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Initial Learnings from the Construction and Commissioning Phase of the First Utility-led Retrofit Geothermal Energy Network for Heating and Cooling in Framingham, MA

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ABSTRACT

In 2020, the Commonwealth of Massachusetts became the first state to authorize a gas utility to pilot a geothermal energy network (GEN). Building on this precedent, the Commonwealth of Massachusetts passed legislation in late 2024 allowing gas utility companies to sell and distribute non-combusting thermal energy to their customers as part of their core business. Geothermal energy networks (GENs) provide non-intermittent, local, resilient and decarbonized heating and cooling to homes and businesses while minimizing the associated increases in electricity consumption. Although gas utility companies in several states have filed plans with their public utility commission to design and construct multiple Thermal Energy Networks (TENs), most with geothermal energy (GENs), currently the Framingham project is the first utility-led retrofit GEN system in the country, with a single-pipe ambient-temperature loop connecting buildings with geothermal heating and cooling equipment. This project represents a historic milestone in the national movement of utilities entering the thermal network market as a modernization pathway. In this paper, we present a case study of some initial learnings from the Framingham GEN throughout the different stages of the project from inception to operations.

The Framingham demonstration project led by Eversource Gas provides heating and cooling to 36 buildings, with 31 residential and five commercial buildings, for a total of 140 individual customers. The buildings are connected by a single 8-inch pipe containing water and 25% glycol along a one mile perimeter. The thermal resources used consist of 88 boreholes distributed amongst three bore fields located beneath parking lots along the loop. Construction of this GEN took approximately 1 year, from the summer of 2023 to the

summer of 2024. The commissioning of the system followed a staged approach, starting in the fall of 2024 and completed in early spring of 2025. This case study describes the processes and learnings gained during the construction, commissioning and first year of operations of this system. Insights gained from this pioneering project can help inform and facilitate future GEN systems in Massachusetts and beyond.

1. Introduction

Massachusetts has an aging gas distribution system, as do many other older cities and states in the United States. Some of the pipelines currently operational were installed in the 1800's, with a substantial portion of the piping in need of near term replacement. However, replacing pipes is a cost-intensive long-term investment that requires consideration of both the policy environment and future energy markets. As energy infrastructure is the foundation of a region's economic development, HEET took on the challenge of optimizing thermal energy system design to meet the many needs of the future.

After proposing a single-pipe ambient-temp geothermal network as a possible path forward, Home Energy Efficiency Team (HEET) worked with Buro Happold (2019) to conduct a study evaluating the techno-economic feasibility of networked geothermal systems for Massachusetts. The study found that in low-density residential neighborhoods and medium-density mixed-use areas, individual geothermal networks could fully meet the heating and cooling demand of these areas with only 500' boreholes in the street right-of-way. Thus, some of the capital investment currently required to replace Massachusetts' aging gas infrastructure could be redirected toward the development of geothermal networks as a potential modernization pathway, where gas pipe retirement is feasible from a safety and reliability perspective. Furthermore, interconnected geothermal systems could enable network expansion beyond areas where gas infrastructure is slated for repair or replacement.

In Massachusetts, recently passed legislation (An Act promoting a clean energy grid, advancing equity, and protecting ratepayers, Commonwealth of Massachusetts, 2024) fully allows gas companies to pursue geothermal networks as part of their core business. This definitional change allows gas companies (or thermal companies!) to better and more securely address the regulatory order passed in 2023 by the Massachusetts Department of Public Utilities (DPU) that required utility companies to evaluate the use of non-gas options, such as geothermal networks, as alternatives to expanding the gas system or making additional investments in gas infrastructure (DPU 20-80B, 2023).

The Framingham pilot served as a regulatory and commercial innovation. Under the approved DPU order, Eversource fully funded all residential and commercial building conversions, reducing substantial financial barriers to customer participation. While Eversource retained ownership of the distribution infrastructure, in-building equipment was transferred to the customer (after the two-year Pilot Testing Period), along with a quarterly fee structure and customer protection plan designed to ensure savings as participating customers' electric usage increased. The regulatory framework enabled Eversource to test the viability of GENs as a new utility business line that addresses both historic requirements of reliability and affordability and safety while also fully aligned with the Massachusetts Global Warming Solutions Act and commonwealth-wide climate goals.

Over the past seven years, regulators in Massachusetts have approved six installations in the Commonwealth, five of which will be installed by gas utility companies (DPU 19-120, 2020; Massachusetts Office of the Attorney General, 2020). The positive results from the Buro Happold and HEET (2019) study led directly to the commissioning in 2024 of the first utility-owned, neighborhood-scale retrofit geothermal network system in the country - the Framingham project led by Eversource Gas. This geothermal network system is being financed entirely through Eversource Gas, using the same ratepayer-based financial structure utilized by gas utility companies to deliver gas.

This paper presents an initial case study on the Framingham geothermal energy network (GEN). This case study covers the process from site selection and design of the system to construction, commissioning and operations. The emphasis of the case study is to share a compilation of the learnings gathered during this first pilot project so they can benefit the growth of the GENs industry overall.

2. Site Selection

While GENs are a versatile technology that can perform effectively in most areas, strategic site selection can help to maximize and expand upon a utility style growth model and ensure that the first projects minimize challenges while maximizing learnings.

