Somerville Networked Geothermal Feasibility Study

HEET Kickstart Report

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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 specific type of thermal energy network – is an emerging technology capable of vastly improving the efficiency of electric-led 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 Central Hill, a neighborhood within the city that houses its City Hall, local high school, and public library, among a dense residential building stock.

Buro Happold, in collaboration with Brightcore, supported the city through several public engagement meetings and the preparation of a techno-economic analysis of a theoretical networked geothermal system within Central Hill. In 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 Central Hill; and technical recommendations were made on how to approach test well drilling, permitting, and piping installation. Overall, it was found that the neighborhood is a largely heating-dominant community, which, if fully supported by only geothermal boreholes, risks creating a long-term thermal imbalance in the ground. The consultant team has made several recommendations to capitalize on surrounding assets to mitigate this risk, including identifying additional sources of heat recovery, whether through existing sewer lines, industrial or other heat-producing facilities, or thoughtfully identifying buildings for network inclusion that would yield a more balanced thermal profile year-round. In addition to the technical work done by the consultant 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.

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

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2 Introduction

2.1 Motivation

Somerville, Massachusetts has long been a leader in sustainability and climate-conscious action. The city's current 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-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 heat. And while the buildings 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), 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 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 highest density 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 Central Hill neighborhood in Somerville. The remainder of the report is structured as follows:

[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

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- 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.

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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 oil-based systems toward electrified, geothermal systems that utilizing similar distribution infrastructure to the natural gas network.

It is well understood that natural gas has detrimental implications 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. It is also well understood that natural gas has detrimental implications to human health and well-being. Natural gas infrastructure is susceptible to leaks and explosions, which has become a prominent issue in the state of Massachusetts. In 2018 for example, leaks and explosions resulting from inadequate maintenance and replacement caused a deadly disaster in the Merrimack Valley region. Thus, finding a solution to eliminate the dependence on gas-based heating systems while avoiding utility bill increases for customers is a key pathway to achieving many of the state's sustainability and equity goals. Today, 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 consistently "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 this pipe where it is either warmed or cooled depending on the temperature gradient to 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.

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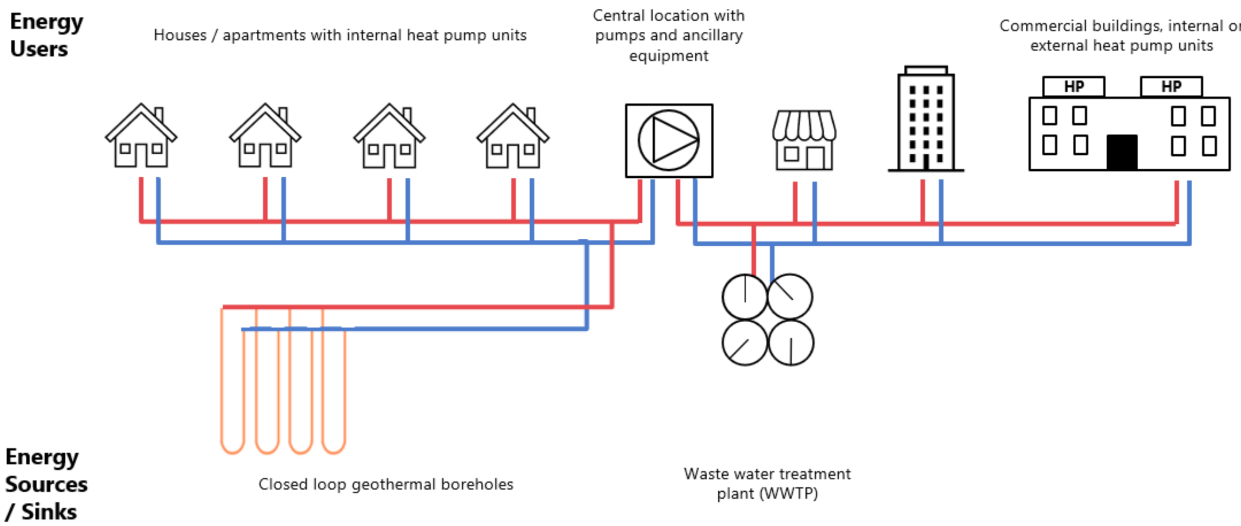

Figure 3-1. Concept diagram of a networked geothermal system.

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 in particular 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.[5] This act resulted in the definition of a state-wide goal of carbon neutrality by 2050 and an 85% reduction in direct GHG emissions compared to its 1990 baseline. In addition to legislation, the state of Massachusetts has published multiple statewide policies that were intended to serve as roadmaps towards achieving net zero by 2050. The foundational policy published by the commonwealth is known as the Massachusetts Clean Energy and Climate Plan for 2050,[6] 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 towards clean energy and decarbonization.[7]

In 2020, Massachusetts passed "An Act For Utility Transition to Using Renewable Energy" which is a bill outlining the transition plan for the state to move from natural gas toward clean energy in alignment with the state's mandated GHG targets.[8] 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

[5] Mass.gov. "Global Warming Solutions Act." https://www.mass.gov/info-details/global-warming-solutions-act-background
[6] Mass.gov. "Massachusetts Clean Energy and Climate Plan for 2050." https://www.mass.gov/info-details/massachusetts-clean-energy-and-climate-plan-for-2050
[7] Mass.gov. "Department of Public Utilities Order 20-80." https://www.mass.gov/news/department-of-public-utilities-issues-order-20-80
[8] MA Legislature. Bill S.2302. https://malegislature.gov/Bills/190/S2302

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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.[9] 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.[10] As a part of this bill, the state's electric utilities were mandated to develop Electric Sector Modernization Plans to provide a path towards 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.[11,12]

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.

