

Smart Electric Power Alliance

Insight Brief: Thermal Energy Networks for Utility Carbon Reduction

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Thermal Energy Networks for Utility Carbon Reduction

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About SEPA

The Smart Electric Power Alliance (SEPA) helps all electric power stakeholders accelerate the transformation to a carbon-free electricity system. SEPA concentrates our focus on the following areas to maximize impact: Transportation, Energy Storage, Resilience, Emerging Technology, Policy, and Energy Equity.

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Introduction

As natural gas and electric utilities accelerate their work to reduce carbon emissions, they are evaluating paths to help customers decarbonize building heat. Heating electrification with air source heat pumps is an often-discussed pathway, with customer incentives, Federal tax credits, and market momentum all being used to encourage deployment. However, electrification poses business risks to natural gas utilities, and electric utilities are starting to consider the implications of the potential peak load increases that come with widespread building and vehicle electrification.

Recently, policymakers in 12 states[1] have crafted legislation that asks utility regulators and utilities to explore a new path to decarbonizing building heat: thermal energy networks. Abbreviated as "TENs," these systems are also known by a variety of other terms, including networked geothermal, district geothermal heat, ambient temperature loops, and others. The technology has existed for decades but seen only niche use in the U.S., and until recently, many utilities lacked a pathway to offer TENs service to customers.

Now, utilities around the country are proposing and even managing first-of-a-kind utility TENs demonstrations, while states and NGOs are developing incentive programs and safety guidance and facilitating knowledge exchange. But for the uninitiated, there are many questions: Why are we just hearing about this technology now? How (and how well) does it work, will customers want to use this technology, and how big of a role could it play in the decarbonization strategies of natural gas and/or electric utilities? How much would a TENs approach to utility carbon reduction cost customers, and what benefits would they receive in return?

In the summer of 2024, the Smart Electric Power Alliance embarked on a landscape scan of the current use and future potential of TENs for utility carbon reduction. The central question framing our work was, **"Given that TENs offer high potential for low-carbon heating but are rarely used (or known) today, which aspects of this technology should states and utilities explore?"**

This question led us to examine some key factors that appear likely to shape future adoption in the context of utility carbon reduction strategies. We reviewed literature (including primary and secondary sources such as utility regulatory filings, economic analyses, case studies and whitepapers, media articles, and more) and held a series of one-on-one conversations with industry experts to gather the experiences of groups involved in TENs and geothermal heat today, including states, regulatory bodies, natural gas utilities, electric utilities, environmental advocates, and labor representatives. Together, this research highlighted the importance of growing the utility industry's experience with the infrastructure necessary to support TENs deployment, the need to refine estimates of long-term consumer and grid benefits, and the critical role of supportive legislation, regulation, education, and incentives in supporting utilities and consumers in adoption.

This brief defines geothermal energy networks, outlines initial carbon reduction use cases, and offers frameworks to understand possible paths to increased deployment. Figure 1 summarizes our research findings on the motivators and opportunities for utility deployment.

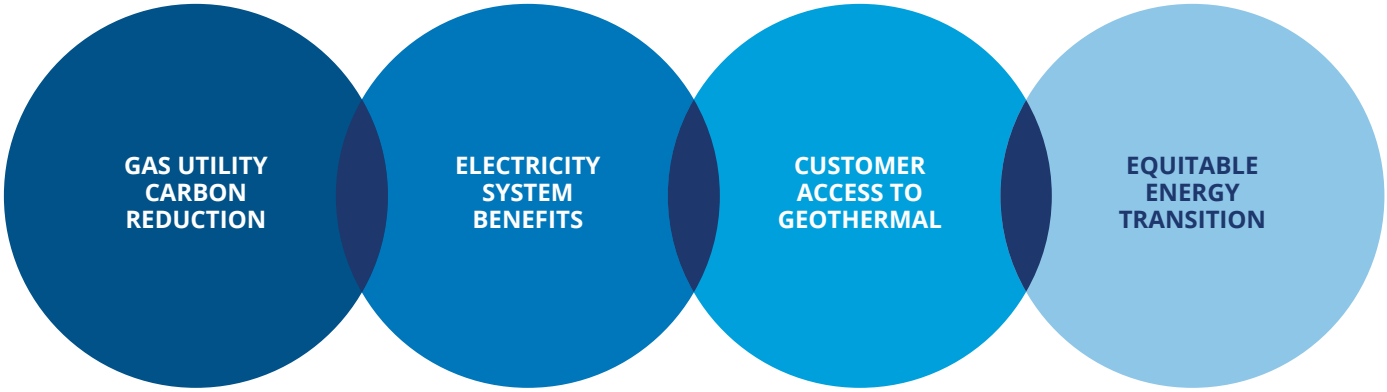
Thermal energy networks (TENs) are heating and cooling systems. They convey heat from the ground to buildings ('thermal energy') using shared wells, pumps, and neighborhood-wide water piping to transmit the heat among buildings ('network'). Buildings on the network need ground source heat pumps to convert the shared thermal energy to individual space conditioning. TENs efficiently make heat from the energy input; as a result, they offer an extremely high coefficient of performance even compared to air source heat pumps. Some TENs use waste heat or water-based resources instead of the earth. This brief focuses on TENs using geothermal energy.