Many factors can be considered in the site selection (*e.g.*, community composition, access to cooling solutions, prevalence of delivered fuels, etc.). However, one of the learnings from the Framingham project suggests that a small number of selection criteria are critical for a well-functioning network. Specifically, the availability/accessibility of bore field and horizontal pipe locations, as well as the potential for load diversity are the main initial factors that will drive many of the design decisions and the performance of the system. Finding a site that provides all of these sufficiently will allow a project owner to be more flexible on other desired features and plan for future expansion of an existing system.

The selection of the Framingham site for Massachusetts' first utility-led geothermal energy network was driven by technical, social, and legal suitability. Eversource conducted a rigorous two-phase site screening and scoring process across its NSTAR Gas territory. Twenty-one neighborhoods were initially evaluated for "go/no-go" criteria, including:

- Presence of existing natural gas customers
- Availability of right-of-way and public property for bore fields
- Existing infrastructure data
- Diversity of heating sources and building stock
- Community interest and regulatory feasibility

Thirteen neighborhoods advanced to a second round of scoring, using a 0 – 100-point scale to compare:

- Drill-ability and bedrock depth

- Right-of-way access for the ambient loop
- Customer mix (gas, oil, electric)
- Cooling demand potential (to balance thermal load)
- Municipal interest and community participation
- Site constructability and estimated cost per ton

The Framingham Concord Street neighborhood ranked highest, standing out for:

- A diverse mix of low-income housing, single-family homes, and commercial properties
- Access to public lots for three bore fields (Farley building, Fire Station #5, Framingham Housing Authority lot)
- Existing thermal conductivity data from a nearby drilling project
- Proactive support from the City of Framingham, including public works and permitting staff
- Participation from the Framingham Housing Authority (FHA), which committed 10 affordable housing apartment buildings

Community enthusiasm was confirmed by door-to-door outreach and canvassing, which yielded 44 letters of interest in one weekend. This, along with local government collaboration and stakeholder feedback, reinforced the site's selection.

Test well drilling and thermal conductivity testing as part of the site evaluation played a critical role in characterizing subsurface conditions. Where no nearby data existed, a test borehole was drilled, and water was circulated through the loop to assess thermal response. This enabled the design team to model ground capacity with greater precision and ensure that the bore fields could adequately support the load requirements. This step proved crucial in building confidence in the long-term viability of the loop and helped validate early design assumptions.

Another important factor that was considered when finalizing the site selection for the Framingham project was stakeholder engagement**.** In order to maintain customer trust and cooperation, transparency with the ratepayers and community participants was required, as well as a demonstrable lack of bias.

The most important factors for site selection will generally be cost or complexity drivers such as geological conditions, environmental challenges, difficult pipe crossings, etc. Much of the required information for this part of the process can be obtained through public or online sources. Items such as existing conductivity tests in the area, geological data, and mapping are all easy ways to improve the rigor around site selection.

In Framingham for example, there was existing thermal conductivity data from a nearby site that was used for initial assumptions around ground performance. The benefit to an open quantitative approach is that the final site can be justified easily by pointing to the model and scoring approach. While the available space and project specific technical considerations are key to the physical construction of a system, engagement with the community and multiple stakeholders can facilitate key processes such as permitting, easements, participation of municipal facilities, etc.

Balancing all of these components and considerations is, in the end, driven by the people engaged in the process and it is recommended that the team who completes this process has continuity throughout the project. In conclusion, the site selection process itself can provide an opportunity for learning, engagement, and alignment even as it minimizes the challenges for a first installation.

2.1 The Framingham Community

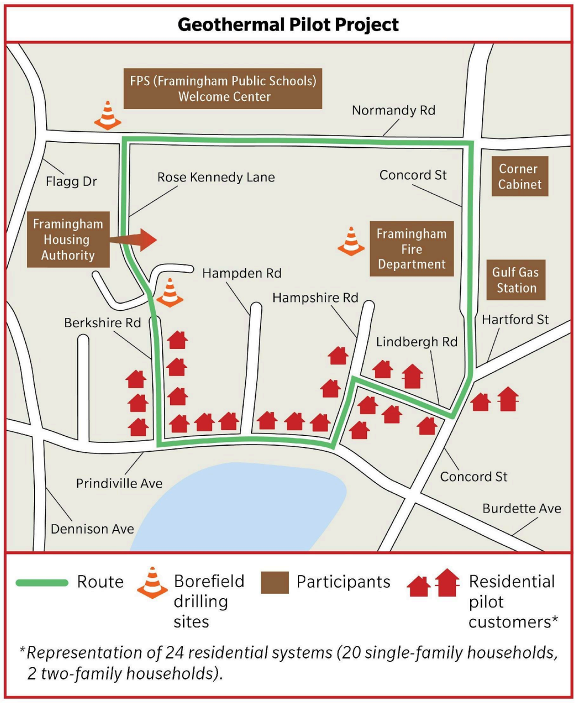
Advancing energy resilience and energy access are strong local priorities for the City of Framingham that helped inform this project's development. Since 2021, the City of Framingham has been an active partner in the MetroWest Climate Equity Project, working with regional partners and local community liaisons to better understand the needs of the Framingham neighborhoods and to improve municipal capacity to support and engage these populations. Through conversational surveys, residents have expressed the significant need for affordable programs to reduce energy consumption in their homes and switch to local and resilient energy sources. Citing the impacts of extreme heat, residents have also shared comfort issues, medical conditions, and age-related vulnerabilities that are making effective, efficient, and affordable clean air conditioning solutions a necessity. The risks of extreme heat and the need for innovative, cost-effective cooling solutions were further highlighted by the City's participation in the 2023 Heat Watch Campaign with the Christa Corrigan McAuliffe Center. The study identified the selected neighborhood through heat mapping as being bordered by encroaching heat islands and experiencing high ambient temperatures that will be most severe in the mornings and evenings of increasingly hot summers.