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

Name	Agency/Funder	Description
Renewable Electricity Investment Tax Credit (IRC Section 48)	Internal Revenue Service (Federal)	Reduces Federal income liability for a percentage of the cost of a qualified clean energy system installed during that year
IRC Section 25D: Residential Clean Energy Credit	Internal Revenue Service (Federal)	Tax credit based on amount invested in qualifying residential energy property
Modified Accelerated Cost-Recovery System (MACRS)	Internal Revenue Service (Federal)	Cost recovery through depreciation deductions. Applicable for geothermal heat pumps.
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
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
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

[9] MA Legislature. "An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy." https://malegislature.gov/Laws/SessionLaws/Acts/2021/Chapter8
[10] MA Legislature. Bill H.5060. https://malegislature.gov/Bills/192/H5060
[11] Eversource. "Electric Sector Modernization Plan." https://www.eversource.com/content/residential/about/sustainability/renewable-generation/electric-sector-modernization-plan
[12] National Grid. "Massachusetts Grid Modernization." https://www.nationalgridus.com/Our-Company/MA-Grid-Modernization

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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
Mass Save Residential Rebates	Mass Save (State)	Rebates for energy efficiency technologies, including heat pumps
Alternative Energy Portfolio Standard[13]	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”

3.3 Best Practices for System Implementation

A key advantage in the design and construction of these networked geothermal systems is the ability for them to leverage waste heat sources to further improve efficiency. Specifically in Somerville, waste heat sources include ice rinks, data centers, grocery stores, breweries, and other general manufacturing facilities. Heat is recoverable from various sources across the city, with sources being 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 shown in Eversource’s initial utility-owned networked geothermal system, metering and monitoring is essential to understanding and optimizing its long-term performance. Eversource’s metering and monitoring system was designed to account for all data necessary to calculate the synchronous and asynchronous load cancellation observed on hourly, daily, and seasonal scales.[14] 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. Table 3-2 summarizes the data collected in Framingham to measure system performance.

Table 3-2. 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 wellfield 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)

[13] Mass.gov. “APS Renewable Thermal Qualifications.” https://www.mass.gov/guides/aps-renewable-thermal-statement-of-qualification-application
[14] 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

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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's supply and return connection (measured and logged throughout project lifetime)
Cost and time required for well recharge	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

Finally, per Massachusetts DPU requirements, operators of networked geothermal systems are now mandated to 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.[15]

[15] Mass.gov. "DPU establishes networked geothermal guidelines." https://www.mass.gov/news/dpu-establishes-network-geothermal-guidelines

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4 Site Selection

As briefly discussed in Section 3.3, site selection is a critical component for ensuring a successful networked geothermal demonstration study. Buro Happold has conducted an initial site selection analysis for three systems within the city of Somerville based on discussions with the city's Office of Sustainability and Environment. The three sites include the neighborhoods of Ten Hills, Central Hill, and a mixed-use corridor along Somerville Avenue. After initial discussions with HEET and the city of Somerville, it was determined that the bulk of the Kickstart analysis would focus on Central Hill given the city's interest in including their municipal buildings on a geothermal network. Thus, it should be noted that this report focuses exclusively on the techno-economic viability of the Central Hill neighborhood.

4.1 Geospatial Review

Somerville is the densest city in New England,[16] and while urban density is an indicator for viability for the deployment of cost-effective networked geothermal system, there are also challenges to implementing 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 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.[17,18] 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.[19]

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 could provide additional network capacity. Building typologies were mapped across the city to uncover neighborhoods with more diverse mixes of residential and commercial buildings, in order to capitalize on thermal load diversity in an implemented networked geothermal system.

