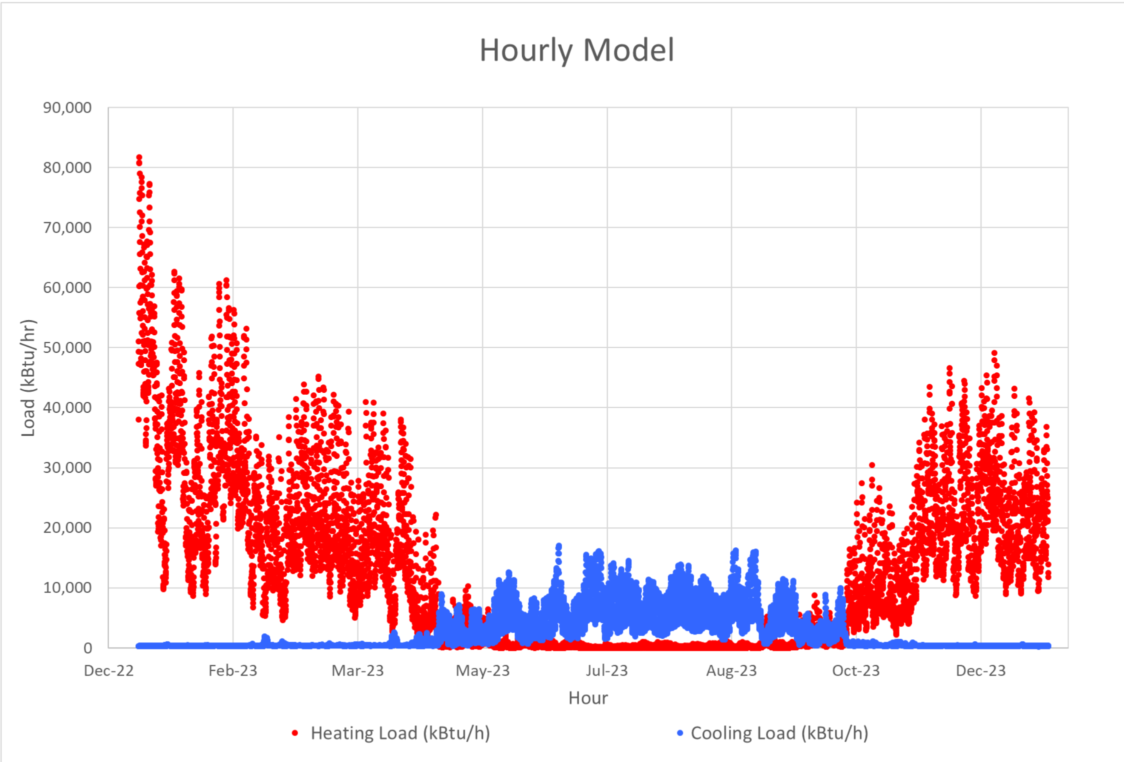


Figure 6-7. Central Hill full load profile.

6.5.2 Ten Hills System Modelling

Full System Load

In the Ten Hills area, Brightcore estimated the potential capacity of the borefield and what percentage of the total building load could be accommodated. The goal of this modelling exercise was to optimize the borefield thermal capacity and keep the entering water temperatures (EWTs) between 25°F and 90°F over a 25-year period. To meet these requirements, the peak load for each hour was reduced or "shaved" to a certain percentage of the total building peak, where the shaved load would require auxiliary sources of thermal energy to meet total demands. Due to the imbalance in the heating and cooling loads, this leads to a significant reduction of the heating load, but no shaving required on the cooling load. A summary of the shaved loads and their percentage of the total area load are summarized in Table 6-9 and shown graphically in Figure 6-8.

Table 6-9. Ten Hills loads handled by geothermal.

	Shaved Load	Percentage of Total Load
Annual Heating (kBTU)	25,152,617	79%
Peak Heating (kBTU/hr)	6,369	29%
Annual Cooling (kBTU)	14,055,803	100%
Peak Cooling (kBTU/hr)	9,567	100%

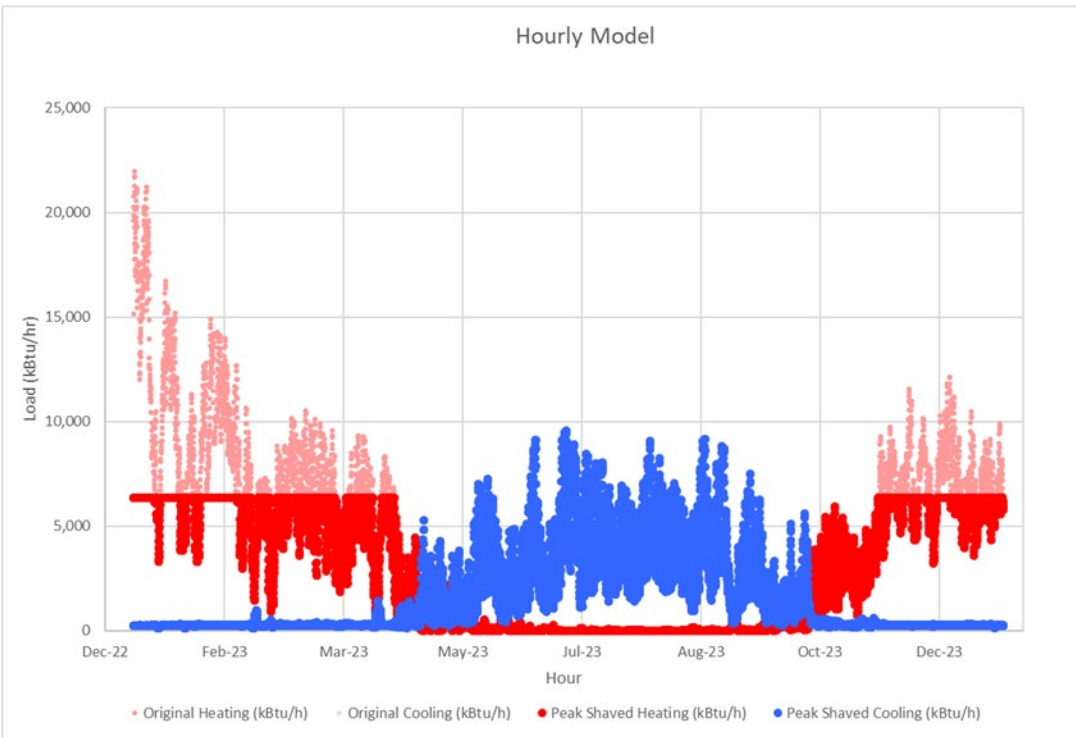


Figure 6-8. Ten Hills shaved load.

Because the limiting factor of this geothermal system is maintaining balance of the borefield, not all 516 bores laid out in the available drilling area are required to meet these loads. Th modelling exercise found that this system could maintain balance and cover the above loads using only 238 boreholes. This means that drilling beneath I-93 would not be required, and the boreholes drilled at the Somerville Housing Authority could be less compact, leading to fewer logistical issues with drilling. The results of this modelling show that a geothermal network installed in the Ten Hills area could cover the full cooling load of the network, but supplemental sources of heating would be required to cover the remaining heating load not supplied by the geothermal system.