2.2 The Local Community at the GEN Loop

Situated in South Framingham, the GEN project encompasses approximately 20 acres of a suburban neighborhood between Normandy Road and Prindiville Avenue. The area includes three census tracts designated as Disadvantaged Communities which are home to underserved populations and low-income families. All three census tracts are impacted by their proximity to legacy pollution and high incidences of health conditions such as asthma. A high proportion of the neighborhood's elderly and disabled residents live in affordable housing units managed by the Framingham Housing Authority. The Farley Administration Building on Normandy Road also serves as a critical site for the Framingham Public Schools to connect children and families with healthcare, childhood education, and afterschool programming, as well as other community resources.

The buildings on the Framingham loop represent a unique cross-section of the community's building stock. The loop includes 36 buildings: 31 residential and five commercial. The residential buildings include single and multi-family homes as well as apartment buildings from the Framingham Housing Authority (FHA). Commercial buildings include a school building, a gas station, a fire station, and retail commercial buildings.

Air conditioning, lower energy consumption and lower maintenance are some of the benefits to the residents from the Framingham GEN project. Most homes on the Framingham GEN are identified as colonials and are on average around 80 years old, relying on older natural gas, heating oil, and inefficient electric resistance for winter space conditioning. Housing units on Rose Kennedy Lane owned and managed by the FHA were not equipped with central air conditioning and required the maintenance staff to annually install and remove window air conditioning units in every apartment individually. Additionally, with only about 30% of the space in single-family and small multi-family homes identified as having installed air conditioning, the intensification of extreme heat in the summer puts these residents at risk. The GEN system improves space conditioning for these residents, while minimizing maintenance costs particularly for the housing campus.



*Representation of 24 residential systems (20 single-family households, 2 two-family households).

Figure 1: Schematic showing the layout of the Geothermal Pilot at Framingham. Figure modified from Eversource (Eversource, n.d.)

3. GEN System Design Characteristics

The Framingham GEN system is a 5th generation district heating and cooling system that uses geothermal boreholes as the main thermal sources and sinks, as described in Magavi et al (2024). The GEN system has a capacity of 375 tons to serve 1,498,991 cubic feet of conditioned space (Eversource, n.d.a). The system has three main components: the thermal resources, the distribution loop and the buildings (Magavi et al, 2024; Varela and Magavi, 2024). The distribution system consists of one mile of an 8-inch single pipe circulating water with 25% glycol at ambient temperatures and connecting the different buildings with the boreholes. There are three bore fields located below municipal areas such as: 1) the parking lot of the Farley building, 2) the parking lot of the Engine #5 fire station and 3) a cul-de-sac at Rose Kennedy Lane as depicted in Figure 1.

Both inclined and vertical boreholes were used at the Framingham site. In total 88 boreholes were drilled at the Framingham GEN site, with 35 of them drilled at the Farley building using inclined boreholes to minimize the surface footprint. There are two bore field platforms at the Farley building, with 19 boreholes in the north platform and 16 in the south platform as depicted in Figure 2. Each borehole has a depth of approximately 675ft for a total borehole length of 7,377 m. At this location the borehole heat exchanger consists of double U-bends as designed by Celsius Energy (n.d.).

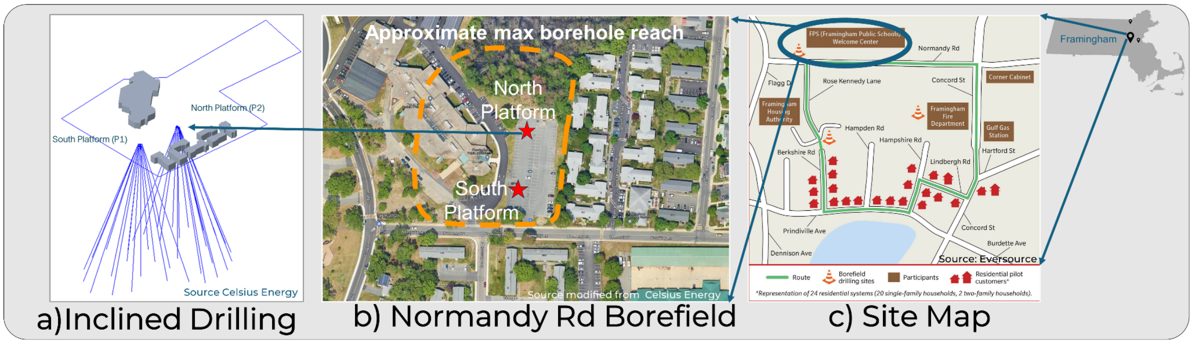


Figure 2: Schematic showing the layout of the inclined bore fields at the Farley parking lot. a) sketch of inclined boreholes by Celsius Energy, b) aerial view of the location of the north and south platforms, c) diagram of the Framingham GEN modified from (Eversource, n.d.)

The other two bore fields use traditional vertical boreholes distributed in a grid pattern and with a spacing of 20 ft. The depth of each of these boreholes is approximately 600 ft.

