Obligation to serve: utility approach to providing decarbonized heat

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ABSTRACT

This paper explores a re-positioning of the role of the traditional gas utility to compete in a decarbonized world – from providing gas to providing heat to customers. Utility thermal energy networks (UTENs) address three key obstacles: 1) equitably socializing costs of the energy transition and capturing societal benefits, 2) providing a pathway to enabling mass electrification of heat at minimum electric system impact in urban areas, and 3) transitioning the skillsets of gas utility workers.

A viable UTEN offering must first navigate several challenges, spanning project cost, customer participation, and regulatory pathways. This paper considers these challenges through the lens of a first-of-its-kind utility thermal energy network demonstration in Lowell, MA. The demonstration will provide heat to over twenty customers in a mixed-use environmental justice neighborhood with both tenant and owner-occupied properties. Customers' buildings will be weatherized and retrofitted to transition their heating systems from natural gas to a shared ground-source heat pump loop. During the term of the demonstration, the utility will own and operate the shared ground-source loop.

Utilities are uniquely positioned to test novel approaches for decarbonization, and this paper discusses key learnings on site selection, the importance of customer adoption, and the challenge of retrofitting legacy building stock to enable UTEN. To scale UTEN outside of niche applications, we will discuss needed innovations, opportunities for improvement and thoughts on the applicability of this model to other regions. Additionally, this paper will advance the planning for the role that gas utilities could play in deep decarbonization pathways.

Introduction

To achieve its net zero goals, Massachusetts has laid out a path to at least an 85% reduction in greenhouse gas emissions by 2050 from a 1990 baseline. This path includes greenhouse gas reductions of 49% by 2030 in the residential, commercial, and industrial heating sectors (MA EEA 2022). Nationwide, buildings account for 13% of all greenhouse gas emissions, after transportation, power, industry and agriculture (U.S. EPA 2023). But in Massachusetts (MA), that number almost triples to 35% (Commonwealth of MA 2024). Over the next 20 years, meeting the legally mandated emissions reductions in Massachusetts will require the state to transition from a multi-fuel energy delivery system to one that primarily depends on electricity. Massachusetts' aims to decarbonize the building sector by focusing on energy efficiency, targeted electrification, and other innovative technologies. In the future, customers will depend on the electric network to power most aspects of their lives.

Like much of the Northeast, Massachusetts has an old housing stock and approximately "80% of buildings that will exist in 2050 have already been built, making retrofits essential" (Commonwealth of MA 2024). The EFI Foundation, a non-profit focused on advancing the clean energy transition through science-based analysis led by former United States Secretary of Energy Ernest Moniz, notes the Northeast is a "difficult-to-decarbonize geography. . . land-constrained

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and densely populated with relatively limited natural energy resources, aging infrastructure, and winter weather conditions that can stress buildings and energy supplies” (2023).

Alongside the states’ goals, National Grid is committed to delivering a clean, fair, affordable future for our customers by:

- Achieving our 1.5 ºC Science-Based Target (SBT) commitment (National Grid 2022a) aligned to our Clean Energy Vision[1] (National Grid 2022b) targets and the climate ambitions of our states,
- Keeping our heat products delivered through our gas networks cost-competitive with alternatives, and
- Securing an equitable long-term transition from gas where customers are not left behind.

The recent Massachusetts Department of Public Utilities Order 20-80 (MA DPU 20-80) highlighted the need for targeted electrification pilots to meet state targets, recognizing the need to think outside the box and explore alternative technologies and pathways. To achieve both the states and company’s goals, National Grid is exploring alternatives to both traditional gas investment and full electrification in the form of utility thermal energy networks.

The Case for Utility Thermal Energy Networks (UTENs)

Technology Overview

A thermal energy network is a system that utilizes a buried piping network to provide both heating and cooling. A thermal energy network can be thought of in three parts – the source energy, the network loop, and the customer premise(s). Specifically, a utility thermal energy network (UTEN) is a utility application of a thermal energy network to connect multiple buildings across public rights-of-way. Table 1 details the system components.

[1] National Grid’s Clean Energy Vision is to fully eliminate fossil fuels from both the gas and electric systems by 2050.