1 Note: The states with enacted legislation in 2024 include Massachusetts, Minnesota, New York, Colorado, Washington, Maryland, Vermont, and California, and states with filed legislation include Connecticut, Rhode Island, Maine, and Illinois. Activities across these states vary including regulatory investigation, stakeholder convenings, project proposals, engineering design and feasibility studies, and in-the-ground demonstration projects. *See:* Building Decarbonization Coalition (2024). Thermal Energy Networks (TENs) State Legislation.

Figure 1. Motivators and Opportunities for Utility-Led TENs

TENs Complement Many Pathways to Decarbonizing Utility Systems

Deploying TENs for geographically-targeted use cases complements other tools for carbon-free energy, including clean energy supply and broad building decarbonization. Gaining experience, driving innovation, and expanding market capacity can increase long-term adoption.



TENs are getting attention in energy policy for their potential as a non-pipeline option for natural gas distribution utility carbon reduction. TENs can replace segments of decommissioned gas distribution pipeline, can be deployed as an alternative to new pipeline, or can be deployed to leverage waste heat from large commercial facilities.

TENs can use thermal energy or waste heat to heat and cool buildings, rather than fuel or electricity—and they are even more energy-efficient than air source heat pumps. Increasing TENs deployment would provide emissions reductions while avoiding some of the pressure that other forms of building decarbonization place on the electric grid.

Utility deployment can help manage and spread out the upfront costs and complexity that currently limit geothermal heating adoption. If deployed by natural gas utilities, TENs may benefit both natural gas and electricity customers. Supportive regulation and integrated planning will be key to balance short-run costs and long-run benefits to all stakeholders.

Projects co-created by communities and utilities may yield energy justice benefits if they are selected, designed, and operated equitably. Stakeholders desire varied outcomes, such as cost savings, clean transition pathways for gas workers, choice of non-emitting heating source, sovereignty over energy, and others.

Source: SEPA (2024). Based on literature review and industry interviews.

Learnings from SEPA's scan provide important information to help shape policy conversations about how to support communities and utilities in decarbonizing buildings and managing energy costs. For energy policy leaders in states or at utilities where there is no formal path to TENs today, this insight brief shines light on learnings to-date and essential questions that must be addressed when considering the potential value of TENs. Key points include:

1. **The technology is proven outside of the utility construct.** Useful points of reference include district geothermal retrofits at universities and new residential developments.
2. **Natural gas decarbonization policy is motivating new interest in TENs.** As a strategy for natural gas distribution utility decarbonization, TENs may offer more appealing business opportunities and a clearer pathway for its existing workforce to apply their skills to low-carbon heating, relative to heating electrification.
3. **Use can support targeted decarbonization of heat.** TENs are inherently place-based strategies, making them useful for geographically targeted carbon reduction, energy affordability, resilience, and equity.
4. **Utility deployment requires new, supportive regulation.** Utilities are well positioned to expand deployment and coordinate usage for grid benefits but, until very recently, have lacked incentives or authority to offer geothermal service to customers.
5. **Balancing stakeholders' diverse interests is essential.** Many stakeholders, including climate advocates, community groups, certain natural gas utility labor unions, and certain natural gas and electric utilities, are excited to expand utility use. Balancing needs and perspectives among this diverse group adds complexity but will drive broad support for geothermal energy networks as an energy transition investment.