There are several options available to supplement heating. Sources of waste heat could be located within the Ten Hills area to be integrated into the full hybrid system. While there are no significant direct producers of waste heat within the area, it may be possible to extract waste heat from the municipal sewer system if sufficient sewer piping is located near the network. Solar thermal may be another option for providing additional heating to the network in which their panels could be installed on the available roof space at the Somerville Housing Authority complex and subsequently use solar energy to generate heat for inclusion in the broader network. Additionally, the proximity of the Mystic River to the Ten Hills area opens the possibility of using the river as a heat exchanger, allowing energy from the river to be used to satisfy portions of the system's load. Existing heating systems in the larger buildings on the network, such as the existing gas fired heaters at the Somerville Housing Authority, could also be used to better balance the system loads. These heating sources could be used to heat the Housing Authority buildings when necessary and be used to inject heat into the geothermal loop at other times to supply heat to the rest of the network. A final option for supplemental heating is installing additional heating elements in the geothermal heat pumps in each building in the network. These systems would be run only when the geothermal cannot meet the full heating load to cover any remaining heating requirement of a building. To fully supplement the heating load of the Ten Hills area, approximately 15,600 kBTU/hour of heating would be required in addition to the geothermal system.

Regardless of the method chosen to balance the network, there are minimal risks to the long-term performance of the system. The main considerations for this type of hybridized approach concern the proper commissioning of controls needed to turn on the supplemental heating systems when necessary and their impacts on the system's overall capital expenditure.

6.5.3 Central Somerville Avenue System Modelling

Full System Load, No Waste Heat

At Central Somerville Avenue, Brightcore estimated the potential capacity of the borefield and what percentage of the total building load could be accommodated without the inclusion of waste heat. The goal of this modelling exercise was to optimize the borefield thermal capacity and keep the EWTs between 25°F and 90°F over a 25-year period. To meet these requirements, the peak load for each hour was reduced or "shaved" to a certain percentage of the total building peak. Due to the imbalance in the heating and cooling loads, this leads to a significant reduction of the heating load, but no shaving required on the cooling load. A summary of the shaved loads and their percentage of the total area load are summarized in Table 6-10 and shown graphically in Figure 6-9.

Table 6-10. Central Somerville Avenue loads handled by geothermal.

	Shaved Load	Percentage of Total Load
Annual Heating (kBTU)	42,229,663	58%
Peak Heating (kBTU/hr)	9,082	18%
Annual Cooling (kBTU)	24,174,328	100%
Peak Cooling (kBTU/hr)	15,957	100%

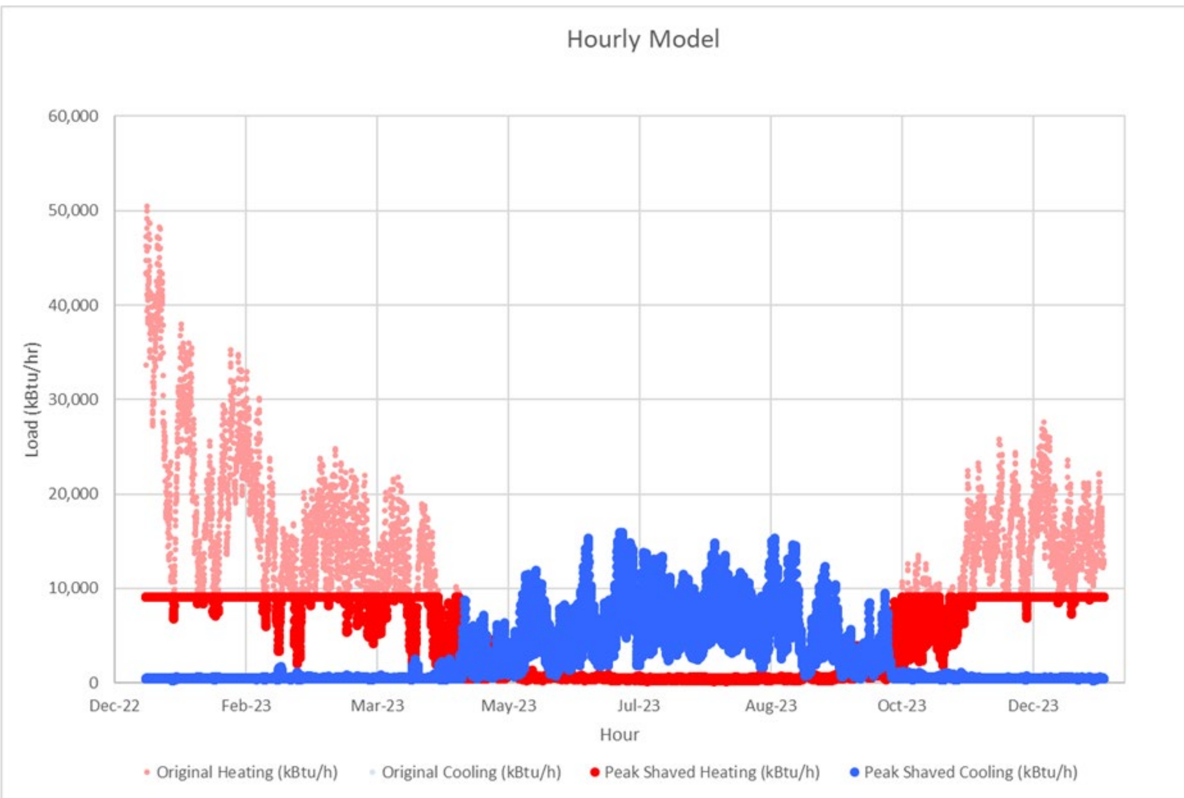


Figure 6-9. Central Somerville Ave shaved loads.

Because the limiting factor of this geothermal system is maintaining balance of the borefield (i.e., ensuring that the amount of heating and cooling pulled from the ground is relatively equal on an annual basis), not all 884 bores laid out in the available drilling area are required to meet these loads. The modelling found that this system could maintain balance and cover the above loads using only 360 boreholes. This allows for eliminating drilling in some areas identified in the original design, and areas that are chosen for drilling could be done so less compactly, leading to fewer logistical issues while drilling.

The results of this modelling show that a geothermal network installed at Central Somerville Avenue could cover the full cooling load of the network, but supplemental sources of heating would be required to cover the remaining heating load not supplied by the geothermal system.

Solar thermal may be one option for providing additional heating to the network. Solar thermal panels could be installed on the available roof space of the commercial building and the ice rinks in the area. These solar thermal panels use solar energy to generate heat, which could then be used to heat the network. Additionally, waste heat from the municipal sewer system could be extracted as an additional heat source if sufficient sewer piping is located near the network.

However, there are several supplemental waste heat sources in the Central Somerville Avenue area. As discussed previously, the ice rinks, Market Basket grocery store, and Aeronaut Brewing Company produce significant amounts of waste heat that could supplement the geothermal system to provide additional heating to the network. This option is analyzed further in the following section.

Full System Load, Including Waste Heat

Waste heat was estimated using industry assumptions and desktop research for the ice rinks, Market Basket grocery store, and Aeronaut Brewing Company in the Central Somerville Avenue area to generate load profiles for waste heat recovery from each source. These waste heat profiles were then used to better balance the geothermal borefield and accommodate additional loads in the network. Simulations determined that the waste heat available from the brewery alone was sufficient to fully balance the system and allow the area's full load to be accommodated by the hybridized geothermal system. A summary of the loads that can be handled by this system are summarized in Table 6-11.

Table 6-11. Central Somerville Ave loads handled by hybrid geothermal system with waste heat recovery.

	Shaved Load	Percentage of Total Load
Annual Heating (kBTU)	72,701,486	100%
Peak Heating (kBTU/hr)	50,455	100%
Annual Cooling (kBTU)	24,174,328	100%
Peak Cooling (kBTU/hr)	15,957	100%

The amount of waste heat available from all sources in the area was found to be greater than what was needed to balance the borefield and cover the area's full heating and cooling loads. Thus, it is possible that additional buildings in the area could be added to the network and utilize this excess waste heat to further balance the borefield and handle additional loads.