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

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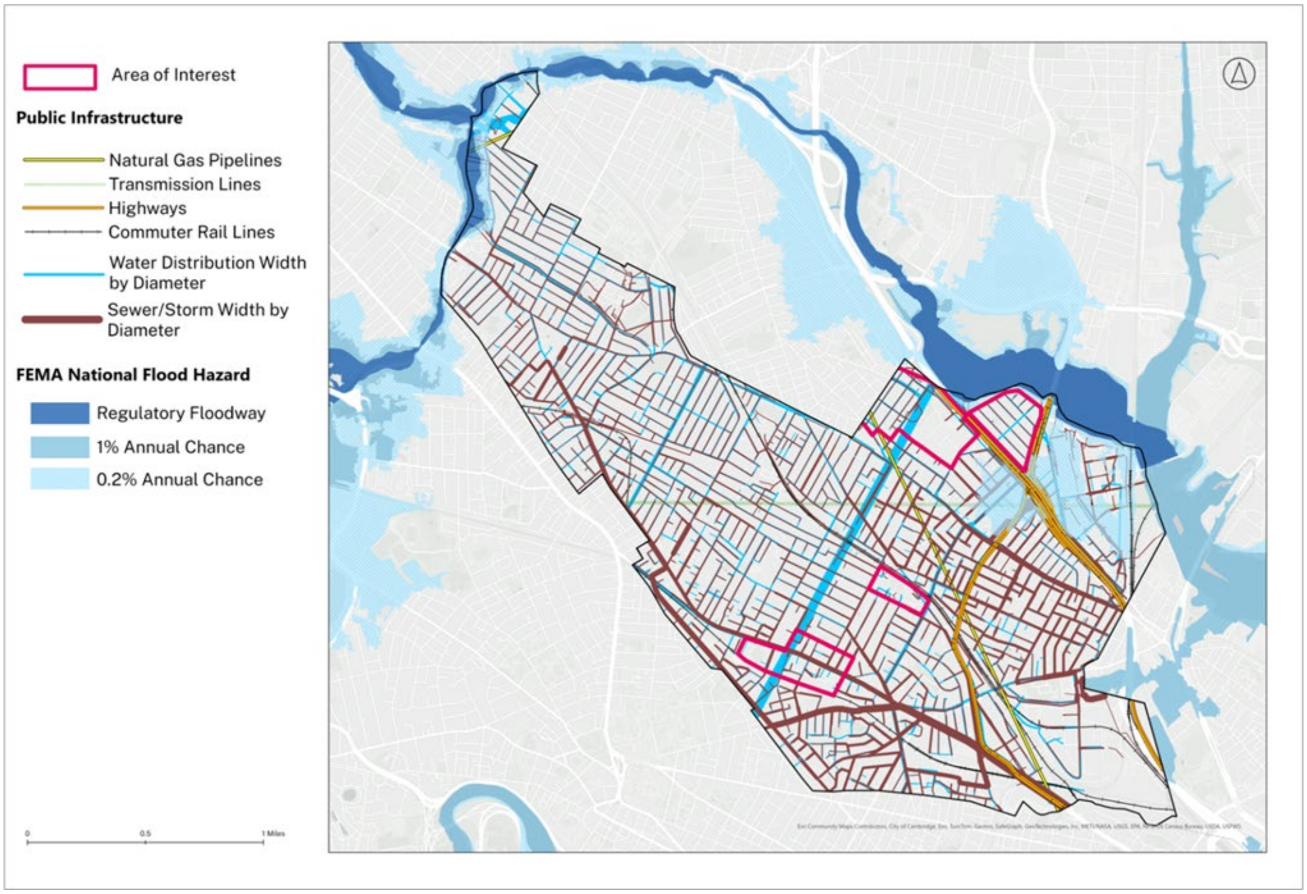

Figure 4-1. Public infrastructure interference and flood zone mapping in Somerville.

4.2 Short-Listed Sites Excluded from Kickstart Analysis

4.2.1 Ten Hills

Ten Hills – a neighborhood located north of the Interstate 93 freeway – is dominated by a large percentage of residential buildings. 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 borehole drilling and/or 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.

4.2.2 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. Buildings including Veterans Memorial Rink, a large public ice rink, 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.

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4.3 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 4-2, there is a limited amount of greenspace and open parking lots surrounding the municipal buildings, and 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 on the other side 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. Further investigation of the site's existing infrastructure, geological conditions related to drillability, and borefield design, are discussed in Section 6.

Figure 4-2. Boundaries for the Central Hill neighborhood.

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5 Stakeholder Engagement and Response

5.1 Public Engagement

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-term timeline associated with potential networked geothermal engagement efforts were focused on city-wide 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 the Somerville's Office of Sustainability and Environment community newsletter and social media channels.[20] 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 system in heating and cooling seasons; increasing knowledge and interest within the community at large.

All engagement efforts led to two virtual community town hall meetings. These were held December 9, 2024 and January 8, 2025 with approximately 100 community attendees. 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 in the prospect of networked geothermal.

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 in the city and was included in the Mayor's mid-term address as well as being included citywide informational newsletters that distributed broadly to the public.

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

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5.2 Next Steps

Somerville has scheduled an additional public engagement meeting for March 25, in which the results of the feasibility study will be shared with the public for comment. This meeting is also being 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.

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6 Techno-Economic Analysis

6.1 Infrastructure Review

6.1.1 Water Tunnel Clearance

A water tunnel runs through southeastern Central Hill near the Somerville Public Library. The state of Massachusetts restricts drilling within 50 feet of a water tunnel, so placing boreholes in the greenspace south of the library is not viable. 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 6-1 shows the location of the water tunnels relative to the Central Hill area.