4. Procurement for Construction

Currently, workforce planning and procurement is one of the major challenges to the construction of a geothermal energy network. The state of the industry is such that contracting companies are capable of performing a subset of the necessary workstreams on a project but cannot complete the entire scope of the work. This results in the need for a collection of different vendors with specific skill sets to work collaboratively in the completion of a project.

The approach with the Framingham project was to allow a single general contractor to manage the entire construction process once the design work was completed. This methodology, while commonplace for utility run projects, is not the only valid construction approach. There are four general ways that the procurement process can be run:

- Engineering, procurement, and construction (EPC) contracting
- General contractor (GC) with subcontracted workstreams
- Owner managed with direct contracts
- Hybrid of general and subcontracted with owner managed direct contracts.

The main benefit of EPC Contracting is simplicity. A single firm executes design of the system and maintains oversight of all contracts through the construction phase. The approach has the lowest level of required involvement from a project owner who maintains a single contract with a project management team supplied by the EPC vendor. This structure is streamlined but expensive, as contracts are not directly negotiated by a project owner. This means there is less control over individual costs and also the EPC vendor can charge a premium for the oversight services.

In the less centralized scenario, a project owner may work with a main general contractor (GC) on a project with each workstream subcontracted by the GC. This gives some of the same benefits of an EPC approach in that there is a single contract to negotiate, but the project owner may have more input and ability to specify subcontractors and control costs. In general, the larger firms that can act as a GC will be able to self-perform one or multiple workstreams, which can also lead to some cost savings. As the industry continues to mature, these firms may quickly become able to plan and manage the entire scope of a geothermal energy network installation. The main challenge observed with this specific approach is that the GC will have a markup on subcontractors that adds to costs and may not have relevant experience with all required workstreams. Given the novel nature of GENs, the GC firms may be "learning as they go", which leads to more direct management from the project owner. Although this learning curve can be challenging, especially for a first project, it is necessary to support the increased deployment of the technology.

Direct Contracting is the most time intensive for a project owner but could potentially result in significant cost savings. Direct contracting with all subcontractors leads to the most control over a project and the ability to negotiate directly on specific work streams. There are immediate cost savings with this approach as there are no oversight markups on any of the workstreams, but it requires a high level of involvement and expert judgement from the project owner.

A typical geothermal energy network project would have at least five main contractors (i.e., civil /loop work, drilling, HVAC installation, electrical, and instrumentation), which requires a procurement process and contract for each. This is both time and labor intensive, so the effort must be weighed against the potential cost savings. One way to address this challenge is to set up fixed-price contracts in advance for clearly defined scopes of work. These contracts can then be used as needed when new projects begin. This allows for easier planning and reduces the time it takes to procure contractors prior to starting work.

One final option could be a hybrid between General & Subcontracted with Owner managed direct contracts which would blend the General Contractor and Subcontracted workstreams with owner managed with direct contracts.

5 Construction Workstreams

The construction of the Framingham network was broken down into three main workstreams: ground exchanger drilling, distribution loop installation, and building HVAC system installation as depicted in Figure 4. There could potentially be a 4th workstream if instrumentation and control systems are considered separately.

Each of the separate workstreams can generally be done in parallel to the others, but there are some important considerations discussed in the following sections for planning to bring the system online and avoid any prolonged customer outages.

Figure 3: The three main components and workstreams for a geothermal energy network. Figure modified from Magavi et al. (2024)

5.1 Ground Heat Exchangers

Ground heat exchanger (GHE) construction is one of the most time intensive aspects of a GEN installation and is directly dependent on the number of boreholes drilled. GHE installation is a multistep process involving the mobilization and use of drilling rig(s), water control management, U-bend piping installation, and grouting. Water and soils management should be clearly stated in any scoping for drilling work, as these tasks have the potential for unclear allocation of responsibilities. For example, the drilling firm may assume that the general contractor will maintain the site conditions and vice versa. This can be a complicating factor when evaluating bids between vendors, as the project owner may miss an important responsibility that is included in one proposal but not another. Defining the responsibilities during the scoping and procurement process in the prior section will avoid budget impacts due to under-scoping.

Drilling geothermal boreholes depends on the subsurface conditions and is thus exceptionally time variable. Given that many individual bores are necessary to complete a given field site, it is important to allocate drilling construction time appropriately and also to ensure good communication with the community and any nearby residents. As was observed when drilling the bore fields in Framingham, operations can take some time to ramp up to full operational speed, so building a buffer to projected timelines is key as with any large construction undertaking. Consideration should be given to the familiarity of the individual drilling crew with the local drilling conditions, as this can add time to the beginning of a drilling construction project. While the ground exchangers are a critical component for the system operation, they are generally not reliant on other workstreams for completion, so could potentially be done well in advance of other project components such as building HVAC installation.

At Framingham, bore fields are located at several sites along the Framingham loop, including below the parking lot of the Farley Administration Building, the cul-de-sac on Rose Kennedy Lane for the Framingham Housing Authority, and the parking lot of Fire Station #5. There are critical advantages to focusing the development of infrastructure on public property.