Because the load covered by the geothermal system increased significantly compared to the shaved scenario, the number of boreholes required to handle this load also increased. An initial model of this scenario determined that 850 boreholes would be required to handle the full load, which is below the 884 bores that were found to fit within the area. However, the limiting factor of this model was the ground becoming too cold during the simulation's first winter, which is when models typically begin. By shifting starting the system until June, the full system load could be handled by only 790 boreholes. Decreasing the borehole count in this way would reduce the overall cost of the system without any long-term effects on system stability.

Figure 6-10 displays the geothermal fluid temperature over a 25-year period, showing that the entering water temperature remains within the 25°F and 90°F limits defined previously and that the system will remain stable.

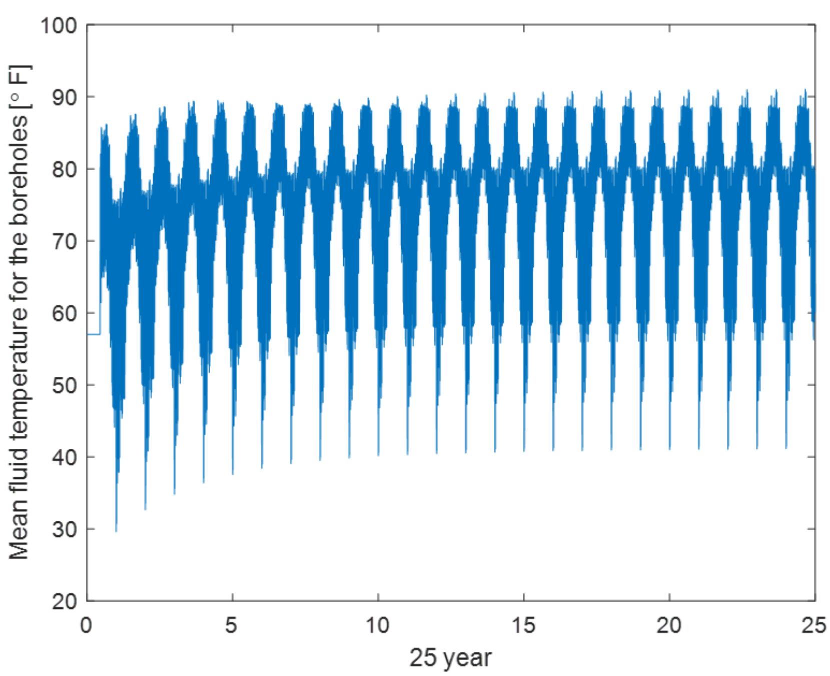


Figure 6-10. Central Somerville Ave hybrid system fluid temperatures.

The results of this modelling show that the full heating and cooling loads of the Central Somerville Avenue area can be accommodated by a hybridized network geothermal system using waste heat extracted from the Aeronaut Brewing Company. It should also be noted that waste heat could also be extracted from the ice rinks and grocery store, allowing the extraction required from the brewery to be lowered or allowing for additional heating applications such as snow melt to be implemented.

6.5.4 Central Hill System Modelling

Full System Load

In the Central Hill area, Brightcore estimated the potential capacity of the borefield and what percentage of the total building load could be accommodated. The goal of this modelling exercise was to optimize the borefield's thermal capacity and keep the EWTs between 25°F and 90°F over a 25-year period. To meet these requirements, the peak load for each hour was reduced or "shaved" to a certain percentage of the total building peak. The maximum thermal capacity of the borefield designed for this area was found to be able to cover a portion of the area's heating load and most of its cooling load; slight shaving of the cooling peaks on the hottest days was still required due to limitations on the size of the borefield. As a result, this borefield design leads to a significant reduction of the heating load, with only minor shaving performed on the cooling load. The heating load that geothermal can handle is larger than the cooling load due to the heat of compression generated by heat pumps during operation. This heat can be utilized for additional capacity during heating season but must be overcome by cooling further during cooling season. A summary of the shaved loads and their percentage of the total area load are summarized in Table 6-12 and shown graphically in Figure 6-11.

Table 6-12. Central Hill loads handled by geothermal.

	Shaved Load	Percentage of Total Load
Annual Heating (kBTU)	40,309,169	37%
Peak Heating (kBTU/hr)	8,170	10%
Annual Cooling (kBTU)	22,098,494	96%
Peak Cooling (kBTU/hr)	10,065	59%

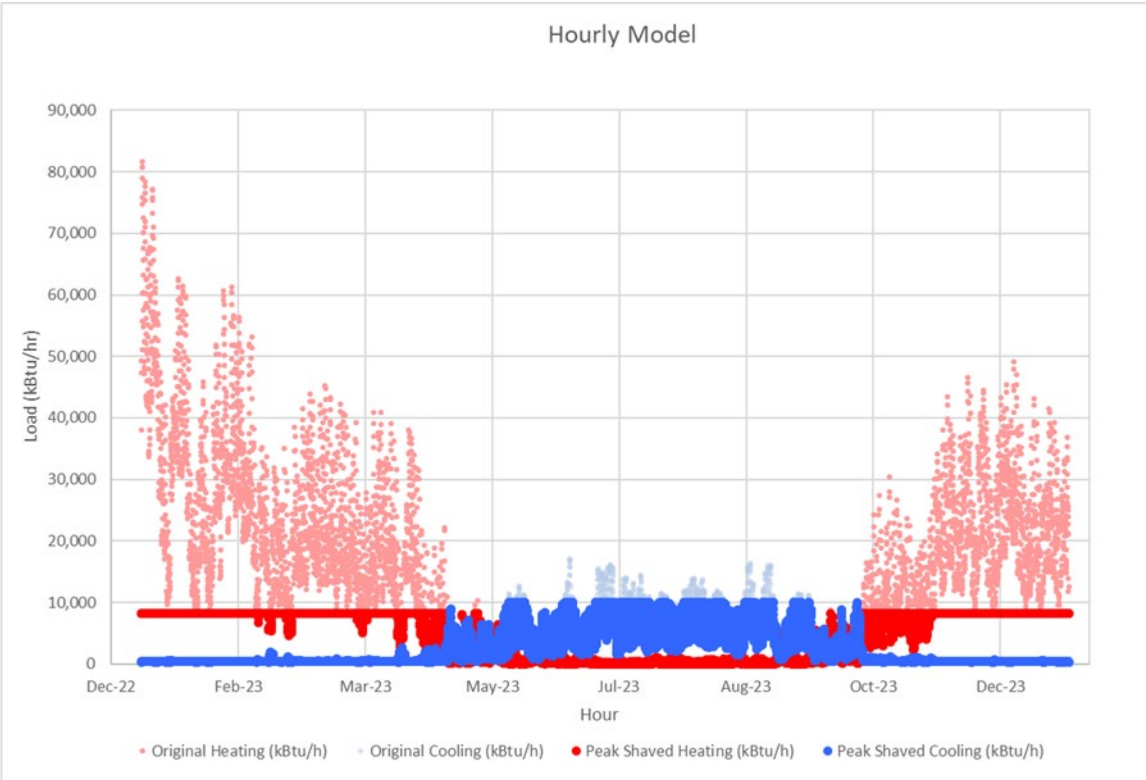


Figure 6-11. Central Hill loads accommodated by geothermal.