Table 1. Utility Thermal Energy Network Description

System component	Description	Notes
Source energy	Underground temperature (or other source) serves as a heat source during winter and a heat sink during the summer	Examples include vertical geothermal wells (500-600 feet deep), horizontal geothermal (five feet deep), waste heat, thermal resources (bodies of water)
Network loop	Fluid circulated through a ground loop absorbs heat or cooling from the constant underground temperature or other heat source	Allows for the simultaneous flow of heating and cooling through pipes buried five feet underground
Customer premise	Any building that uses space conditioning uses a geothermal heat pump connected to the loop to create conditioned air	Thermal network efficiency is affected by the balance of building types and loads on the network. Heat sinks and sources like data centers, ice rinks, grocery stores, and others can provide for higher efficiencies regardless of the outside temperature

State of the UTEN Industry

Deployment of UTEN as a decarbonization solution is in very early stages. While 13 states across the country are implementing policies and incentives to encourage the adoption of UTEN as part of their efforts to reduce greenhouse gas emissions and combat climate change (Kim 2023), none have been scaled past the demonstration stage.

New York became the first state in 2022 to mandate utilities to submit UTEN demonstrations through the "Utility Thermal Energy Networks and Jobs Act" (NY Senate 2021). In December 2023, 13 demonstration proposals were submitted to the New York Public Service Commission (PSC), including four proposals from National Grid (NY DPS 22-M-0429). The proposals investigate a variety of implementation schemes, including using the outfall of a wastewater treatment plant as a thermal energy resource and paying a municipality for use of their geothermal wells.

The furthest along UTEN demonstration is Eversource's project in Framingham, Massachusetts, which will supply heat and cooling to 37 buildings for a total of 140 units (Eversource 2024). Described further below, National Grid completed a UTEN demonstration in 2017 in Glenwood, Long Island, NY that connected 11 customers on a shared loop.

UTEN as a Decarbonization Solution

We introduce a framework of three critical benefits in the transition of building heat to use in evaluating UTENs:

1. Equitably socializing costs of the energy transition
2. Providing a pathway to enabling mass electrification of heat at minimum electric system impact in urban areas
3. Transitioning the skillsets of gas utility workers

Equitably socializing costs of the energy transition

Utility thermal energy networks are a potential solution for equitably socializing the costs of the energy transition from gas to electricity while capturing the societal benefits of doing so. By using thermal energy that is readily available locally, UTENs can create more stable and predictable customer bills less subject to commodity market fluctuations for the most vulnerable customers.

Single-home geothermal heat pumps are cost-prohibitive due to their high upfront price. In addition, geothermal requires outside space for the boreholes, which may not be available for each property owner in dense urban communities. However, socializing the cost of a UTEN and using the utility right-of-way or an easement on privately-owned land means that it is available to everyone in a neighborhood, including low-income and environmental justice communities.

In addition to providing heating, UTENs can also provide cooling to communities that traditionally do not have air conditioning, utilize inefficient and expensive window units, or are more vulnerable to heatwaves. A study on heat-related deaths found that between 1997 and 2016, there were an estimated 2,302 excess deaths in the Northeast due to extreme heat (Weinberger 2020). The study also found that low-income and elderly populations were more vulnerable to heat-related illnesses and deaths. These statistics highlight the urgent need to provide cooling to vulnerable communities, particularly low-income and environmental justice communities, to mitigate the impacts of heat waves and ensure public health and safety. UTENs can be an effective solution to provide cooling to these communities while also transitioning to cleaner energy sources.

Providing a pathway to enabling mass electrification of heat at minimum electric system impact in urban areas

Utility thermal energy networks have the potential to provide heat electrification with less impact to the winter electric peak and overall electricity volume consumption than air-source heat pumps (ASHPs). A National Renewable Energy Laboratory (NREL) study on geothermal heat pumps showed a potential 5.6% avoided winter peak demand in the Northeast compared to other electrified technologies (NREL 2023). In addition, a 2024 study from Oak Ridge National Laboratory (ORNL) found that mass nationwide uptake of single-building ground source heat pumps and building envelope improvement by 2050 could eliminate the need for up to 43,600 miles of new interregional transmission infrastructure, reduce up to 410 GW of nationwide generation capacity requirements, and eliminate more than 7 gigatons of carbon, which is roughly equivalent to all U.S. emissions in 2022 and a present value of $1.6 trillion. Ultimately, ORNL believes ground source heat pumps are primarily “an electric grid cost reduction tool and technology” (ORNL 2023). In addition, data from a recently installed networked geothermal system at Colorado Mesa University shows an overall coefficient of performance of 5.7, with a low of 3.6 in the summer and a high of 8.9 in the winter (Xcel Energy 2023, NREL 2023). ASHPs achieve a low of 1 in the winter during peak cold days below the equipment’s operating temperature (when the ASHP turns into electric resistance heating), with a high of 3 during spring and fall shoulder seasons (Guidehouse 2023). Considering the higher coefficients of performance of networked geothermal systems, it’s likely the benefits of UTENs to the electric grid are even higher than estimated by NREL.