5.2 Distribution Loop

The second major workstream in network construction is the installation of the distribution loop. This encompasses the lateral main distribution piping, service lines connecting the main pipe to each building, and pumping equipment that are used to move the water around the system to distribute thermal energy. GENs generally utilize high density polyethylene (HDPE) piping, similar to those used by gas and water utilities. Distribution loop installation is nearly identical to traditional gas or water utility pipe installations that feature HDPE pipe. This means that the existing utility industry workforce can perform the necessary installation. This potential for workforce redeployment means cost estimates, projected schedule, and potential challenges are well understood. Geothermal pilot projects provide an opportunity to train the internal workforce on unique aspects of geothermal and identify crossover skills. A major learning from Framingham on this workstream is that the cost of a mile of geothermal loop installation and associated services is very similar to a gas line replacement of equal diameter. This is important because it provides an available data source to help with budget projections in other regions. As the work is being performed by potentially the same crews, costs should be relatively well aligned. Mark outs and GIS systems used for gas infrastructure were also applied for the geothermal loop. The other piece of this workstream aside from buried pipe installation is the pumping and control infrastructure, which is also a typical construction activity for a utility or municipality.

Fixed facilities such as the pump house and vaults serve a similar function to gas utility regulator stations and right of way (ROW) pits. A common utility practice that was applied to the installation in Framingham was pre-fabrication of the pump house building, vaults, and equipment offsite. Pre-construction and delivery for final installation can save a significant amount of cost and time in the field. Instrumentation and SCADA systems were installed using the same hardware and approaches as in gas operations. Even operations and maintenance (O&M) work—such as pump maintenance, loop flushing, and system monitoring—shared process similarities, reinforcing geothermal's compatibility with existing utility workflows and labor force capabilities.

The potential challenges to address in this workstream are also typical for the installation of buried piping underneath roadways. Unknown buried facilities were an observed issue on the Framingham installation and rock ledge can be a challenge more broadly throughout the northeast. In some cases, it may make sense to perform test holes and verify the underground conditions in a given area to avoid the possibility of hitting an unknown facility during trenching. Existing knowledge within the organization of a utility or local department of public works can also be critical to avoid areas that may be challenging due to rock ledges or plan for the increased cost of the installation. A final important learning when installing a distribution loop is that installation quality is critical for the later commissioning and operation of the system. Locating and repairing a leak on a low-pressure water system can be a long and expensive process, so ensuring that all fusion joints are acceptable, and pipe integrity is not compromised will reduce the potential for leak investigation. Generally speaking, quality requirements similar to those for gas infrastructure installation can help ensure the lowest risk of leak possible.

5.3 Building Conversions to Geothermal HVAC

Building HVAC installations are the final workstream to complete a geothermal energy network. The building work scope includes both the installation of the ground source heating and cooling equipment units themselves as well as the associated electrical, ducting, and building envelope upgrades required to operate the system. In some cases, the geothermal equipment installation is simply the replacement of an existing furnace or heat pump and all of the associated building systems can be re-deployed to condition the building.

One of the most complex and variable components of the Framingham GEN pilot was the building conversion process. The buildings connected to the system featured a wide range of existing heating systems, ductwork conditions, and space constraints, requiring a diverse set of conversion strategies. Existing heating systems included natural gas furnaces, oil boilers, and electric resistance heat, many of which were over 20 years old and undersized or inefficient. Several homes had no central cooling and relied on window A/C units, while others had outdated central air systems connected to limited ductwork that served only partial areas of the home.

Conversion approaches ranged from straightforward replacements to full HVAC reconfigurations. Some homes were able to reuse existing ductwork, supporting the installation of single packaged or split geothermal equipment with minimal additional construction. Others required entirely new whole-house ductwork to enable sufficient air distribution. In several cases, Variable Refrigerant Flow (VRF) systems were deployed, using combinations of ducted air handlers and ductless heads to accommodate room layouts or minimize disruption in finished spaces. Homes with finished attics or limited wall access frequently required creative solutions, such as placing air handlers in attics and routing ductwork through closets or knee walls.

Depending on the existing system and building layout, the conversion process could be relatively simple or highly complex. Constrained basements, supply-undersized ductwork, and compartmentalized attics required customized designs to integrate new geothermal-compatible equipment. Domestic hot water and appliances were also assessed as part of the conversion. In some cases, these were transitioned to electric systems alongside the geothermal retrofit, while in others they remained on their original fuel source to simplify installation or reduce upfront costs. Instances of mold and asbestos were also identified in some buildings which required additional remediation.

Electrical panel capacity also varied, with some homes requiring service upgrades to support the load from new ground source heat pumps. Panel sizes ranged from 100 to 200 amps, with several properties having only subpanels identified during inspection. These electrical limitations further influenced equipment selection and sizing.

This range of conditions highlights the need for flexible HVAC and domestic hot water design strategies in retrofitted geothermal networks. Lessons learned from the pilot reinforce the importance of pre-installation inspections, ductwork assessments, and close coordination with homeowners to identify the most cost-effective and functional system for each building.

In more challenging conversions, such as some conditions encountered in Framingham, the buildings may require improvements ranging from electrical service upgrades, ductwork installation to health and safety barrier mitigation (such as mold or asbestos) and insulation and air sealing work. The geothermal equipment available on the market currently is quite flexible and generally a solution can be found to convert nearly any building type or layout, but older buildings need significantly more work beyond just the heat pump system.