To cover the full load of the modelled Central Hill area, supplemental sources of heating and cooling will be required to cover the remaining loads not supplied by the geothermal system. However, there are a variety of options available to supplement heating and cooling. To supplement the system's cooling load, the best options would be a mechanical cooling element such as a dry cooler, cooling tower, or electric chiller. This equipment would be used to cover the peak cooling requirements of the most cooling dominant days of the year and would likely not run outside of those times. It is possible that some of the larger commercial and municipal buildings in the Central Hill area already have some of these components as a part of their existing cooling system, which could be integrated into the full hybrid geothermal system. To fully supplement the cooling load, approximately 582 tons of cooling would be required in addition to the geothermal system.

The most efficient way to supplement the system's heating load would be to locate sources of waste heat within the Central Hill area that could be integrated into the full hybrid system. Somerville High School recently installed a natural gas boiler system used to heat the building. This boiler system could be used to heat the school when necessary, and during times of year when the school is not in operation (e.g., non-school hours, summer break) could be integrated into the geothermal system to supply heat to the rest of the network. Supplemental heating could also be generated through waste heat recovery from the municipal sewer system. If sufficient sewer piping is located near the network, waste heat could be extracted from the system and used to heat the network.

Solar thermal is also an option for providing additional heating to the network. Solar thermal panels could be installed on available roof space at City Hall and the 1895 Building, and additional space could potentially be found on the roof of Somerville High School, and larger residential and commercial buildings. These solar thermal panels use solar energy to generate heat, which could then be used to heat the network.

A final option to supplement heat to the network is the new MBTA transformer station on Medford Street. This structure houses a significant amount of electrical equipment used by the MBTA and generates a large amount of waste heat year-round that is currently rejected to the atmosphere. This waste heat could instead be captured and integrated into the network to provide additional heating. To fully supplement the heating load of the Central Hill area, approximately 73,534 kBtu/hour of heating would be required in addition to the geothermal system.

Eliminating Medford Lot Boreholes

Brightcore also investigated reducing the load profile in the Central Hill area so that it could be served by only 240 boreholes. This would allow for boreholes to only be drilled at the locations in front of Somerville High School and the 1895 building, removing the need to drill in the lot adjacent to Medford Street and run piping beneath the MBTA railroad tracks. This model removed the heating load of three City-owned buildings in the area (Somerville Public Library, High School, and the 1895 building) to better balance the load profile, as well as reduce the number of buildings served to allow all loads to be handled by the geothermal system. This configuration would not require supplemental heating (outside of the existing heating systems at the three City-owned buildings) or cooling sources and would be served only by the geothermal system. A map of the remaining network that would be served can be found in Figure 6-12 followed by Table 6-13 listing the total loads that would be covered by the network.

Figure 6-12. Central Hill shaved option – buildings captured.

Table 6-13. Central Hill shaved loads.

	Shaved Load	Percentage of Remaining Load
Annual Heating (kBTU)	14,663,688	24%
Peak Heating (kBTU/hr)	10,789	22%
Annual Cooling (kBTU)	9,145,113	100%
Peak Cooling (kBTU/hr)	7,994	100%

The results of this modelling show that a geothermal network installed only in front of Somerville High School and the 1895 Building could cover the full cooling load of the remaining network and the heating load of all but three buildings. Somerville High School, Somerville Public Library, and the 1895 Building would need to utilize their existing heating system but would have their cooling needs handled by geothermal.

6.5.5 Simulation Results Summary

A variety of options to implement a geothermal network in three areas within the City of Somerville were modeled to determine how much of each load profile could be handled by geothermal. The results of each option modeled in this report are summarized in Table 6-14. It should be noted that more detailed designs of these systems should integrate utility data to develop a more accurate load profile reflective of the variance in HVAC usage across residential buildings.

Table 6-14. Borefield simulation results summary.

Case Summary	Ten Hills Full Load	Central Somerville Ave No Waste Heat	Central Somerville Ave w/ Waste Heat	Central Hill Full Load	Central Hill No Medford Lot Bores
Number of Boreholes required	238	360	790	312	240
Borehole Depth (ft)	500	500	500	500	500
Annual Heating from Geothermal (kBTU)	25,152,617 (79%)	42,229,663 (58%)	72,701,486 (100%)	40,309,169 (37%)	14,663,688 (24%)
Peak Heating from Geothermal (kBTU/hr)	6,369 (29%)	9,082 (18%)	50,455 (100%)	8,170 (20%)	10,789 (22%)
Annual Cooling from Geothermal (kBTU)	14,055,803 (100%)	24,174,328 (100%)	24,174,328 (100%)	22,098,494 (96%)	9,145,113 (100%)
Peak Cooling from Geothermal (kBTU/hr)	9,567 (100%)	15,957 (100%)	15,957 (100%)	10,065 (59%)	7,994 (100%)
Hybridization Required	Yes	Yes	No	Yes	No
Heating Hybridization	1300 tons (various sources)	3448 tons (waste heat or other sources)	Waste heat incorporated with geothermal loop	6127 tons (various sources)	Existing heat systems in 3 city buildings
Cooling Hybridization	N/A	N/A	N/A	582 tons (dry cooler/ cooling tower)	N/A

6.6 Economic Analysis

6.6.1 Incentives

Building upon the research in Section 3.2, some of the incentive programs through Massachusetts and the federal governments have been included as part of the economic analysis, as shown in Table 6-15. Commercial-scale geothermal heating and cooling systems are eligible for an investment tax credit (ITC) through the Inflation Reduction Act (IRA) of 2022. If the project complies with prevailing wage and apprenticeship program criteria, the owner can receive a tax credit of 30% of the project cost after installing the ground source heat exchanger and connecting equipment for heating and cooling a building(s). An additional domestic content adder of 10% is available (bringing the total tax credit up to 40% of the project cost) if the project also meets criteria for using U.S.-produced materials. However, it should be noted that manufacturers are struggling to comply with these requirements as they are currently written, and therefore uncertainty around the feasibility of receiving this adder for near-term projects. Through the direct pay mechanism introduced in the IRA, public entities such as Somerville that may have little or no tax liability can still take advantage of this incentive via an equivalent payment from the Internal Revenue Service (IRS). Further guidance on this process is available from the IRS directly.

Additionally, in Massachusetts, commercial-scale geothermal systems are eligible for an incentive of $4,500 per ton of capacity through the Mass Save program. Currently, it is assumed that this system would receive the full incentive value; however, it should be noted that systems over 150 tons are required to receive pre-approval from the program before the incentive rate is finalized. The estimated capacity of the systems discussed here range from 665 tons to 1330 tons.

Table 6-15. Incentives included in economic analysis.

Incentive Funder	Incentive Type	Rate	Conditions
Federal	Cash (via direct payment)	30% of project cost	Project complies with prevailing wage and apprenticeship program criteria
Federal	Cash (via direct payment)	10% of project cost	10% bonus for ITC for domestically manufactured equipment
Mass Save	Cash	$4,500 per ton of capacity	Systems >150 tons require pre-approval from program

6.6.2 Order of Magnitude Cost Estimate

Drawing from Brightcore's experience with drilling in Massachusetts and the preliminary borefield designs, an order of magnitude cost estimate for each scenario is shown in Table 6-16. As discussed previously, a 30% ITC has been applied to the ground-loop heat exchanger installation cost and assumes receipt of the full potential Mass Save incentive. Although not quantified in this study, the mechanical retrofit costs associated with this project would likely also be eligible for the 30% ITC.

Table 6-16. Cost breakdown for ground-loop heat exchanger.