The lower impact on the electric grid compared to ASHPs could make UTEN attractive as a non-wires alternative (NWA), where system constraints make alternatives more expensive. A non-wires alternative is a solution that avoids or defers the need for traditional investments in electric grid infrastructure, such as building new transmission lines or substations, by using alternative methods to address grid constraints or capacity needs. NWAs can include demand response programs, energy storage, and energy efficiency initiatives that reduce peak load on the system. By using NWAs, utilities can reduce costs, improve grid reliability, and integrate more renewable energy resources into the grid. If UTEN costs are less expensive than electric system upgrades, benefits accrue to electric customers in a NWA framework. Additionally, incentives available to customers could reduce upfront costs to customers for transitioning to UTEN.

Furthermore, an orderly transition to net zero that includes coordination of gas and electric system planning will require capturing opportunities to optimize overall energy system costs and reliability. A utility can make calculated decisions about where on the gas system to prioritize investment (e.g., leak prone natural gas pipe (LPP) repair or replacement) and/or plan to decommission sections of the gas network in favor of electric heating or UTEN. Gas utilities may leverage targeted electrification to avoid network reinforcements or LPP replacement if customer adoption barriers can be overcome and if electric network capacity is available or can be upgraded to support the incremental load.

Transitioning the skillsets of gas utility workers

The potential to transition the skillset of gas workers can be considered through UTEN's three segments: source energy, distribution loop, and customer premise.

The source energy of UTEN projects is typically geothermal energy. Drilling geothermal boreholes requires expensive equipment and extensive training. Depending on the jurisdiction, workers may also need to be licensed or certified to operate drilling equipment. Standing up a drilling department, hiring experienced drillers, creating a training program, and retraining workers for this type of work would be challenging, given the different skillsets required, prohibitive upstart costs of equipment, and long lead time for achieving drilling certification.

The second segment is the distribution loop. The UTEN distribution main and supply and return lines to buildings involve the same pipe material and fusion techniques as a gas system, and therefore the skills involved with installing and maintaining these are similar to those of a gas system. The primarily difference between the two systems is the depth - UTEN pipe is typically buried at four to five feet below grade depending on the frost line, whereas gas pipes are laid three feet underground.

The third segment of a UTEN system includes the customer premise. In Massachusetts, utilities are prohibited from owning, installing, and maintaining gas piping and appliances located inside a customer premises, which is considered a competitive service. Utilities may only provide service up to the building's meter or service entrance. Piping and appliances beyond that point are customer owned, and therefore work beyond that point is the responsibility of the building owner. In MA, Mass Save is the umbrella organization for utilities to offer energy efficiency programs and electrification services to customers. Mass Save and similar programs at other utilities involve contracting out to a third party to do the in-building work. Because of this point of demarcation for customer and utility-owned assets, work within a customer premise would not be carried out by utility workers.

Utility thermal energy networks may offer new opportunities for gas workers to be trained to transition their existing skills installing, maintaining, and inspecting gas piping into performing similar work associated with UTEN. Workers may also have the opportunity to learn about new technologies and processes and develop new skills needed to install and maintain UTEN. Additionally, the skills and knowledge gained by gas workers during the heat decarbonization transition can make them more versatile and valuable in the job market.

Lowell Demonstration Overview

In 2021, National Grid filed a Geothermal District Energy Demonstration Program with the Massachusetts Department of Public Utilities to explore the ability of networked geothermal to 1) reduce emissions from customer energy use in service of environmental justice communities, 2) manage gas constrained areas and investments designed to meet peak day needs on the gas system, 3) avoid LPP replacement, and 4) manage diverse load profiles. The networked geothermal program focuses on shared-loop systems that serve multiple independent residential and/or commercial customers, aiming to validate the performance of shared loops and investigate how to optimally deploy shared loops to create the best value for customers, leveraging the renewable and bi-directional nature of geothermal heating.

In December 2022, National Grid selected Lowell, Massachusetts for its first demonstration location in partnership with the City of Lowell and University of Massachusetts, Lowell. The site was selected for its diverse load profile and its siting in service of an environmental justice community. The networked geothermal system consists of the following components, as shown in Table 2.