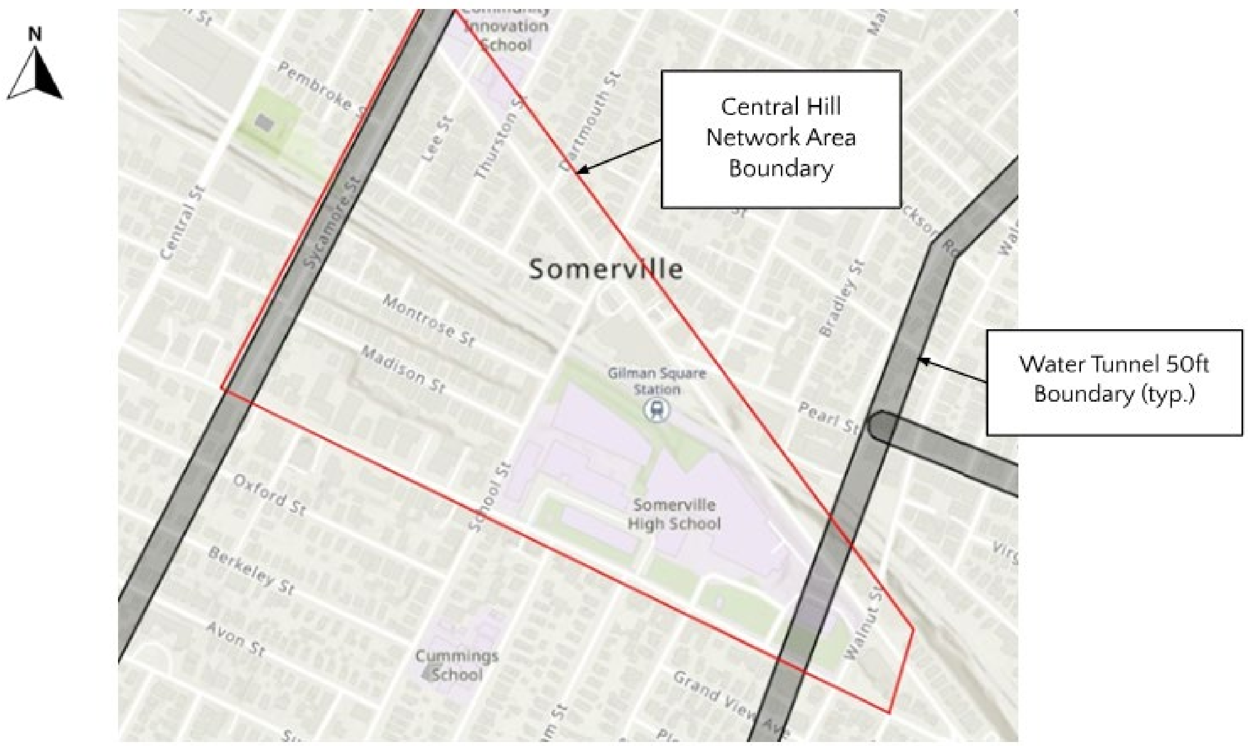

Figure 6-1. Central Hill water tunnel setbacks.

6.1.2 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. There are no restrictions related to drilling near MBTA rail lines, but close coordination will be necessary to avoid disrupting MBTA infrastructure. During borefield design, a 50-foot setback from the railway was added to avoid potential interference.

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6.1.3 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. Brightcore recommends performing 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.

6.2 Environmental Review

6.2.1 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.

Brightcore has reviewed data 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 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.

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.

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6.2.2 Implications for Drilling

Mud rotary drilling would likely be utilized in the overburden as it is the most effective approach when drilling through till and clay. Steel casing is typically installed from the top of the borehole until bedrock is reached in order to maintain hole integrity. After encountering bedrock, the drilling process is switched from mud to air drilling. 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 rock is reached.

In water bearing formations, air drilling must be accompanied with a dewatering system to manage the produced water that surfaces along with the 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.

6.3 Drilling Logistics

6.3.1 Drill Rig

The GTD GT35 or Comacchio GEO 600 drill rigs are ideal for drilling throughout the Central Hill area (Figure 6-2). These track mounted drill rigs are capable of both mud rotary and air drilling, both of which will be necessary for geothermal well installation in this area.

Figure 6-2. GTD GT 35 Drill Rig.

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6.3.2 Drillable Areas

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 are approximately 32-45 feet long and 8.5 feet wide, with about 14 feet of overhead space required for mobilization. During drilling, approximately 40 feet of overhead space is required. At 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 using the mud rotary drilling technique. Water can be sourced from a nearby fire hydrant and must be connected to a pump staged near the drill rig. 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 further on a future site walk.

After being used for drilling, water that was used and produced mixes with the pulverized bedrock and becomes a slurry, which then must be cleaned of drilling spoils before being discharged. At the drill rig, a diverter is set up to divert the slurry away from the drilling area to discharge 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.

Once all sediments have been removed from the drilling water, it is discharged to the sewage or stormwater systems. 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. Prior to discharge to any of these systems,

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appropriate permits would be obtained. Depending on the water system's jurisdiction and permitting, there may be requirements for further treatment and testing to verify compliance with water quality criteria prior to discharge. This may mean that water will need to be held onsite in the weir tank for an extended period before discharging. 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.