The building HVAC system workstream is the only construction scope that cannot be fully completed without the others already being in place. As the building HVAC systems need the thermal energy that is delivered by the piping network and ultimately the ground exchangers, the final commissioning of HVAC systems can only be completed once there is water in the distribution loop and the system is circulating. Another important lesson learned from the conversion work on the Framingham project is that there are parts of the building conversion scope that can be completed while the other workstreams are still underway. To the extent possible, electrical upgrades, ducting installation, and other building envelope work should be completed as early as possible in the process. This minimizes the time required to cut a building HVAC system over from the previous source to the newly installed heat pump. Another option when a more prolonged outage is required is to plan for temporary space conditioning solutions during the cutover period. Especially for critical commercial buildings such as schools, emergency services, etc., having temporary space conditioning equipment on hand should be included in the overall project planning.

A final important learning for the building HVAC installations is that quality control and inspections are critical to achieving a system with a high level of performance. Using well vetted installation vendors and ensuring that installed equipment is properly sized and oriented will avoid costly repairs or reinstallations in the future. Even minor inefficacies such as over-sized service pumps can compound across the system to ultimately affect the overall efficiency and performance. Industry training and certification is a final way to help mitigate some of the risk involved with building conversion work.

6. Data Collection and Monitoring

Robust data collection is a foundational element of the Framingham GEN project, supporting both operational oversight and performance evaluation. The system incorporates multiple layers of monitoring infrastructure to ensure comprehensive visibility into real-time system behavior and long-term trends.

6.1 Loop-Level Monitoring

Eversource's Supervisory Control and Data Acquisition (SCADA) system is deployed across the networked loop to continuously monitor flow rates, temperatures, pump speeds, and system pressures. SCADA enables real-time operational control and rapid detection of system abnormalities. This visibility allows operators to optimize pump speeds, balance energy exchange, and maintain consistent performance across varying load profiles.

6.2 Bore fields and Commercial Buildings Performance Evaluation

To support third-party performance analysis and long-term evaluation, an independent evaluation vendor was contracted to install dedicated instrumentation and data logging systems. Their monitoring infrastructure includes BTU meters, variable flow sensors, and temperature probes strategically placed at commercial buildings and bore fields. Data loggers installed at the bore fields interface with programmable logic controllers (PLCs), ensuring that key thermal and flow metrics are consistently recorded for evaluation. Sensor types and locations are outlined in the monitoring scope, which includes both supply and return temperature readings from buildings and loop connections.

6.3 Residential Data Collection via Symphony

Residential system performance is additionally tracked using Symphony, a monitoring platform integrated with individual geothermal equipment. This platform captures detailed information on residential equipment usage, runtime trends, and heating/cooling behavior. The Symphony data helps assess customer-level performance, identify inefficiencies, and support user education on optimal system usage.

Together, these systems provide a layered and redundant data architecture. SCADA ensures centralized operational control, the evaluation vendor delivers third-party evaluation and verification, and Symphony provides customer-side usage insights. This multi-source monitoring approach supports both technical optimization and transparent reporting to regulators and stakeholders.

7. Commissioning

Commissioning of a geothermal energy network is a two-part process. The first involves the starting of the distribution system and ensuring proper operations. The second half of the process is the commissioning of the individual building systems to interface with the networked loop.

Commissioning of the network starts with an initial pressure test of the system. This is generally a hydrostatic test that ensures that there are no pre-existing leaks on any of the installed pipes and fittings. Ground exchanger loops should be tested and verified by the drilling vendor as they are installed. This should be recorded on a log and provided to the system operator as part of the project deliverables. The distribution loop is also pressure tested by filling it with water and running the circulation pumps for a period of time to remove as much air and debris as possible. Once the initial circulation period has been completed, pressure can be applied to the system and observed over a period of time. Guidelines for pressure testing can potentially be based on existing pressure test procedures for gas line installation, if available. If the system maintains a static pressure without significant losses, the test can be considered successful. The final commissioning piece prior to adding customer loads to the system is a verification that the instrumentation installed for data collection and monitoring is functioning optimally. Ensuring that all sensors have been calibrated, are reading correctly, and controls are functioning properly is required for system operation.

An important item that was demonstrated during the commissioning of the Framingham system is the criticality of establishing and following good processes and procedures. Having step-by-step procedures and documentation will help to avoid challenges such as valves left in the incorrect position, trapped air in the network, or pumps started up out of sequence. While geothermal energy networks are inherently safe due to the low operating pressures and temperatures on the system, poor startup practices can lead to system disruptions and troubleshooting that could ultimately affect customers connected to the system. After initial startup, the system pressure should be closely monitored for a period of time to ensure no leaks have developed and strainers should be cleaned of any debris that was present in the piping during startup.

Similarly, building system commissioning should be completed in a deliberate and documented manner. A pressure test of the service line, flushing for any air and debris, and then pump startup according to manufacturer's recommendations will reduce the risk of operational problems. A common issue that was observed on several building system startups was air pockets causing system heat pump errors after a number of hours of operation. This can be prevented by the inclusion of equipment such as air scoops and strainers on the service piping.

8. Operations

Operations of a geothermal energy network primarily involve real time monitoring of the system, optimization of network performance, and responding to any problems that occur. This information required to control the system is acquired through temperature and flow sensors installed on the network and a real time supervisory control and data acquisition (SCADA) setup for monitoring. Using the flow and temperature data, pump speeds on both the bore fields and distribution loop can be modulated up and down to optimize energy use and system performance. Control can be performed either by manual adjustments of the pumps or preferably through an automatic control logic that responds to real time conditions. The real time aspect of the monitoring also allows for an operator to respond quickly to any potential problems such as leaks or equipment failure by system notification rather than waiting for a customer to report an issue.