Table 2. Lowell Demonstration: Utility Thermal Energy Network Description

System component	Description	Notes
Source energy	Ground Source Heat Exchange	36 six-inch diameter geothermal boreholes 600 feet deep in one borefield located in a parking lot, and eight boreholes in a street right-of-way
Network loop	Distribution Main and Service lines	Water and 25% glycol mixture (to prevent freezing) will be distributed via approximately 2,000 feet of eight-inch-high density polyethylene pipe to the service lines for each building. Depending on building size, the service lines will vary from two-inch up to six-inch.
	Pump House and Energy Transfer Equipment	Central pump house will include the borefield pumps, the central distribution pumps and ancillary equipment. A smaller pump building for the eight boreholes in the right-of-way will house the heat exchanger and circulator pump for the housing authority building
Customer premise	Mix of single family, multi-family and commercial units	Every building will be weatherized to increase energy efficiency, converted to heating and cooling through a ground source heat pump(s), and will receive a heat pump water heater replacement for a gas-fired water heater.

All customers participating will have the costs fully covered to convert from fossil-fuels to electric (including any electric panel upgrades required) through a mix of incentives available from Mass Save and the demonstration budget.

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Lowell Demonstration Key Learnings

Through the previously identified framework of key opportunities for UTEN to contribute to decarbonization, we discuss learnings from the Lowell Demonstration in Table 3. This offers a unique perspective of being a first mover, the pain points and how those have been addressed.

Table 3. Key Learnings from Lowell Demonstration

Benefit areas	Lessons learned
Equitably socializing the cost of the energy transition	**Site selection – how to identify locations suitable for UTEN?** • A detailed screening is required, including but not limited to geology, borefield space, load diversity, community interest and support. • Easy access to space for the borefield(s) and a smooth process for entering an easement contract are both crucial for the project's financial efficiency. Using the utility right-of-way for boreholes has the potential to alleviate space constraints in urban areas.
	Retrofitting legacy building stock – what does it take to convert existing buildings? • New England has predominantly older buildings, and therefore the diversity of building types requires conversion strategies that are specific to each building. • There is a need to introduce alternative heating and cooling equipment to state electrification and energy efficiency incentive programs. • UTEN system costs do not scale linearly and are unique to space constraints, complexity for diverse load, and building type.
Enabling mass electrification of heat at minimum electric system impact in urban areas	**Customer adoption - what does it take to get to 100%?** • Half of eligible customers signed up for the program, potentially due to the complexities of the renter and building owner relationship. • Urban neighborhoods that have multi-family buildings are more likely to have the mix of residential, commercial, and industrial customers required for load diversity. • Inability to achieve 100% customer adoption highlights the difficulty in using targeted electrification demonstrations to achieve gas decarbonization goals.
Transitioning the skillsets of gas utility workers	**Capability - how do utility worker skillsets transfer to UTEN?** • More data points are necessary, which can be gathered during construction, operations, and maintenance. The design and engineering of UTEN systems will also require the upskilling of workers.

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Equitably Socializing Costs of the Energy Transition

Site selection

A key desired learning for the Lowell Demonstration is to understand how to identify locations suitable for UTEN. To identify sites for the first demonstration location, the company looked for motivated applicants who could serve as "anchors" for each site and locations with multiple options for routes and borefields. Anchors are large commercial and industrial customers who could support a big portion of the load and could potentially provide space for the geothermal borefield, pump house, in-kind funding (e.g., for building retrofit), and/or could support customer outreach to fill up the loop. Site application solicitation was done primarily through National Grid customer account managers or inbound communication from customers. Anchor customers submitted an application of a proposed demonstration site to be considered.

Once the site passed the initial criteria screening (environmental justice communities, gas constrained areas, leak prone pipe areas, and areas with diverse load profiles), the applications were analyzed through a site selection matrix developed with an engineering consulting firm. The site selection matrix is an extensive decision analysis tool designed to score each site. The tool used a series of two screenings to down-select sites. In the first screening, each site is evaluated for environmental impacts (presence of natural resources, sensitive receptors on site, environmental contamination), geologic conditions (depth to bedrock less than 100 feet), public infrastructure interference given the potential for urban locations (transit tunnels, rail, public drinking water tunnels), and space availability for the borefield and ambient loop. The second screening for the down-selected sites included a more in-depth review of infrastructure operations (age of equipment to be replaced, ability to cut and cap natural gas utilities, proximity to cast iron), customer willingness and community stakeholder acceptance (community interest; municipal, customer, and community organization support), location in an environmental justice or low-income community, land availability for infrastructure easements, impact to environmental resources at a deeper level (aquifers, subsurface environmental contamination, permitting, drinking water wells), building loads (potential for simultaneous heating and cooling), and more in-depth geological conditions review.