6. **Increasing adoption requires finding ways to manage high upfront costs and long payback periods.** TENs offer significant long term benefits and monetary savings. Successful implementation will require careful planning and communication of the long term financial benefits to consumers and utility stakeholders.
7. **Consumer awareness and financing support are needed.** Initial utility efforts find that extensive outreach and education are crucial to secure community buy-in. Inclusive financing and upfront incentives will be needed to extend benefits to all consumers.
8. **Demonstrations are balancing impact with 'in the ground' learning.** First-of-a-kind utility TENs policy and projects explore how to make this existing technology work in the context of the regulated utility construct. Monitoring, evaluation, and learning—including impact evaluations—are crucial to validate this use case in terms of costs and performance and identify pathways to scale.

Technology Basics: How It Works

Thermal energy networks (TENs) provide energy-efficient, low-emissions heating, cooling, and energy storage by transferring heat between a group of connected buildings and a carbon-free source of heat, such as the ground (geothermal energy), water (hydrothermal energy), or other buildings (waste heat energy).[2] This brief focuses on TENs that use geothermal heat for building heating and cooling. This approach uses wells and pumps to access the ground's heat and circulate it through a loop of underground water pipes, while geothermal heat pumps in each building use the thermal energy to provide cooling in summer and heat in winter. TENs are akin to a networked version of individual geothermal (ground source) heat pumps, scaled up to heat a whole city block, street, or neighborhood. Figure 2 shows a geothermal energy network.

Geothermal heat resources exist everywhere, from rural to urban communities and from coast to coast in the United States.[3] An understandable misperception about TENs is that they require high-temperature heat resources to work. However, unlike geothermal power production—which does need the significant heat found only a mile or more below ground—TENs use the more modest year-round heat (45-55°F) available just 100-700 feet below the ground in much of the United States. In geologic terms, these are low-temperature, shallow resources.

Using this heat offers energy consumption and carbon emissions benefits:

- **Reduced Emissions:** Individual geothermal heat pumps that serve single buildings produce only 10-20% of the average annual space heating emissions of a propane furnace,15-30% of a natural gas furnace, and about 50% of an air-source heat pump.[4]
- **Higher Heating Efficiency:** Geothermal heat pumps are more energy-efficient than air source heat pumps because they use the ground's constant temperature as a thermal battery. TENs offer even higher system efficiency than geothermal heat pumps because they balance the different energy loads of networked buildings (residential, office, commercial, data centers, etc.). The Coefficient of Performance (COP) is used to benchmark heating equipment performance and measures a "percent efficiency" ratio of heat provided per energy input. TENs achieve a (COP) of 6 to 8, compared to 4 to 5 for individual ground-source heat pumps, 2 to 3 for air-source heat pumps, and about 1 for the highest-efficiency gas furnaces.

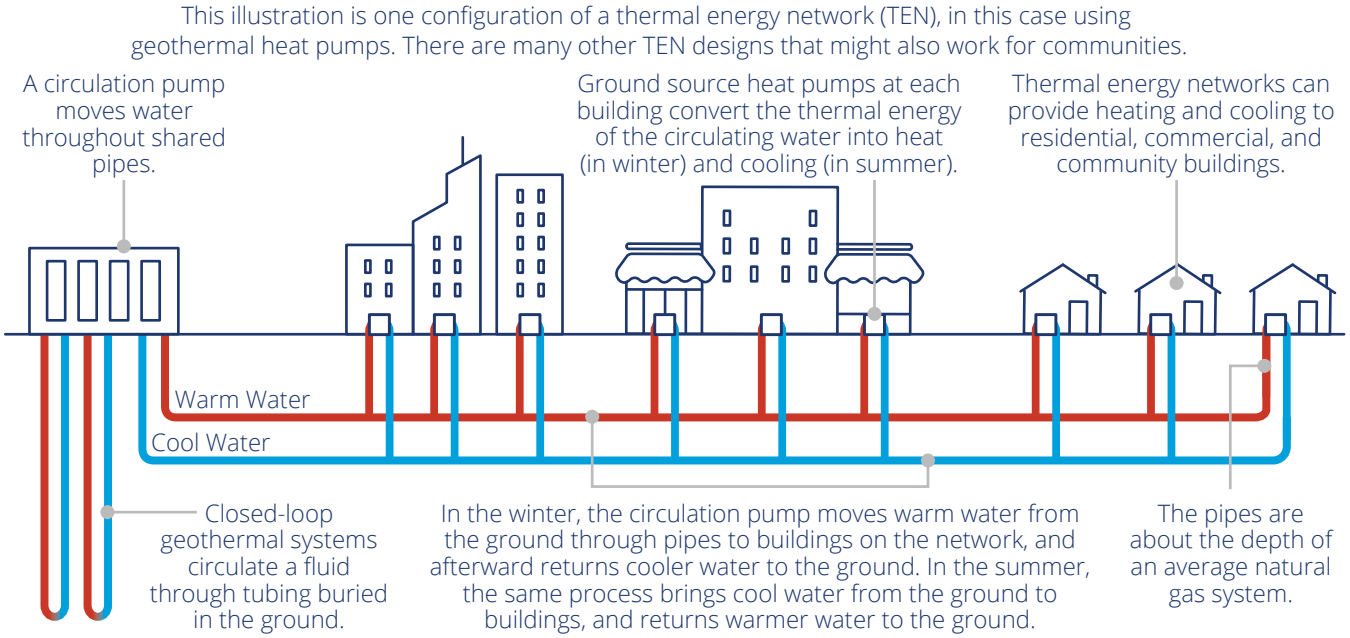
Despite these energy efficiency benefits, high upfront capital costs, a long payback period, and lack of consumer, utility, and regulatory awareness have limited adoption of