Project Cost Breakdown	Ten Hills Full Load	Central Somerville Ave No Waste Heat	Central Somerville Ave w/ Waste Heat	Central Hill Full Load	Central Hill No Medford Lot Bores
Borefield drilling and ground-loop heat exchanger installation	$9,650,000	$14,500,000	$22,900,000	$14,120,000	$11,050,000
Lateral piping installation	$4,450,000	$6,600,000	$6,600,000	$4,900,000	$1,400,000
Total Installation Cost (Gross)	$14,100,000	$21,100,000	$29,500,000	$19,020,000	$12,450,000
Mass Save Rebate	*($3,586,500)*	*($5,985,000)*	*($5,985,000)*	*($3,771,000)*	*($2,997,000)*
Federal Tax Credit (Base, 30%)	*($3,154,050)*	*($4,534,500)*	*($7,054,500)*	*($4,574,700)*	*($2,835,900)*
Total Installation Cost	$7,359,450	$10,580,500	$16,460,500	$10,674,300	$6,617,100
Federal Tax Credit (Domestic Made Content, 10%)	*($1,051,350)*	*($1,511,500)*	*($2,351,500)*	*($1,524,900)*	*($945,300)*

6.6.3 Electric and Carbon Savings

Brightcore assessed both the electric and carbon savings by comparing the sized GSHP system to individual ASHPs installed at each building throughout the area to handle its heating and cooling loads. It should be noted that each of the savings' calculations focus only on the portion of the load served by the geothermal system, and do not consider other heating or cooling methods that would be used to supplement loads on buildings not fully covered by geothermal. The savings are summarized in Table 6-17 and are based on the annual loads and the geothermal systems modeled for all three cases in the previous sections.

Table 6-17. Annual electricity and carbon savings summary.

Project Cost Breakdown	Ten Hills Full Load	Central Somerville Ave No Waste Heat	Central Somerville Ave w/ Waste Heat	Central Hill Full Load	Central Hill No Medford Lot Bores
Carbon use reduction (tons CO_2/year)	739	1,244	1,995	1,180	463
Energy and Maintenance Cost Savings ($/year)[31]	$820,000	$1,390,000	$2,170,000	$1,200,000	$620,000

6.7 Test Borehole and Thermal Conductivity Test

Brightcore typically recommends installing a test borehole and performing a thermal conductivity test on the ground beneath the site. A test borehole is a single borehole that is installed to the design depth (500 feet). The borehole is used to determine the preferred drilling method, determine the amount of water produced by the geology, and confirm the design parameters. After the borehole is drilled, looped, and grouted, there is a five-day rest period before the thermal conductivity test is performed. A thermal conductivity test aims to determine the ability of subsurface formations to conduct heat, which is essential in understanding the viability of harnessing geothermal energy from a particular area. This test involves a series of measurements and analyses to assess the thermal conductivity of the geological layers intersecting the proposed borefield. It should be noted that the equipment required to install a test borehole is nearly identical to what is required for a full-scale system. Full scale may require additional space to stockpile consumables.

6.8 Permitting

6.8.1 Dewatering Permit

A permit is required to discharge water to a publicly managed water system. The type of drain that is most accessible at a given drilling site – stormwater or sanitary – will determine what type of permit is needed. The City of Somerville's stormwater system (Municipal Separate Storm Sewer System or MS4) is authorized under the National Pollutant Discharge

[31] Electric saving based on a utility rate of $0.2709/kWh. Source: U.S. Energy Information Administration

Elimination System (NPDES) General Permit for Dewatering and Remediation Activity Discharges, also referred to as the Dewatering and Remediation General Permit (DRGP), in Massachusetts and New Hampshire. Thus, discharging to a stormwater drain in Somerville requires compliance with the DRGP criteria for water quality. Somerville's sanitary sewer system is regulated by the Massachusetts Water Resources Authority (MWRA). Thus, a Construction Site Dewatering Permit must be obtained from MWRA before discharging to a sanitary sewer drain.

Acquiring NPDES permit coverage typically takes at least three months; in some cases, longer depending on agency responsiveness or other project-specific complexities. The permit will dictate the terms of discharge, including requirements for testing and quality criteria. In total, the permit fee combined with the cost of acquisition and compliance measures typically range $25,000-$30,000. However, depending on the discharge criteria required by the permit, additional filtration equipment may be required which would incur additional costs.

6.8.2 Additional State and Local Requirements

The Commonwealth of Massachusetts requires all drillers to be certified by MassDEP. Brightcore's team maintains current certifications with the state. Based on the most current guidance available online from the City of Somerville, it appears that the following local permit requirements may apply for this project:

- The City of Somerville Water & Sewer Department regulates use of all fire hydrants. Before utilizing hydrants on the site for water supply, a permit would need to be acquired for each hydrant. Each permit incurs a $200 cost, plus a $2,200 refundable deposit, less a water usage charge.
- The city's Engineering Department requires a permit for any project that involves moving more than 200 cubic feet of soil, which would likely encompass any borehole drilling. The fee for a permit review of a large project is $2,500, which would likely be required for each drilling site in a network.
- If the ultimate project scope requires trenching or excavation in the public right of way (e.g., for running lateral piping throughout the network) and/or street or sidewalk occupancy (e.g., for staging equipment), the appropriate Street Occupancy/Trench Permitting would need to be acquired from the city's Engineering Department.

6.9 Operation and Maintenance Considerations

All the underground piping is HDPE fusion welded, pressure test, as per industry accepted standards and applicable codes. Operation of a closed loop geothermal system is typically limited to monitoring the pressure, temperature, and flow through the loop. Annual maintenance of the source side of the system is limited to circulating fluid monitoring for levels of corrosion inhibitor, condition of antifreeze (if used), pH and other parameters recommended by the heat pump or chiller manufacturer. The expected useful life of the loops and source side piping is >100 years.

6.10 Assumptions and Exceptions

- This study assumes prevailing wage, non-union labor rates for the construction of the ground loop system.
- The costs provided are representative of costs near the date of this report issuance and may vary dependent on labor and material cost fluctuations.
- Plans provided are schematic and not for construction.
- Cost estimate assumes eligibility for 30% ITC base rate – this will depend heavily on the project delivery team and their familiarity with ITC criteria.
- Cost estimate assumes that Mass Save will apply for the full system tonnage. This will require pre-approval from the program before the incentive rate is finalized.
- Ground temperatures and building cooling loads are based on current conditions and do not take into account future climate change impacts for building load profiles.
- Building load profiles used were generated from ComStock and ResStock – databases that provide general usage profiles for different building types in various regions throughout the country. More exact heating and cooling loads will need to be determined in a future project phase and may impact system sizing.
- The City of Somerville provided utility data for city owned buildings, housing authority buildings, and a small number of residential buildings. This data was not used to generate load profiles as the majority of buildings in each area did not have utility data available.
- Residential building load profiles utilized are generalized for average building types in the region and do not account for further weatherization upgrades if they were to be performed alongside heat pump installation.

7 Conclusion

7.1 Site Expansion and Recommendations

This Kickstart study, which aimed to further explore the techno-economic viability of networked geothermal systems in the Central Hill neighborhood, Ten Hills neighborhood and Somerville Housing Authority complex, and along Central Somerville Avenue, identified that while each site is viable for implementing a networked geothermal system, long-term thermal balance across the network will need to be thoughtfully considered during further stages of design. Based on the modelling results, which have been largely informed by simulated building stock information rather than real customer data, the Somerville housing stock uses thermal energy in a significantly heating-dominant manner. This can be attributed to several reasons (e.g., poor building insulation, variance in human-building interaction, lack of data to reflect a warming climate requiring more cooling). As a result, it was found that relying on a full 100% geothermal network would result in ground temperature imbalances over time, yielding poorer network efficiencies over time.