One of the main takeaways from operating a utility scale system is that as a geothermal energy network grows, it becomes inherently more stable due to increased thermal mass. Water temperatures change relatively slowly (2-3 degrees over a few hours), even on the coldest or hottest days of the year. That stability allows for control adjustments to be made well in advance of any potential customer impacts from the system operating outside of the designed thermal range. The large system thermal mass also provides an interesting protection against outages as even with the distribution loop circulation stopped, there is enough latent thermal energy in the water that customers can continue to run their systems for a period of time before water temperatures are outside of the heat pump's operating range. This could allow a system operator to make repairs or correct an equipment issue without any disruption to customers.

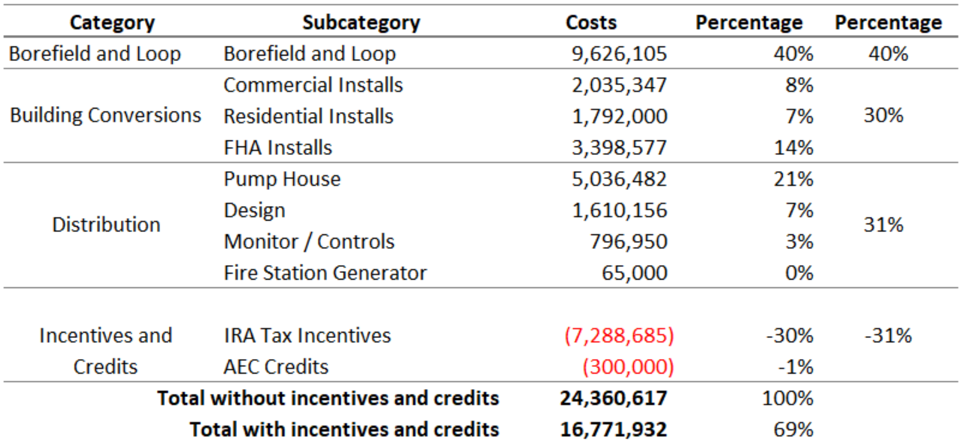
Another interesting observation from operating a utility scale geothermal energy network is the efficiencies that can be achieved when there are diverse load demands on the system. In the shoulder months especially, there are periods of time with a mix of heating and cooling demands on the system that can balance out. The result is that bore fields are not required for system operation and the pumps can be disabled for periods of time, allowing customers to "trade" energy on the system. The result is a very high operating efficiency for the overall system.

From a system performance standpoint, the last lesson learned from operating a geothermal energy network is the importance of data collection and observation of the system by personnel that are well versed in it. Temperature and flow data across the system can indicate potential inefficiencies such as bypass valves being left partially open or partial blockages in piping. Comparing the operating data to what was specified in the engineering documentation will help to determine if there is an actual issue or system conditions are within the expected range. Additional instrumentation such as bore field fiber-optic lines can add another layer of information that can be used to diagnose problems as well as to optimize system controls. There is expected to be much more learning over time from operation and data streams of the Framingham project.

9. Costs

The estimated costs related to the construction and operations of the Framingham GEN project were reported by Eversource to the DPU in the 21-53 filing in 2024. The costs can be grouped into three main categories: bore field and loop, building conversions and other costs related to system distribution, with 40%, 30% and 31% each as listed in Table 1 and illustrated in Figure 4. Costs for future projects are expected to be significantly reduced compared to the Framingham project due to the learnings acquired with this first project.

The costs of building and installing the Framingham GEN system were fully undertaken by Eversource Gas with approval from the Massachusetts DPU. Customers receiving services from the GEN loop pay a pilot rate that was defined for 24 months as: residential customers \$9.75/month, income-eligible customers \$7.3/month and commercial customers \$21/month (Eversource, n.d.).



Category	Subcategory	Costs	Percentage	Percentage
Borefield and Loop	Borefield and Loop	9,626,105	40%	40%
Building Conversions	Commercial Installs	2,035,347	8%	30%
	Residential Installs	1,792,000	7%	
	FHA Installs	3,398,577	14%	
Distribution	Pump House	5,036,482	21%	31%
	Design	1,610,156	7%	
	Monitor / Controls	796,950	3%	
	Fire Station Generator	65,000	0%	
Incentives and Credits	IRA Tax Incentives	(7,288,685)	-30%	-31%
	AEC Credits	(300,000)	-1%	
	Total without incentives and credits	**24,360,617**	100%	
	Total with incentives and credits	**16,771,932**	69%	

Table 1: Costs of the construction of the Framingham GEN project grouped by categories. Original costs were reported in the Massachusetts DPU 21-53 filling from Eversource Gas (DPU, 2024).