2 Fry, N., Adebayo, P., Shor, R., and Mwesigye, A (2024). A review of district energy technology with subsurface thermal storage integration. *Geothermal Energy, 12(29).*

3 U.S. Department of Energy (2019). GeoVision: Harnessing the Heat Beneath Our Feet.

4 RMI (2023). Clean Energy 101: Geothermal Heat Pumps.

Figure 2. Snapshot of a Geothermal Energy Network



Source: SEPA (2024), adapted from a District Heating and Cooling diagram from U.S. DOE (2023). Community Geothermal Heating and Cooling Design and Deployment.

geothermal heating and cooling.[5,6] U.S. Energy Information Agency (EIA) estimates that about 700,000 U.S. residential households use geothermal heat pumps as their primary source of heat, representing about 0.6% of the space heating market.[7] TENs adoption is even more limited, with only a few dozen university, municipal, and private projects in the U.S.[8] One utility has an active TEN demonstration as of December 2024, and several more are in development.

Utility Context: Why and Why Now

State, Federal and utility support for geothermal heating dates back to the 1980s and 1990s.[9] While interest has ebbed and flowed over the years, it began to rise again in the late 2010s, around the time that environmental advocates saw opportunities to have utilities deploy TENs specifically as a pathway to decommission the natural gas distribution network.[10] More recently, power system modeling studies have forecasted the potential costs and benefits of TENs to help decarbonize natural gas and electric systems. For example, a 2022 Massachusetts study by Energy and Environmental Economics compared various ways natural gas utilities could comply with state climate legislation by 2050. Compared to a high-electrification scenario relying on air source heat pumps to electrify 90% of building heat, converting 25% of buildings to TENs could avoid about 25% of the winter peak electricity demand

5 Pace University Energy and Climate Center (2021). Overcoming Legal and Regulatory Barriers to District Geothermal in New York State.

6 Oak Ridge National Laboratory (2019). GeoVision Analysis Supporting Task Force Report: Thermal Applications—Geothermal Heat Pumps. ORNL/TM-2019/502.

7 U.S. Energy Information Administration (2023). Annual Energy Outlook 2023. Table 21. Residential Sector Equipment Stock and Efficiency, and Distributed Generation.

8 Pace University Energy and Climate Center (2021), cited above, reviewed 23 district and campus-style TENs in the U.S. and Canada. U.S. DOE GeoVision (2019) identified 22 in the U.S.