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. 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. In the case of this location, inclined drilling in the areas in front of Somerville High School and the 1895 Building allows for thermal capacity below the surrounding buildings and green spaces to be utilized. This concept is illustrated in Figure 6-3.

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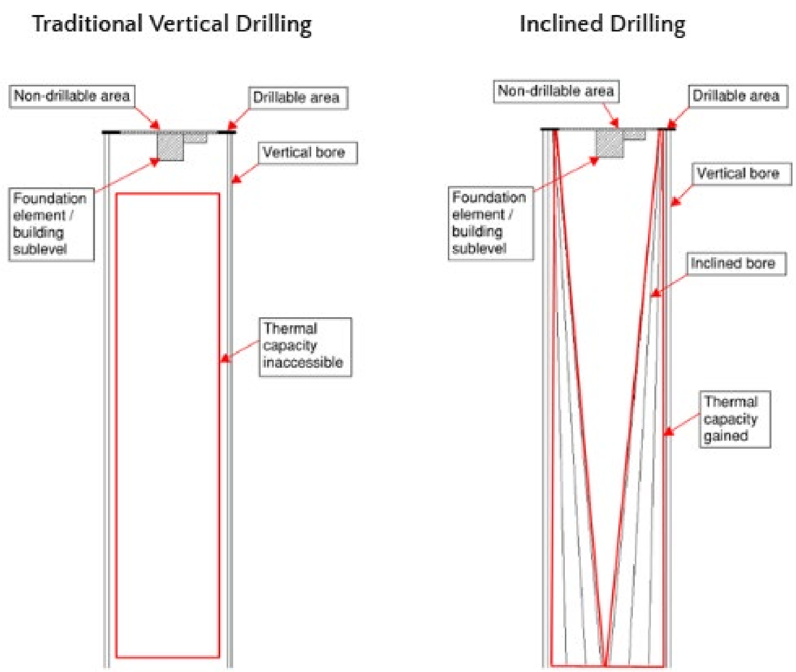

Figure 6-3. Concept diagram of inclined drilling.

6.4.2 Preliminary Borefield Layout

Brightcore analyzed each of the drillable areas identified within the Central Hill area 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 10 feet.

It was determined that a total of 240 boreholes could be fit 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 could be fit within the open lot to the north of Somerville High School. Therefore, a total of 312 boreholes to a depth of 500 feet could be fit within the drillable areas at Central Hill. The preliminary layout of this borefield can be found in Supporting Information at the end of this document. The total count of boreholes in each location is also summarized in Table 6-2.

Table 62. Total borehole count for each drillable area in Central Hill.

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**

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6.5 Geothermal Capacity Model

6.5.1 System Loads

Brightcore was provided typical hourly heating and cooling load profiles for each type of building located within the Central Hill area by Buro Happold. These load profiles were generated from ComStock and ResStock, databases of load profiles for building types in different regions.[21,22] These generalized load profiles were then normalized to the square footage of each building within the Central Hill area to determine the building's estimated load profile. The heating and cooling loads expected for the full Central Hill area are summarized in Table 6-3 and shown graphically in Figure 6-4.

Table 6-3. Central Hill total heating and cooling loads.

	Total Load
Total Heat (kBTU)	128,457,412
Peak Heating (kBTU/hour)	94,465
Total Cooling (kBTU)	20,673,569
Peak Cooling (kBTU/hour)	15,632

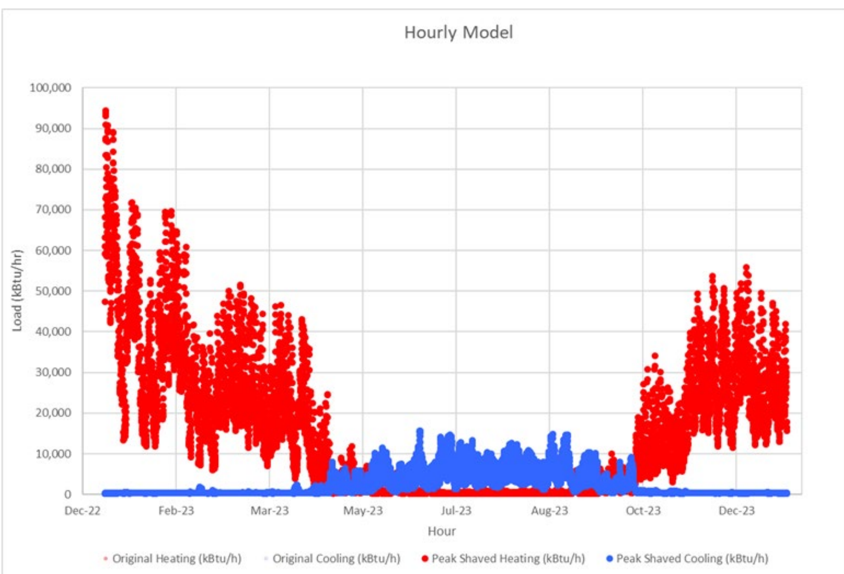

Figure 6-4. Central Hill cumulative heating and cooling loads on hourly basis.