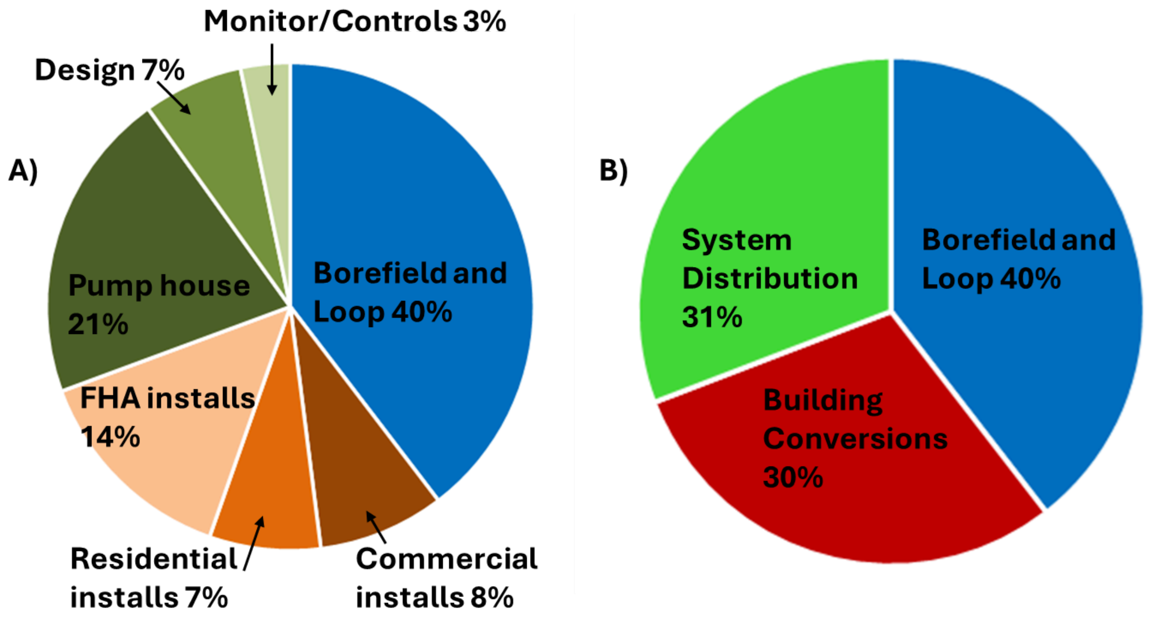


Figure 4: Costs of the construction of the Framingham GEN project by category. A) all construction costs but subcategories, B) construction costs grouped by three categories: building conversions, bore field and loop, and system distribution (DPU, 2024).

10. Conclusions and Key Lessons Learned

The Framingham Geothermal Energy Network (GEN) pilot stands as a landmark effort in the re-imagining of our future energy system, being the first utility-led, retrofit geothermal energy network system in the United States. Designed to modernize heating in an existing neighborhood, the project represented a bold step toward thermal comfort, resilience, and affordable energy access. As a complex, first-of-its-kind implementation, the pilot generated a wealth of technical, operational, and social insights that will guide future utility-scale deployments. The intention of these authors is to continue to share out key lessons learned over time ensuring that this project seeds improvements in efficiency, cost, and positive impact in every project that comes after it.

KEY LESSONS LEARNED

System Startup and Commissioning

Commissioning the Framingham GEN involved connecting dozens of buildings to a centralized bore field and loop, testing interconnected equipment, and transitioning customers to geothermal heating and cooling. This phase highlighted the need for rigorous preplanning and real-time problem solving.

- **Extended Bore Field Flushing and De-Airing:** The initial flushing process, meant to remove construction debris and trapped air from the closed-loop system, took significantly longer than anticipated—up to six weeks. The delay impacted scheduling and highlighted the importance of integrating bore field conditioning into project timelines. Best practices identified include using visual flow indicators, segmenting loops for isolated testing, and documenting flushing rates and endpoints.

- **Strategic Air Trap Placement**: Improper air management caused early system lockouts and increased troubleshooting time. The experience underscored the value of hydraulic modeling during design and ensuring access to purge ports in tight utility closets. In future phases, engineers will use lessons from Framingham to map optimal venting locations at design stage.
- **Clear and Consistent Scheduling Communication:** Coordinating access to homes, HVAC contractors, and commissioning technicians proved logistically complex. A lack of centralized communication in early phases resulted in missed appointments and customer frustration. Implementing a dedicated scheduler role and using shared calendars with contractors mitigated these issues.
- **Detailed Startup Checklists:** Valve sequencing errors and pressurization mistakes created startup delays. A standardized checklist, co-developed by field teams and engineers, helped streamline activation. Laminated field guides, startup videos, and staff training improved compliance and confidence.

Customer Behavior and Heat Pump Usage

One of the most revealing aspects of the Framingham GEN pilot was the customer adaptation process. Unlike conventional gas or oil heating systems, geothermal HVAC equipment operate continuously and most efficiently when set to maintain a steady indoor temperature. Educating customers—many of whom were unfamiliar with geothermal or electric heating systems—was critical to optimizing performance and ensuring satisfaction.

- **Importance of Thermostat Education:** The pilot team discovered that thermostat behavior directly influenced system performance and customer experience. Many users initially treated the heat pump like a conventional furnace—adjusting the temperature frequently. This led to discomfort and increased energy consumption. Outreach materials explaining the value of maintaining a consistent setpoint helped curb this behavior and reduced support calls.
- **Promoting Stable Temperature Habits:** Outreach staff emphasized the benefits of steady-state operation. Customers who adopted the 'set-it-and-forget-it' approach reported better thermal comfort, fewer perceived temperature swings, and improved satisfaction. The program incorporated behavioral prompts, such as refrigerator magnets and digital reminders, to reinforce these habits.
- **Behavioral Guidance During Transition:** To support the behavioral transition, the project employed high-touch customer support—including door-to-door visits, installation-day walkthroughs, and call-in hours. These touchpoints were critical in helping residents understand their new systems and empowering them to manage indoor

temperatures effectively. Future projects may benefit from integrating behavior change specialists early in the deployment process.

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