9 Oak Ridge National Laboratory (2008). Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers (ORNL/TM-2008/232.)

10 HEET (n.d.). Our History. Accessed July, 2024.

growth, about 15% of the increased electric capacity and could avoid some of the statewide per-kWh incremental costs of electrification.[11] In a separate effort, Oak Ridge National Laboratory examined the national technical potential of geothermal heat and in 2023 found that mass adoption of geothermal heating—to the tune of 5 million individual geothermal heat pumps by 2050, or 70% of all U.S. buildings—would greatly reduce peak electric demand, reduce generation and capacity needs, and reduce costs of electrification (see Table 1 for more detail).[12]

Utility-led deployment may help overcome consumer barriers to the level of adoption modeled in these studies. Utilities may benefit from adopting TENs to help meet their carbon reduction targets, support grid management, and identify lines of business compatible with economy-wide decarbonization. Until very recently, however, utility regulation has not generally allowed existing utilities to offer their customers geothermal service. States considering whether and how to amend current utility regulation to allow utilities to offer geothermal service are uncovering a variety of questions about how best to do so.[13] The geothermal heat industry recognizes the rising interest in TENs, and groups of nonprofits, the drilling industry, utilities, and other stakeholders are exploring how to increase the size and skill of the geothermal drilling workforce as well as how to leverage the natural gas utility workforce's existing capabilities to accommodate increased deployment. Table 1 summarizes the history, present state, and future potential of TENs.

Table 1. Potential Evolution of Geothermal Energy Network Use and Value to the Grid

Recent History	▪ In 2020, just 23 geothermal energy networks–mostly owned by universities and municipalities–were operating in the United States, generating 75 MW of thermal energy (MWth). ▪ Utilities faced regulatory barriers to offering geothermal heat.
Present State	▪ Utilities are deploying TENs for targeted, street-by-street decarbonization. These efforts are funded by a mix of government, private, and customer funds. ▪ Between 2021 and 2024, eight U.S. states enacted legislation enabling or requiring utilities to demonstrate TENs. One of these states also filed legislation that would permanently enable natural gas utilities to provide geothermal service (Massachusetts). Four other states are also considering legislation for utility TENs demonstrations. ▪ Four of the eight states with enacted legislation support demonstrations by natural gas, electric, and/or water utilities, while the other four focus exclusively on natural gas utilities. ▪ State support varies and can include education, tax incentives, and other incentives. ▪ High construction costs, a small geothermal drilling industry, and soft costs (e.g., awareness, coordination, regulation) limit broad deployment. ▪ Advocates and associations are convening working groups, hosting workforce education and training, and compiling shareable project data.
Future Possible	Studies of individual geothermal heat pumps provide a sense of what TENs could achieve at scale: ▪ Installing 5 million *individual* geothermal heat pumps by 2050 could cut 7,000 million metric tons of carbon emissions from natural gas and electricity systems combined, save at least 10% ($316 billion) on all-in electricity costs, reduce U.S. electric power system generation and capacity needs by 11% or more, and lower peak electric demand in some hot climate zones up to 28%.[14] This illustrates the potential scale of impact of networked geothermal systems, which use similar technology. ▪ With further technological innovation, 28 million U.S. households could install geothermal heat pumps and 17,500 geothermal energy networks could be installed, with highest potential in the Northeast, Mid-Atlantic, Midwest, and South.

Source: SEPA (2024). Based on literature review. Source documents are cited throughout this brief.

11 Energy and Environmental Economics (2022). The Role of Gas Distribution Companies in Achieving the Commonwealth's Climate Goals.

12 Oak Ridge National Laboratory (2023). Grid Cost and Total Emissions Reductions Through Mass Deployment of Geothermal Heat Pumps for Building Heating and Cooling Electrification in the United States.

13 *For example:* Illinois Commerce Commission (2024). Thermal Energy Network Report.

14 Oak Ridge National Laboratory (2023). Grid Cost and Total Emissions Reductions Through Mass Deployment of Geothermal Heat Pumps for Building Heating and Cooling Electrification in the United States.

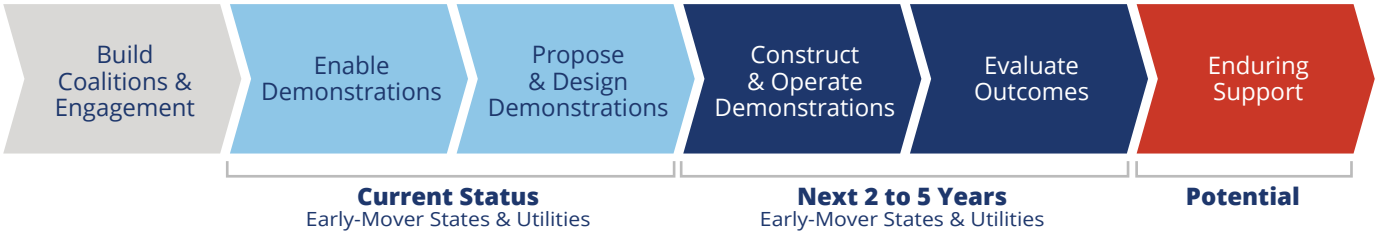
While geothermal resources are available everywhere, utility regulatory dialogue today is focused on TENs for targeted carbon reduction. Key use cases being discussed include:

- **End-of-Pipe or No-Pipe Communities:** TENs provide a building heat source for communities moving away from natural gas as an end-use fuel. If other building end-uses can be electrified (e.g., natural gas cooking, natural gas appliances), utilities reduce investment in the natural gas distribution system, allowing them to move away from repairing leak-prone gas pipes, replacing aging pipes, or extending natural gas infrastructure to new areas. To maximize the potential benefits of this use case, utilities should proactively compare the net costs and benefits of geothermal energy networks to other solutions (for example, ongoing natural gas system maintenance, building-by-building heat electrification with air source heat pumps, individual ground source heat pumps, etc.).
- **Community Choice and Vulnerable Communities:** Geothermal heat has low operational costs, is cost-effective in the long run, and is a reliable, on-site resource. This makes it valuable in areas where heating costs are high, where customers are reliant on delivered fuel, in remote locations, or in communities that prioritize local resilience. Utility-led TENs and state- or municipal-led TENs may both be relevant; for example, 11 awardees in the U.S. Department of Energy Geothermal Technologies Office (GTO) CommunityGEO program are testing a variety of ownership models.[15] Empowering communities to select TENs requires education, financial support, and robust stakeholder engagement in planning efforts.
- **Moderate Development Density:** Geothermal heat resources exist everywhere, from rural to urban communities, but TENs are most energy-efficient in medium-density, mixed-use neighborhoods. The U.S. DOE Geothermal Technologies Office is funding projects that will help communities of all types learn about how to maximize geothermal resources for their region and setting.
- **Waste Heat:** Some state TENs policies, such as New York's, provide pathways for utilities to develop TENs using other sources of heat beyond geothermal. District heat with waste heat can be used in high density areas and as a solution for managing large load growth from data centers.
- **Electric Utility Customers:** While the utility TENs concept is rooted in natural gas system decarbonization, four of the eight states with final legislation supporting utility TENs as of 2024 provide opportunities for electric utilities to demonstrate the technology.[16]

Case Studies to Inform Deployment

Utilities subject to new state requirements that mandate utility TENs demonstrations will soon need to propose demonstration and pilot sites. Figure 3 summarizes the activities that stakeholders can watch for and learn from, based on a review of state policies, documentation for current proposals and projects, and industry conversations.

Figure 3. Path to Geothermal Energy Network Projects and Policies



Source: SEPA (2024).

15 U.S. Department of Energy Geothermal Technologies Office (2023). DOE Announces $13 Million to Support Community Geothermal Heating and Cooling Solutions.

16 Building Decarbonization Coalition (n.d.). Thermal Energy Networks (TENs). Accessed August, 2024.

- **Build Coalitions & Engagement; Enable Demonstrations**: Policy engagement among key stakeholders to expand supportive legislation and utility regulation to new states will be crucial.
- **Propose & Design Demonstrations:** The next two years will likely bring numerous planning and scoping activities leading up to the utility TEN site proposal deadlines stipulated in state TENs policies.
- **Construct & Operate Demonstrations:** Once constructed, TENs will operate on a demonstration or pilot basis, gathering learnings over several years. The first-of-a-kind Massachusetts utility demonstrations—noted below—will operate for two years.
- **Evaluate Outcomes:** Impact and process evaluations and cost-effectiveness testing will be crucial to objectively assess performance throughout and after this period.
- **Enable At Scale (Potential):** Seven of the eight states with TENs legislation have enabled them on a demonstration or as-approved basis. Discussions about scalability can draw upon evaluation results.

TENs case studies are becoming widely available as interest in utility TENs increases. Below, we provide examples of several projects and state funding programs from more recent private developments and the states and utilities taking earliest action on TENs.