Table 6-2 and Figure 6-4 indicate that the load profile for the area is highly heating dominant. It should be qualified that these initial load estimates are informed from building stock models and are not reflective of the true human interaction with building heating and cooling systems, which may vary between buildings and smooth out the differences in

[21] https://comstock.nrel.gov/
[22] https://resstock.nrel.gov/

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cumulative thermal loads. Additionally, these loads do not account for the expected rise in cooling demand that would result from a warming climate in Somerville.

6.5.2 Model 1: Maximum Borefield Capacity

Brightcore first estimated how much load the borefield designed in the previous section could produce and what percentage of the total load that would correspond to. The goal of this modeling 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. In order 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, with only minor shaving performed on the cooling load. A summary of the shaved loads and their percentage of the total area load are summarized in Table 6-4 and shown graphically in Figure 6-5.

Table 6-4. Central Hill, Model 1 shaved heating and cooling loads.

	Shaved Load	Percentage of Total Load
Annual Heat (kBTU)	38,025,241	30%
Peak Heating (kBTU/hour)	35,759	8%
Annual Cooling (kBTU)	20,395,814	99%
Peak Cooling (kBTU/hour)	10,942	70%

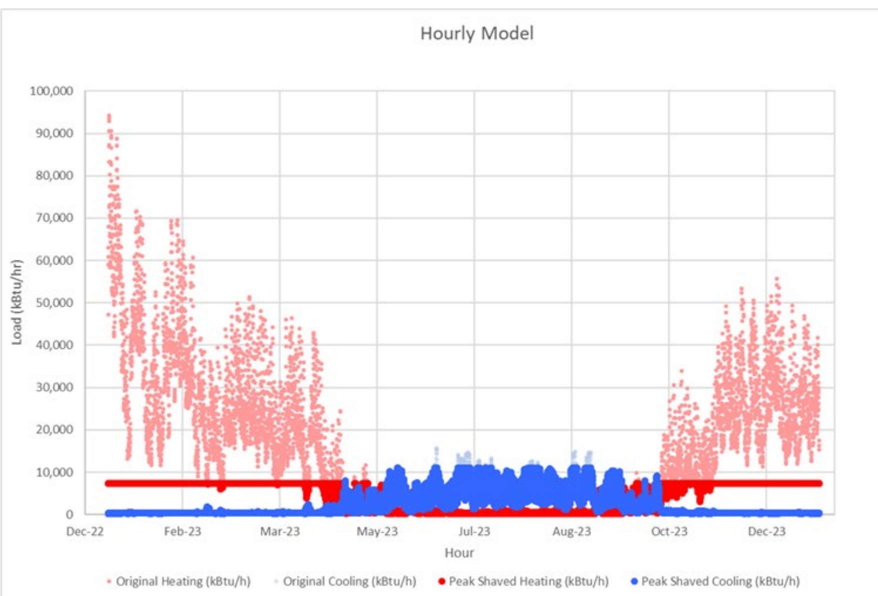

Figure 6-5. Central Hill, Model 1 total heating and cooling loads.

In order 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.

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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 390 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 7,266 tons of heating would be required in addition to the geothermal system.

6.5.3 Model 2: Service Area Reduction and Removing Heat Loads

Another option to implement a geothermal network in the Central Hills area while using fewer supplemental heating and cooling sources is to reduce the area being served by the network. This can be accomplished in two ways: first, by removing buildings from the network entirely, and second by removing only buildings' heating loads from the network in order to better balance the overall load. Buildings that were removed from the network would not receive any heating or cooling from the geothermal system. Buildings that had only their heating load removed would still receive cooling from the geothermal network but would need to provide their own heating from a different source. Brightcore investigated several options for shrinking the overall network area.

The first model that was investigated in the manner involved shaving the system's load until the remaining network could be covered by the proposed geothermal system coupled with a relatively small dry cooler to better balance the system's load. This was accomplished by removing buildings in the network that lie to the north of the MBTA commuter rail line plus a few additional buildings, as well as removing the heating load from 26 of the remaining buildings with the highest heating load profiles. This configuration allows for the remaining network to be covered by the geothermal system with the addition of a 300-ton dry cooler used to inject additional heat into the borefield to better balance the load. A map of

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the remaining network that would be served can be found in Figure 6-6, followed by Table 6-5 listing the total loads that would be covered by the network.

Figure 6-6. Buildings included as part of Central Hill, Model 2.

Table 6-5. Central Hill, Model 2 shaved heating and cooling loads.

	Shaved Load	Percentage of Total Load
Annual Heat (kBTU)	23,585,801	26%
Peak Heating (kBTU/hour)	15,548	23%
Annual Cooling (kBTU)	12,553,062	100%
Peak Cooling (kBTU/hour)	8,903	100%

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6.5.4 Model 3: Further Service Area Reduction Without Hybridization

Model 3 builds upon the previous model with the intent to remove the hybridizing dry cooler from the system. This involves removing additional buildings from the network but allowing for some of the buildings with their heating loads removed in the previous model to have their heating added back into the network, with only the 10 highest heating offtakers being removed in this case. Modelling of this system shows that the remaining load could be covered using only 282 boreholes, down from 312 in the original network. A map of the remaining network that would be served can be found in Figure 6-7, followed by Table 6-6 listing the total loads that would be covered by the network.