However, there are a multitude of centralized and decentralized strategies that could be leveraged to mitigate this risk, as has been utilized in Framingham's demonstration study. Centralized equipment, whether they be introducing new commercial-scale HVAC equipment, solar thermal, or utilizing existing commercial heating systems to supplement a network, can all be utilized to offset the heating imbalance seen in each site's conceptual design. At a decentralized, building level, existing or newly introduced all-electric heating systems can be used for top-up capacity that would only be run when the geothermal network could not meet the full heating load. These strategies will have varying impacts on the system and customer-facing costs and can be optioneered in more detail beyond this feasibility study. Finally, waste heat, which has been studied primarily in the Central Somerville Avenue neighborhood, is another opportunity that could be further explored in Ten Hills (through the Mystic River) and Central Hill (through wastewater heat recovery from the nearby sewer main).

Another area of future exploration as part of this work will be to strategize the final site selection around opportunities to further expand over the coming decades. It is widely accepted that larger networks are more resilient and have better ability to capitalize on economies of scale, making the network cost per building (and ultimately, customer) drop over time. When considering network expansion beyond Central Hill, identifying nearby pockets of commercial buildings, which tend to have higher cooling loads, will help grow the network while minimizing the risk of creating further thermal imbalance. In Ten Hills, the natural direction of system expansion should aim to move towards more commercial buildings, whether along Mystic Avenue or Broadway. Finally, Central Somerville Avenue can be expanded in several directions due to mixed-use nature of the entire street.

7.2 Community Engagement and Future Work

As discussed in this report, community engagement is critical to the success of a networked geothermal pilot project. Thus, further outreach is planned to continue educating the Somerville community on this technology, its benefits to residents and businesses, and the logistics involved with installing it. Beyond this feasibility study period, it is also recommended that the City begin evaluating which entity, whether part of the City or an outside organization, own and operate the system, as this will be necessary to begin the process of customer acquisition and the final determination for where a networked geothermal system would be located.

Overall, it is clear that Somerville will need to identify a long-term solution to electrifying heating systems across the city. Coupling their challenges in grid capacity and high population density, networked geothermal could be a feasible technology to address this objective. By leveraging a growing knowledge base on the design, construction, and operation of these systems, coupled with widespread funding support and new business models to support its implementation, Somerville has an excellent opportunity to be a leader in the future of clean heat.

8 Appendices

8.1 Residential Customer Experience

Developing a successful business case for a new thermal energy network requires adequate buy-in from its future customer base. During the lifecycle of a feasibility study, the timing of developer/system owner engagement, securing funding, and acquiring customers all must coincide with one another in a systematic path to progress the project in an effective manner (Figure 8-1).

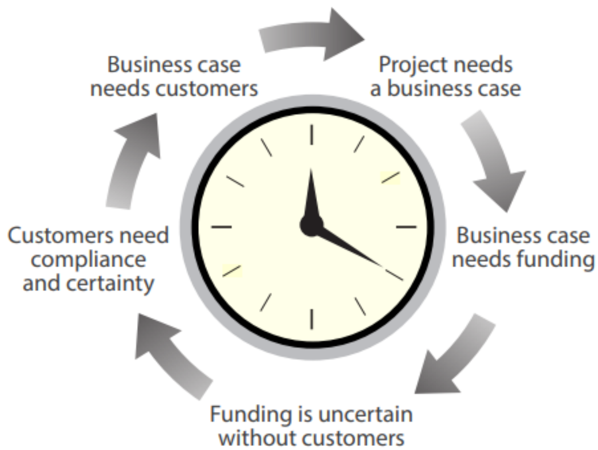


Figure 8-1. Timing of thermal energy network development.

One of the most involved components of the project development process, from a residential customer's perspective, will be the potentially required building retrofits needed to make their building compatible with the networked geothermal system. The level of complexity in these retrofits is primarily dependent on the existing type of heating and/or cooling systems, although there may be additional upgrades related to building weatherization (e.g., air sealing, increasing insulation, window replacement) and electrical service that may be needed to ensure the building can comply with specifications defined by the network developer. In general, best practice is to perform retrofits to the heat and cooling system and the building envelope at the same time, to minimize cost and disruption to the homeowner. This also has the effect of reducing peak load requirements in these buildings but will increase costs as well.

As part of the initial stakeholder engagement associated with this feasibility study, for residents living in one of the three study areas (i.e., Central Hill, Ten Hills, Central Somerville Avenue), a survey was distributed asking residents about their existing heating and active cooling systems in use in their homes, which is summarized in Figure 8-2. Overall, the building stock in Somerville is aging (82% were constructed before the first building code went into effect nearly 50 years ago), and while there is evidence that some buildings have already gone through electrification-related upgrading (e.g., installing air-source heat pumps), many existing residential buildings rely on furnaces, steam radiators, and hot water baseboard heating or window air conditioners to provide adequate space conditioning.

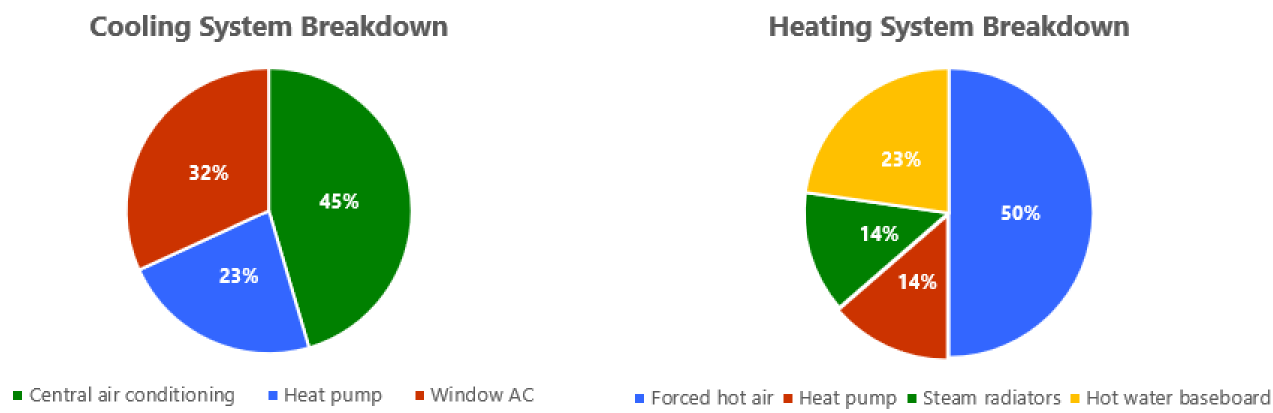


Figure 8-2. Resident engagement survey results - existing residential heating and cooling system types.

Based on the initial survey results, Table 8-1 shows a generalized breakdown of the expected requirements needed to convert residential homes into compatible participants in a networked geothermal system. Conversion of a residential home can vary widely between light touch and significant retrofits. In some instances, all that will be required to make a home compatible is a connection to the newly installed network, in others a whole new system will be required (i.e., no components will be able to be conserved). In general, any home retrofit project will be considered material on some level, certainly as far as the homeowner is concerned. For homes with amenable existing systems or envelopes that already perform well, retrofits to connect to a network system could incur impacts on the order of days to weeks. In cases where an entirely new system is required in addition to building envelope performance enhancements, the implications can include weeks to months of heavy home construction and disruption of heating, cooling, water, and ventilation systems. This may require rooms or whole homes to be vacated while work is performed, which can temporarily displace residents. This is not uncommon for home improvement projects, but in the interest of minimizing it is worth mentioning.