Learnings from the site selection process have centered on space and logistics. Although multiple options for routes and borefields was a first screen, the demonstration showed that an initial map-based review of land use was not detailed enough and lacked a property owner review. There have been challenges in securing easements for the borefields and pump house due to the large space required to support the thermal energy load in a medium density area, actual on-the-ground needs for the current and/or future use of the space, easements requiring legislation and payment due to state ownership of land (which applies to all state-owned land in Massachusetts), and unknown environmental contamination from previous subsurface land uses. If an application-based system is used in the future for site selection, it will be important to confirm the anchor applicants have authority over the easement for the borefield. If the applicant is not the owner of a potential easement, the easement property owner will have to be identified and contacted to confirm their interest before a site is selected. In addition, it will be important to confirm that the applicant has informed potential participants that would make up the project site so an initial gauge of customer interest could be ascertained. National Grid realizes that not all sites will have space for a borefield, so the Company will be drilling first-of-its-kind geothermal wells within the existing road right-of-way for a portion of the design. These wells will test the viability of using the existing right-of-way as a thermal source rather than using a separate borefield. This presents numerous challenges, including disruption for road users and nearby

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residents, as well as the potential risk of encountering unmarked utilities. However, it also offers the opportunity to establish a more scalable utility business model that reduces or eliminates the need for borefield space, which has been a significant constraint for UTEN.

Retrofitting legacy building stock to enable UTEN

Understanding what it takes to convert existing buildings to enable UTEN is key. In the Lowell Demonstration, building stock is varied, with a mix of single and multi-family (double- and triple-deckers), apartment buildings (Lowell Housing Authority building with 12 units), single family homes converted to university buildings, and commercial buildings with multiple tenants, all together totaling 143 tons. Approximately 80% of existing heating is through natural gas boilers and the remaining 20% is natural gas forced air furnaces. A few customers have electric baseboards, rooftop solar and oil-fired furnaces. Learnings from building conversions have centered on the need for diverse retrofit strategies, alternative equipment, and the need to create site-specific financial estimates.

In urban areas, New England has predominantly older buildings, and therefore the diversity of building types requires conversion strategies that are specific to each building. Ground source heat pump equipment will be placed in basements, mounted on walls both indoor and outdoor, and mounted on rooftops. Where feasible, ground, second and third floor units with boilers will have new ducts installed. Where duct work isn't feasible, variable refrigerant flow wall-mounted units will be installed. The age of the buildings has indicated previous presence of asbestos in at least one property, which was abated when the current owner purchased the property but may require special attention during construction.

The state's Mass Save program has generally focused on single-building design and consequently, the Lowell Demonstration's design includes ground source heat pump equipment that is not eligible for state incentive through the Mass Save program. To prove the equipment meets EnergyStar requirements, the engineering contractor requested a letter from the ground source heat pump manufacturer. Since the equipment is similar or better to the current eligible equipment offerings for the state Mass Save Program, we anticipate the equipment will be eligible to receive the rebate. There may be a need to introduce alternative heating and cooling equipment to state electrification and energy efficiency incentive programs for UTEN to scale in the future. If a customer chooses to fully electrify with an induction stove and electric dryer, a portion of the additional cost will be offset with Mass Save rebates.

Project costs from the 2017 Riverhead Demonstration, a networked geothermal system for 11 single-family homes completed by National Grid in Glenwood, Long Island, NY (NY PSC 2020), were used for the demonstration program's initial $15.6 million estimate for up to four sites with costs escalated to account for inflation. The Riverhead Demonstration encompassed one property owner with ample green space to be used for the borefield. As seen in the construction procurement process for the Lowell Demonstration, the costs involved in the development, installation, and maintenance of geothermal systems and related buildings and equipment in 2024 have increased compared to the 2017 Riverhead Demonstration. Economic factors and factors specific to Massachusetts have impacted costs and resulted in increases from the original estimates. These include factors such as: drilling, equipment, customer density, building type, pumphouse design, and infrastructure establishment in a complex urban environment. The mix of residential, commercial, and industrial customers needed for load diversity may be more common in urban neighborhoods that include multi-family buildings. The additional costs are typical of urban environments, which may lack space and require purchase of easements, and a more complex system with a separate pump house and energy transfer station, which is required for a larger design and multiple building types. Future projects should consider that larger UTEN system costs do not scale linearly, and retrofits require unique conversion strategies. To allow for additional buildings to potentially connect to the system in the future, the Lowell Demonstration's distribution main will be eight-inch. The cost and feasibility of system expansion is not currently being tested as part of the demonstration but would provide additional valuable learnings for UTEN as a business model.