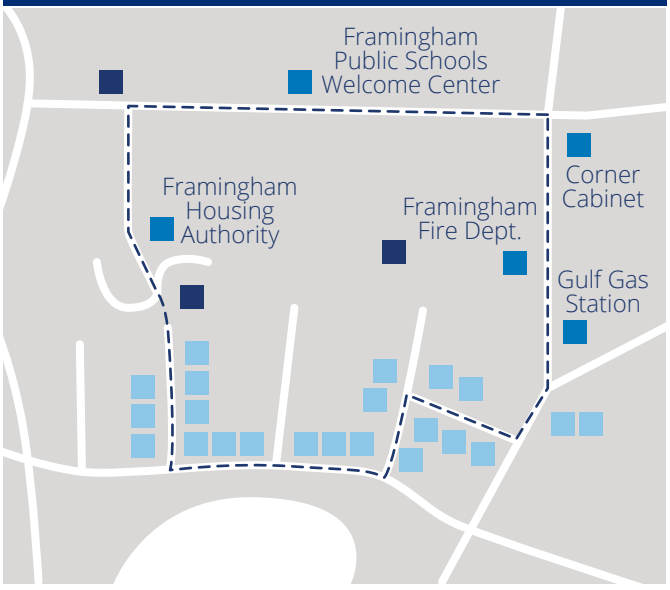
Eversource (MA) and National Grid (MA)

First U.S. Natural Gas-to-Geothermal TENs Demonstrations

A variety of legislation, utility regulation, and guidelines facilitate TENs in Massachusetts, including TENs-enabling legislation from 2021, requirements for natural gas distribution utilities ("Local Distribution Companies") to consider non-gas alternatives to gas network expansion and repair,[17] and TEN development guidelines from the Massachusetts Department of Public Utilities (DPU) Pipeline Safety Division.[18]

- **Eversource** has the first active TENs retrofit, serving 36 buildings (24 residential, five commercial) and 135 customers in a medium-density neighborhood in Framingham (see Figure 4).[19] The system uses 90 boreholes and about one mile of shared main. Eversource first proposed TENs in 2019 as part of a natural gas rate case, received Massachusetts DPU approval to proceed in 2020, and switched the TEN 'on' in 2024. The demonstration will run for two years; the natural gas system is being retained as backup. Eversource and local partners secured grant funding from the U.S. DOE Geothermal Technologies Office Community Geothermal Heating and Cooling Design and Deployment initiative to help expand the TEN in the future, and study best practices for scaling and interconnecting TENs.[20]

Figure 4. Eversource TEN Demonstration Site Map



Source: Eversource (2024). Geothermal Pilot Project in Framingham.
Note: Residential Pilot Customers includes 24 residential systems (20 single-family households, 2 two-family households).

17 Massachusetts Department of Public Utilities (2023). D.P.U. 20-80-B, Investigation by the Department of Public Utilities on its own Motion into the Role of Gas Local Distribution Companies as the Commonwealth Achieves its Target 2050 Climate Goals.
18 Massachusetts Department of Public Utilities (2024). Press Release: DPU Establishes Network Geothermal Guidelines.
19 Eversource (2024). Geothermal pilot reference guide. Accessed November, 2024.
20 HEET (2023). Department of Energy Awards $715,000 to Plan an Expansion of Networked Geothermal in Massachusetts Neighborhood.

- **National Grid** filed its TEN demonstration with the Massachusetts DPU in 2021 to explore the potential of TENs to reduce end-use emissions in environmental justice communities, manage gas-constrained areas, avoid leak-prone pipe replacement, and manage diverse load profiles. National Grid is preparing the demonstration (in part partnership with the City of Lowell and the University of Massachusetts, Lowell), including recruitment of 66 eligible gas customers across 22 buildings, and site design in the mixed-use neighborhood.[21] The utility has also proposed another demonstration in Boston at a public housing property.[22,23] National Grid has shared early learnings from its Lowell experience that may be useful to other early-moving utilities planning customer outreach, site selection, project development (e.g., legal access to rights-of-way, the unique requirements of retrofitting older buildings) and other steps.[24]

Large Investor-Owned Utilities (NY)

TENs Proposals Are Balancing Many Objectives

New York's seven largest investor-owned utilities each proposed TEN pilots in 2023, following passage of the Utility Thermal Energy Networks and Jobs Act and New York State Public Service Commission Utility Thermal Energy Networks rules.[25,26] The Act emphasizes the role of utilities and their workforces in achieving building sector decarbonization and supporting equitable access to affordable clean energy for all consumers. At least one of each utility's pilots must be located in a designated 'disadvantaged community' as defined by the state's Climate Justice Working Group. In 2024, nine of 12 proposed pilots had created final engineering design and customer protection plans but are still subject to further regulatory review and approval. The TENs proposals are designed to yield learnings across a range of conditions throughout New York state. While TENs in New York are dynamic and subject to change, we provide a snapshot of two utilities' proposals at the time of this brief to illustrate the breadth of use cases and innovations that utilities can explore.