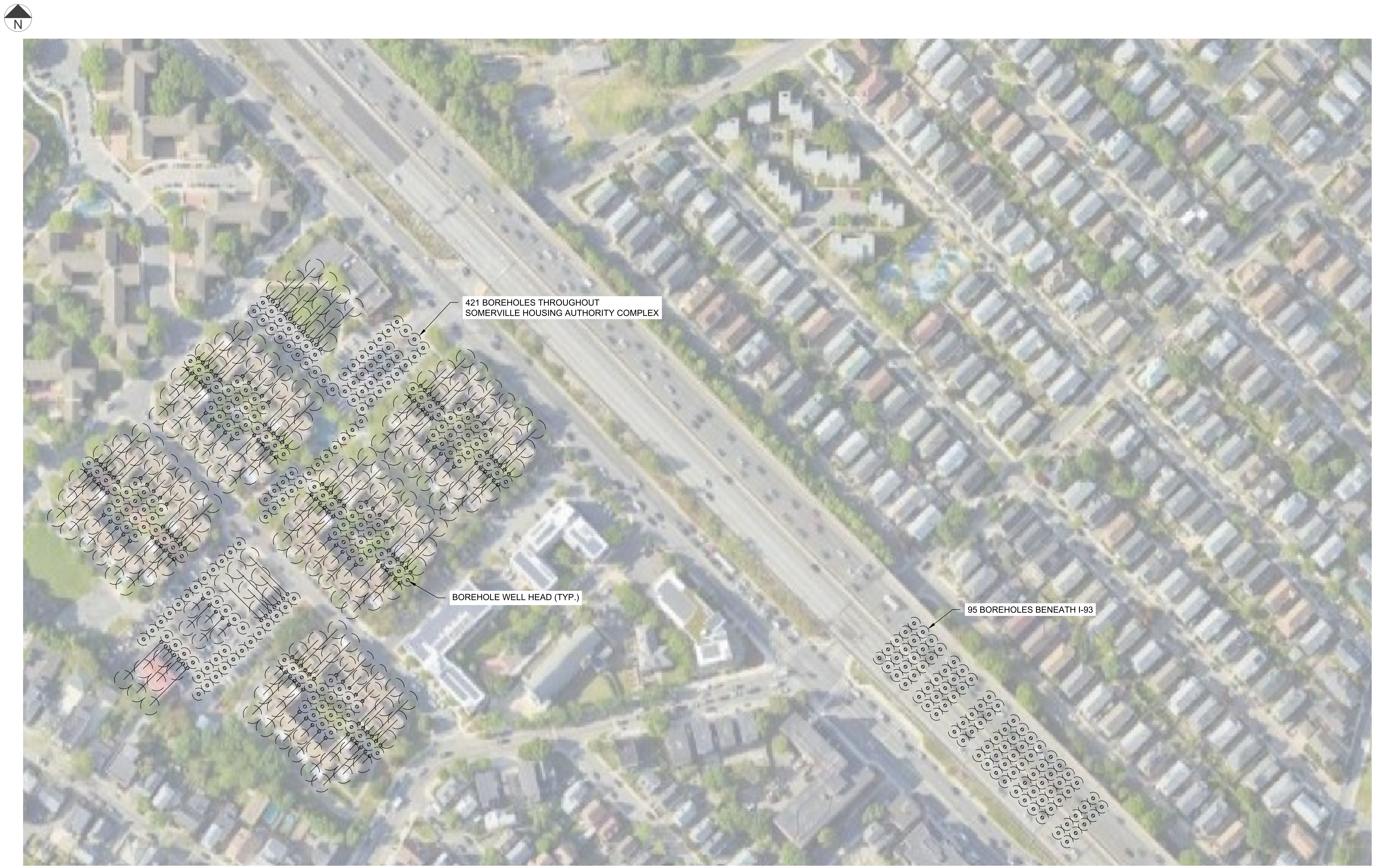
A few notes on expected costs: Cost of connection between network and home will depend on size and length of the connection and can vary widely depending on the entry point and envelope type of the building.

Table 8-1. Residential retrofit requirements based on existing space heating system, with relative cost impacts.

Existing Heating System (Space Heating and Domestic Hot Water)	Distribution System	Conversion / Retrofit Requirements	Cost Profile (1-3)
Forced air	Ducting	Connection between network and home as well as water to air heat pump	2
Boiler	Hydronic (piping)	Removal of boiler, connection from network to home, and water to water heat pump	3
Wood/pellet heating	Ducting	Removal of pellet heater, connection from network to home, water to air heat pump	3
ASHPs	Ducting	Connection from network to home required – while the ASHP would likely not be compatible and need replacement (water to air heat pump required), the rest of the building would be otherwise considered “network-ready”	2
ASHPs	Mini split (refrigerant)	Removal of mini-split units and refrigerant, connection from network to home, installation of ducts, water to air heat pump required. Could consider water to refrigerant options as well.	3
GSHPs	Hydronic (piping)	Minimal – connection between network loop and in home unit required	1
On-demand hot water	Hot water line	Water-to-water heat pump and connection from network to home required. Can remove on-demand heating unit but not required.	3
Hot water tank	Hot water line	Connection from network to home, water to water heat pump required	2
Hot water heat pump	Hot water line	Connection from network to home required	1

8.2 Geothermal System Drawings for Three Sites

The following pages include additional engineering drawings for each of the three study areas explored as part of this feasibility study.



LEGEND

- TOP OF BOREHOLE
- INCLINED BOREHOLE
- BOREHOLE THERMAL CAPACITY (VERTICAL BOREHOLES)
- BOREHOLE THERMAL CAPACITY (INCLINED BOREHOLES)

PRELIMINARY BOREFIELD LAYOUT
SOMERVILLE THERMAL ENERGY NETWORK
TEN HILLS

SCALE: 1" = 75'

0 75 150

GENERAL NOTES:

1. TOTAL BOREHOLES IN LAYOUT: 516
   - 1.1. 421 THROUGHOUT SOMERVILLE HOUSING AUTHORITY COMPLEX (202 INCLINED, 219 VERTICAL)
   - 1.2. 95 BELOW I-93 RAISED HIGHWAY
2. BOREHOLE DEPTH: 500 FT.
3. BOREHOLE SPACING: MIN 5 FT.
4. MAX INCLINE ANGLE: 10 DEG
5. HORIZONTAL CIRCUIT PIPING NOT DETAILED
6. REFERENCE: SOMERVILLE MA, GOOGLE MAPS

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REV.	DATE	DESCRIPTION
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DATE	03/10/2025
CLIENT NAME	CITY OF SOMERVILLE
CLIENT STREET	93 HIGHLAND AVE
CLIENT CITY/STATE/ZIP	SOMERVILLE, MA 02143
PROJECT NAME	SOMERVILLE UTEN
PROJECT STREET	93 HIGHLAND AVE
PROJECT CITY/STATE/ZIP	SOMERVILLE, MA 02143
TAX NO.	
PROJECT NO.	
CHECKED BY	GMG
DRAWN BY	RJZ
SCALE	1" = 75'
SUBMISSION	FEASIBILITY STUDY
DRAWING TITLE	TEN HILLS PRELIM LAYOUT
DRAWING NO.	GEO-101
SHEET	1 OF 3