Providing a Pathway to Enabling Mass Electrification at Minimum Electric System Impact in Urban Areas

Customer adoption

Understanding customer interest and what it would take to get full customer adoption for targeted electrification of a site is key to using UTEN demonstrations as a gas decarbonization tool. Of the 63 gas customers eligible to participate in the program comprising 22 separate buildings, 60% were market-rate residential, 29% were income-eligible residential for bill payment assistance programs, and 11% were commercial. Of that eligible group of customers, approximately half signed up (31 eligible customers, across 11 buildings, with 10 property owners). About 60% are residential, eligible for the Home Energy Assistance Program, and don't own their property. These customers tend to be low-income, younger, single parent homes who are likely to be on a utility payment plan. About 20% of customers in the demonstration are retired on a fixed income and a further 10% are moderate income families who are likely on a payment plan and may participate in existing state energy efficiency incentive programs with financing. The remaining customers are commercial/industrial.

To test the response from different marketing strategies, National Grid's target outreach campaign was multi-pronged and included: 1) mailing an introductory notice signed by the Lowell City Manager, 2) mailing a postcard that included the Lowell Demonstration website and a hotline, 3) mailing a targeted letter with more information on the benefits of networked geothermal, 4) door-to-door outreach with door hangers, 5) phone calls to owner-occupied buildings with follow-up in-person meetings to evaluate the existing gas appliances, 6) yard signs for interested participants, 7) flyers in various languages spoken in the area and two informational videos on the website and YouTube.

The Lowell Demonstration may show that the mix of residential and commercial and industrial customers needed for load diversity may be more common in urban neighborhoods that include multi-family buildings with a range of incomes. Learnings focused on the dynamic between renters and building owners are crucial to understand what kind of messaging and incentives may be necessary to scale a UTEN offering. Despite numerous and targeted outreach approaches, National Grid was only able to make contact with about 50% of the eligible property owners. For those with whom National Grid was able to make contact, 100% initially expressed interest in participating. One property owner withdrew, likely because the owner is considering selling the buildings. There was low response from the mailings, which did not result in identifying potential participants. Direct phone calls and in-person meetings were the most effective, with numerous customers expressing interest.

Participants in the Lowell Demonstration are gas customers of National Grid and the property owners for the buildings that are part of the program. However, renters are typically the gas customer, not the building owner of a rental property. The incentive offering (new appliances and upgrades to the building) and participant fees (for use of heating and cooling) created a split incentive between property owners and renters that will need to be taken account for UTEN sites.

In addition, the two-year demonstration agreement would not be possible with renters, who typically have leases on a shorter timeframe. For scaling this offering in the future, an analysis will need to be undertaken on customer payment structures. There are a variety of structures that can be considered, including a fixed thermal fee based on square footage, a British thermal unit (BTU)-metering based fee based on the heat used, a fully allocated cost to serve (all overhead, inspection and system maintenance costs), a system benefit cost that incorporates the reduced load on the electric system compared to alternate technologies, such as ASHPs, and others not mentioned here.

The difficulty in achieving 100% customer adoption in the Lowell Demonstration geography highlights the difficulty in using targeted electrification demonstrations to achieve gas decarbonization objectives. Figure 1 below demonstrates the need for 100% customer adoption to ensure avoided gas infrastructure.

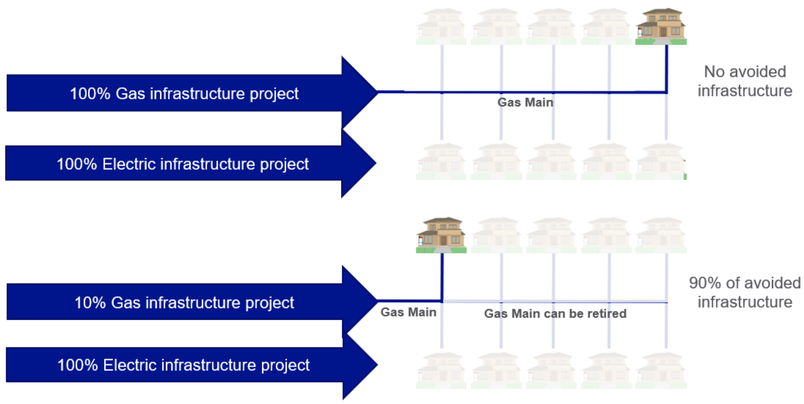

Figure 1. Impact of targeted home electrification on gas pipeline retirement

Targeted electrification combined with gas system decommissioning would have the greatest impact in achieving the states' decarbonization goals; however, in the Lowell scenario the gas system will continue running alongside the demonstration geothermal system. In addition, operating data to evaluate the winter peak load compared to alternate technologies, such as ASHPs, will be incorporated in the evaluation and monitoring portion of the project after it is put into service.