Figure 6-7. Buildings included as part of Central Hill, Model 3.

Table 6-6. Central Hill, Model 3 shaved heating and cooling loads.

	Shaved Load	Percentage of Total Load
Annual Heat (kBTU)	18,550,453	24%
Peak Heating (kBTU/hour)	12,647	21%
Annual Cooling (kBTU)	11,072,844	100%
Peak Cooling (kBTU/hour)	9,207	100%

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6.5.5 Model 4: Removing the Medford Lot Boreholes

Finally, Model 4 aims to reduce the load profile to where 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 required additional buildings to be removed from the network but allowed for the heating loads of additional buildings to be added back to the network after previously being removed. In this case, only the five largest heating loads had to be removed, encompassing the four city-owned buildings in the area (Somerville Public Library, High School, City Hall, and the 1895 building) and the YMCA. This configuration would not require supplemental heating (outside of what is existing at the buildings in blue) or cooling sources and would be served by only the geothermal system. A map of the remaining network that would be served can be found in Figure 6-8, followed by Table 6-7 listing the total loads that would be covered by the network.

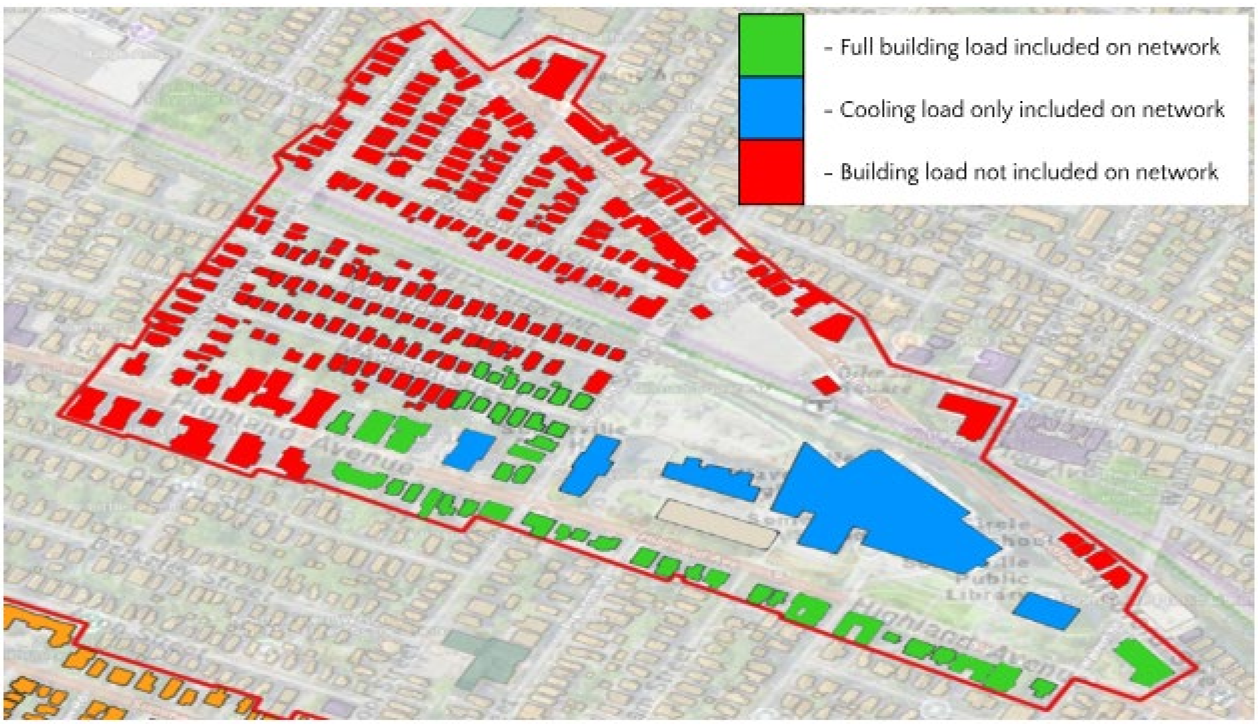

Figure 6-8. Buildings included as part of Central Hill, Model 4.

Table 6-7. Central Hill, Model 4 shaved heating and cooling loads.

	Shaved Load	Percentage of Total Load
Annual Heat (kBTU)	18,550,453	24%
Peak Heating (kBTU/hour)	12,647	21%
Annual Cooling (kBTU)	11,072,844	100%
Peak Cooling (kBTU/hour)	9,207	100%

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6.5.6 Simulation Results Summary

There are a variety of options and configurations to cover portions of the Central Hill load profile with a geothermal network and other heating and cooling sources. The results of each configuration investigated in this report are summarized in Table 6-8 below. It should be noted that additional configurations and borehole sizes are possible by adding or removing different buildings from the network, and more accurate simulations may be performed in the future utilizing utility data from each of the buildings to develop a more accurate load profile reflective of the variance in HVAC usage across residential buildings.