LEGEND

- TOP OF BOREHOLE
- INCLINED BOREHOLE
- BOREHOLE THERMAL CAPACITY (VERTICAL BOREHOLES)
- BOREHOLE THERMAL CAPACITY (INCLINED BOREHOLES)

PRELIMINARY BOREFIELD LAYOUT
SOMERVILLE THERMAL ENERGY NETWORK
CENTRAL SOMERVILLE AVE

SCALE: 1" = 125'

0 125 250

GENERAL NOTES:

1. TOTAL BOREHOLES IN LAYOUT: 916
   - 1.1. 178 IN FOUNDERS MEMORIAL RINK LOT (104 VERTICAL, 74 INCLINED)
   - 1.2. 84 IN VETERANS MEMORIAL RINK LOT (45 VERTICAL, 39 INCLINED)
   - 1.3. 178 IN ST. ANTHONY'S CHURCH LOT (86 VERTICAL, 92 INCLINED)
   - 1.4. 325 IN MARKET BASKET FRONT LOT (325 VERTICAL, 32 INCLINED
   - 1.5. 119 IN MARKET BASKET SIDE LOT (70 VERTICAL, 49 INCLINED)
2. BOREHOLE DEPTH: 500 FT.
3. BOREHOLE SPACING: MIN 5 FT.
4. MAX INCLINE ANGLE: 10 DEG
5. HORIZONTAL CIRCUIT PIPING NOT DETAILED
6. REFERENCE: SOMERVILLE MA, GOOGLE MAPS

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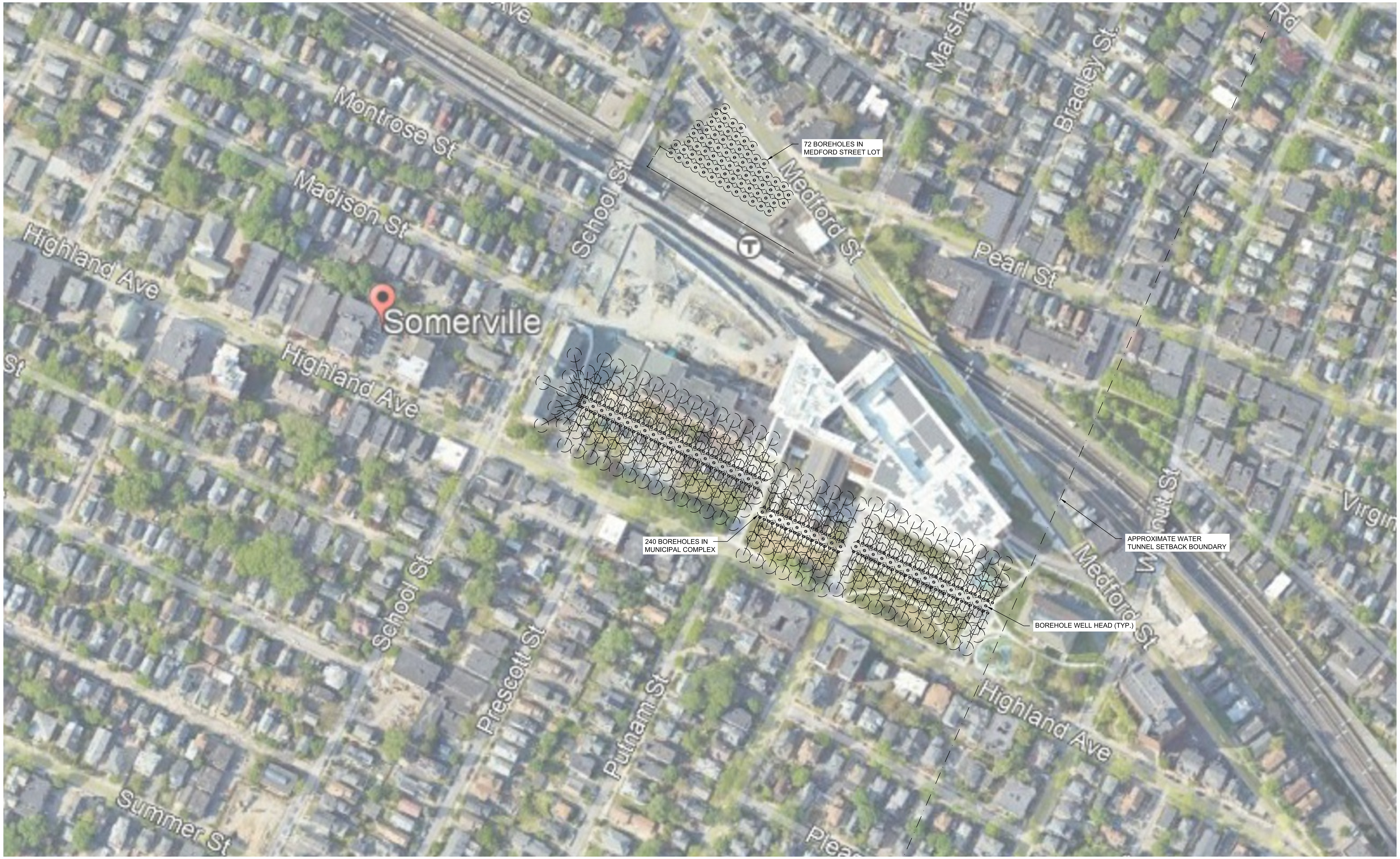
CLIENT CITY/STATE/ZIP	SOMERVILLE, MA 02143
PROJECT NAME	SOMERVILLE UTEN
PROJECT STREET	93 HIGHLAND AVE
PROJECT CITY/STATE/ZIP	SOMERVILLE, MA 02143
TAX NO.	
PROJECT NO.	
CHECKED BY	GMG
DRAWN BY	RJZ
SCALE	1" = 125'
SUBMISSION	FEASIBILITY STUDY
DRAWING TITLE	CSA PRELIM LAYOUT
DRAWING NO.	GEO-102
SHEET	2 OF 3

N



LEGEND

- TOP OF BOREHOLE
- INCLINED BOREHOLE
- BOREHOLE THERMAL CAPACITY (VERTICAL BOREHOLES)
- BOREHOLE THERMAL CAPACITY (INCLINED BOREHOLES)

PRELIMINARY BOREFIELD LAYOUT
SOMERVILLE THERMAL ENERGY NETWORK
CENTRAL HILL

SCALE: 1" = 100'

0 100 200

GENERAL NOTES:

1. TOTAL BOREHOLES IN LAYOUT: 312
   1.1. 240 IN FRONT OF SOMERVILLE HS & 1895 BUILDING
   1.2. 72 IN OPEN LOT ON MEDFORD STREET
2. BOREHOLE DEPTH: 500 FT.
3. BOREHOLE SPACING: MIN 5 FT.
4. HORIZONTAL CIRCUIT PIPING NOT DETAILED
5. REFERENCE: SOMERVILLE MA, GOOGLE EARTH

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DATE	03/10/2025
CLIENT NAME	CITY OF SOMERVILLE
CLIENT STREET	93 HIGHLAND AVE
CLIENT CITY/STATE/ZIP	SOMERVILLE, MA 02143
PROJECT NAME	SOMERVILLE UTEN
PROJECT STREET	93 HIGHLAND AVE
PROJECT CITY/STATE/ZIP	SOMERVILLE, MA 02143
TAX NO.	
PROJECT NO.	
CHECKED BY	GMG
DRAWN BY	RJZ
SCALE	1" = 100'
SUBMISSION	FEASIBILITY STUDY
DRAWING TITLE	CENTRAL HILLS PRELIM LAYOUT
DRAWING NO.	GEO-103
SHEET	3 OF 3