Transitioning the Skillsets of Gas Utility Workers

Determining how current gas worker skillsets can transition to UTEN work is ongoing. National Grid has entered into a Memorandum of Understanding with the gas unions that provides the opportunity for them to observe the installation of UTEN projects and work together with the Company to determine how the unions' skillsets may best be used in the installation and maintenance of future geothermal networks. Prior to installation work beginning in Lowell, National Grid will work with the unions to develop a schedule for them to observe aspects of the work. National Grid has also committed to meeting periodically with the unions to discuss future roles and responsibilities for its union work force related to UTEN. We anticipate that these meetings during the construction, and operations and maintenance of the demonstration, will provide a clearer understanding of the capabilities needed.

Additional skillsets to consider and potentially transition from gas experience is in the design and engineering of the project. The design and engineering of the Lowell Demonstration has been contracted out to a third-party design company that has extensive experience with geothermal systems. It is a specialty type of design that requires expensive modeling programs, such as TRNSYS, to model the behavior of transient systems. While workers doing similar design and engineering work for the gas system could transition to modeling UTENs, it would require extensive retraining and potentially new skillsets.

Scaling Utility Thermal Energy Networks

To scale UTEN for broad utility implementation as an option for heat decarbonization, there are both short and long-term challenges to overcome.

In the short term, project and customer costs could be reduced by selecting a site with new construction compared to retrofits and higher density over lower density. About one-third of the Lowell Demonstration costs are due to customer premise costs, including equipment and building retrofits. In addition, higher density could bring a more diverse load, which due to the ability to shift heating and cooling load simultaneously, could require fewer or no boreholes to be drilled. For example, Con Edison in NY proposed a UTEN demonstration that would utilize heat from a data center to warm nearby buildings on a shared loop. Capturing and quantifying the benefits of reduced infrastructure buildout or maintenance (e.g., on the electric side as a non-wires alternative or on the gas side as an LPP alternative) could provide cost benefits.

In the long term, we see five areas that could drive scaling of UTEN:

1. Additional demonstrations add to the available data on UTEN feasibility
2. Innovation in technology to drive down costs
3. Requirement to optimize investment in UTEN and the gas network
4. Regulatory framework for cost recovery and ownership models
5. Integrated energy planning between electric and gas utilities

First, data from additional demonstration projects is critical to understanding long-term feasibility around aspects such as ownership models and costs. On January 29, 2024, National Grid announced a second demonstration with the Boston Housing Authority to replace an aging gas boiler loop serving 129 units at seven public housing buildings in Dorchester, Massachusetts (Boston Housing Authority 2024). In addition to this second demonstration, National Grid is completing final engineering design for three of the four UTEN projects in NY, which test different use cases. These include a split ownership model where another entity owns the borefield and National Grid pays for the thermal resource and builds the distribution system. Additionally, one of the demonstrations involves utilizing waste heat from a wastewater treatment plant outlet and another demonstration provides heat and cooling to a large public housing building in a dense urban environment interconnecting with nearby retail buildings. Each utility's service territory provides a unique opportunity and the more demonstrations completed around the country, the more data points we will be able to use to evaluate UTEN feasibility.

Second, innovation will be required to drive down costs, expand accessibility, and bring UTEN closer to parity with natural gas or ASHPs. Customer costs could decrease with general equipment cost decline or technologic improvement of ground source heat pumps through increased coefficients of performance or ability to create steam for use in hydronic baseboard systems, driving down the need for building duct work and retrofitting. Drilling, which typically makes up one-third of total project costs, could also see declines with improved techniques that are faster with more ability to control drilling direction, use different configurations like angled drilling, drill to deeper depths with higher temperatures thus requiring fewer boreholes, create various configurations underground to increase thermal conductivity, improvement in the heat exchanger design, and increased competition through development of a robust market. Alternative sources of thermal energy that require no or fewer boreholes could also bring down costs, such as concentrating heat from wastewater, drilling closed-loop systems into an aquifer to take advantage of increased thermal conductivity, utilizing ambient heat in underground spaces such as parking lots and subways, transferring thermal energy from data centers, utilizing heat sinks like ice rinks and grocery stores, and utilizing thermal energy from water bodies like lakes and canals, among many other sources. There are many companies working in these innovative spaces so it's possible we may see a breakthrough that could create significant cost declines.[2]