Table 6-8. Results summary from Central Hill modelling.

Case Summary	Model 1	Model 2	Model 3	Model 4
Number of Boreholes	312	312	282	240
Borehole Depth (feet)	500	500	500	500
Annual Heating from Geothermal (kBTU)	38,025,241 (30%)	23,585,801 (26%)	18,550,453 (24%)	15,316,736 (23%)
Peak Heating from Geothermal (kBTU/hour)	35,759 (8%)	15,548 (23%)	12,647 (21%)	10,580 (20%)
Annual Cooling from Geothermal (kBTU)	20,395,814 (99%)	12,553,062 (100%)	11,072,844 (100%)	8,758,226 (100%)
Peak Cooling from Geothermal (kBTU)	10,942 (70%)	8,903 (100%)	9,207 (100%)	7,761 (100%)
Total Buildings Served	285	163	85	58
Buildings with Shaved Heating	0	26	10	5
Hybridization Required	Yes	Yes	No	No
Heating Hybridization	7,266 tons (various sources)	300 tons (dry cooler for heat injection)	N/A	N/A
Cooling Hybridization	390 tons (dry cooler/cooling tower)	N/A	N/A	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 6-9. Commercial-scale geothermal heating and cooling systems are eligible for an investment tax credit (ITC) through the Inflation Reduction Act (IRA) of 2022. As long as 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

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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 645 tons to 910 tons.

Table 6-9. Incentives included in economic analysis.

Incentive Funder	Incentive Type	Rate	Conditions
Federal	Cash (via direct payment)	30% of project cost	
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 6-10. 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.

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Table 6-10. Cost breakdown for ground-loop heat exchanger.

Project Cost Breakdown	Model 1	Model 2	Model 3	Model 4
Borefield drilling and ground-loop heat exchanger installation	$14,120,000	$14,120,000	$12,990,000	$11,050,000
Lateral piping installation	4,900,000	$3,080,000	$2,120,000	$1,400,000
Total Installation Cost (Gross)	**$19,020,000**	**$17,200,000**	**$15,110,000**	**$12,450,000**
Federal Tax Credit (Base, 30%)	*($5,706,000)*	*($5,160,000)*	*($4,533,000)*	*($3,735,000)*
Mass Save Rebate	*($4,095,000)*	*($3,330,000)*	*($3,442,500)*	*($2,902,500)*
Total Installation Cost	**$9,219,000**	**$8,710,000**	**$7,134,000**	**$5,812,000**
Federal Tax Credit (Domestic Mode Content, 10%)	*($1,902,000)*	*($1,720,000)*	*($1,511,000)*	*($1,245,000)*

6.6.3 Electric and Carbon Savings

Brightcore assessed both the electric and carbon savings by comparing the sized GSHP to a similar sized ASHP system. 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 6-11 and are based on the annual loads and the geothermal systems modeled for all three cases in the previous sections.

Table 6-11. Annual electricity and carbon savings summary.

	Model 1	Model 2	Model 3	Model 4
Carbon use reduction (tons CO_2/year)	1,130	713	547	474
Energy and maintenance cost savings ($/year)	$1,430,000	$928,000	$740,000	$632,000

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

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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 NPDES Permit

The National Pollutant Discharge Elimination System (NPDES) governs discharge into public water systems. Assuming that nearby storm drains or sewer connections are used to discharge water during the drilling process, and assuming the sites are not already covered by a valid general NPDES permit, the driller would need to acquire an individual NPDES permit before water could be discharged. In Massachusetts, NPDES permits are issued jointly by the Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Protection (DEP).

Acquiring this permit 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 of the underground piping is HDPE fusion welded, pressured 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.

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6.10 Assumptions/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.

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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, identified that a strongly residential-dominant building stock may struggle to maintain thermal balance over the lifespan of the network. However, there are many pathways forward in which this system can still remain economically and technologically viable, whether through auxiliary heat injection, waste heat recovery, or shaving heating load from the network. As design on a network is further detailed, the acquisition of real customer data, rather than simulated building stock information, will also validate the true building performance of buildings that would be integrated into a networked geothermal system, as human interaction with HVAC systems can often vary significantly across households.

Another area of future exploration as part of this work will be to strategize the final site selection around opportunities to further expand it 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.

7.2 Community Engagement and Future Work

As discussed previously, 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 next meeting, slated to take place on the evening of March 25, 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. And, 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.

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N

LEGEND

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

PRELIMINARY BOREFIELD LAYOUT
ARLINGTON THERMAL ENERGY NETWORK

SCALE: 1" = 100'

0 100 200

GENERAL NOTES:

1. TOTAL BOREHOLES IN LAYOUT: 312
   1.1. 72 IN NORTHERN LOT (ALL VERTICAL)
   1.2. 240 IN FRONT OF SOMERVILLE HS/1895 BUILDING
      1.2.1. 193 INCLINED, 47 VERTICAL
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 EARTH

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REV.	DATE	DESCRIPTION
10		
09		
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01		

DATE	02/03/2025
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-100
SHEET	1 OF 1