Third, regulatory policies will need to be enacted for "orderly" customer transition onto UTEN systems to get to full disconnection from gas networks. The Lowell Demonstration did not garner enough customer participation to cut and cap a section of leak prone natural gas pipe and transition the whole street off the gas network, even with the incentives of no-cost heating and cooling upgrades and all new electric replacements for gas appliances. This section of leak prone natural gas pipe will need to be replaced at some point to have a safe and reliable gas network. An "orderly" transition would allow for management of investment in the gas network so as not to run double networks in the same location, and conversely, to allow for cost recovery of not investing in replacing aging pipe.

Fourth, a sustainable and scalable regulatory framework will be required. To date, it has not been determined who will pay for the UTEN or how customers will be billed in the future. For example, this framework could take the form of a cost-of-service approach where UTEN customers "pay their own way" after some initial socialization of startup costs but then benefit from the value UTEN is providing to the rest of the energy system by accounting for the avoided costs. Value could be attributed to avoided gas infrastructure investment and avoided peak demand impacts on the electric network. In February 2024, the NY Department of Public Service published their proposal for UTEN rules that includes guidance on the relationship between the thermal resource and the utility. Specifically, the proposal did not provide guidance on system components including "billing, metering, safety regulations, designation of operational roles and specification of related responsibilities, and operational standards" (NY DPS 2024). In British Columbia, there is a separate regulatory framework for distinct thermal energy utilities and FortisBC Alternative Energy Services, Inc. separated from FortisBC Energy Inc., in 2014 to be regulated under this framework (BC Utilities Commission 2015, FortisBC 2024).

Finally, a systematic way for gas local distribution companies, electric distribution companies, regulators, policymakers, and other stakeholders to develop long-term integrated energy system plans that identify where UTEN makes sense will be required. An integrated energy plan would show the electric distribution company where to build the needed capacity, the gas local distribution company would limit gas investment in these areas, and the community

[2] In no particular order, a non-exhaustive list of companies that are working on these technologies include: Genesys, Eavor, Fervo, Bedrock Energy, Celsius Energy, SHARC Energy, Project Innerspace GeoMap, Dandelion Energy, Darcy Solutions, and many more.

would be onboard to transition from natural gas to UTEN. Integrated energy planning requires a shift from traditional planning processes, which plan gas and electric network infrastructure separately based on projected demand, to a more holistic approach that considers multiple scenarios for customer demand outcomes, evaluates impacts across sectors and networks, and optimizes based on a range of criteria. In the current regulatory state, there is no authority who decides if, when, and how the Lowell Demonstration could be expanded or if these networks should be incorporated into utility infrastructure planning models.

Conclusion

Utility Thermal Energy Networks (UTENs) have a role to play in decarbonizing the building heating sector, while aiming to equitably socialize costs of the energy transition and capture societal benefits, provide a pathway to enable mass electrification at minimum electric system impact in urban areas, and transition the skillsets of gas utility workers. They are not without their challenges, however, as seen through the lens of the Lowell, Massachusetts Demonstration. The Lowell Demonstration has grappled with borefield easement challenges, split incentives between property owners and renters, the lack of customization of the fee for customers participating in the demonstration, the need for customized building conversion strategies in older housing stock, and larger than anticipated project budget due to the complex nature of the system, economic factors, and urban setting needed to obtain a diverse load profile. In addition, the demonstration was not able to obtain the necessary customer participation to cut and cap a section of leak prone natural gas pipe, even with no-cost highly efficient heating and cooling and replacement of natural-gas fired appliances. Near-term project costs could be reduced by utilizing UTEN in new construction and obtaining simultaneous heating and cooling load, reducing the need for boreholes.

In the long-term, there are five areas to focus on for scaling UTEN: more demonstrations to prove various use cases, creation of policy that drives an "orderly" transition, spurring innovation to drive down costs of all the various project components, creation of a regulatory framework that considers the value UTEN provides to both the gas and electric system, and finally, a systematic approach for long-term integrated electric and gas planning. UTENs advance planning for the role that gas utilities could play in deep decarbonization pathways.

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