- **ConEdison**'s three proposals included two TENs in New York City: one leveraging waste heat from a data center to serve a multifamily public housing authority property and one leveraging multiple waste heat sources to serve the heating and cooling needs of 3.6 million square feet of commercial buildings in Rockefeller Center.[27] A third TEN, in a medium-density mixed-use neighborhood in Mount Vernon, would use geothermal heat to serve up to 76 buildings, including 241 residential customers, along with churches, a fire station, and a rec center and aim to retire 500 feet of leak-prone natural gas pipe.[28]
- **National Grid**'s three TENs proposals in New York include efforts to develop a geothermal TEN serving a public housing authority property and commercial buildings (Brooklyn), a geothermal TEN serving a downtown business and arts district (Troy), and a TEN leveraging waste heat from the outfall of a wastewater treatment plant for a mixed-use neighborhood (Syracuse).[29] Separately, National Grid has also completed a geothermal pilot program on Long Island, as an alternative to extending natural gas distribution lines, and has leveraged project details when designing additional projects.[30]

21 Ibid.

22 National Grid (n.d.). Introducing our geothermal energy programs. Accessed September, 2024.

23 City of Boston (January 2024). Boston Housing Authority, National Grid agree to develop networked geothermal heating at Franklin Field Apartments.

24 Nikiforova, K. & Darling, J (2024). Obligation to serve: Utility approach to providing decarbonized heat. In *Proceedings of the 2024 ACEEE Summer Study on Energy Efficiency in Buildings: Panel 6: Utilities and The Future.*

25 New York State Senate (May 2022). Senate Bill S9422, Establishes the "Utility Thermal Energy Network and Jobs Act."

26 New York State Department of Public Service (July 2024). PSC Adopts Initial Utility Thermal Energy Networks Rules.

27 ConEdison (2024). Thermal Energy Networks.

28 ConEdison (2024). Mount Vernon Thermal Energy Network.

29 National Grid (2024). Introducing our thermal energy networks. Accessed November, 2024.

30 National Grid (2020). *Geothermal Gas REV Demonstration Project – Final Report.* Retrieved from NYSERDA: "Understand the Potential of Community Heat Pump Systems."

Colorado Mesa University (CO)

Private Campus Geothermal Retrofit

When Colorado Mesa University (CMU) wanted to expand from a commuter campus, it needed to expand its building footprint.[31] Due to state funding requirements, the new builds had to achieve LEED Gold Standards. The campus completed its initial campus TEN in 2008, achieved payback in 10 years, and has insulated itself against energy price fluctuations while saving nearly $12 million in energy costs so far. CMU has expanded the TEN to include 16 buildings; the TEN now provides 90% of the campus's space conditioning. In 2024, the Colorado Energy Office Geothermal Energy Grant Program (discussed below) awarded CMU approximately $400,000 to help expand the project further.

Whisper Valley (TX)

Private New Construction with Geothermal

This planned "green" community (400 residences in 2024) outside Austin uses TENs for all heating and cooling.[32] It eventually will include 5,000 single-family homes, 2,500 multi-family homes, mixed-use retail, office, and commercial spaces, and schools. Residents pay a fixed monthly charge for the geothermal service, pay for electricity for appliances, and many have solar and storage. During Winter Storm Uri, the geothermal heat pump system (paired with solar for electricity) maintained a constant temperature throughout the storm.

Colorado Energy Office (CO)

State Incentive Program for Geothermal Heating Development

Colorado House Bill HB23-1252 allows any utility in the state to pilot TENs and requires utilities serving 500,000 or more customers to do so.[33] In a related effort, the Colorado Energy Office provides a variety of grants and tax credits for geothermal electricity, geothermal heat pumps, and TENs.[34] In 2024, the Office awarded $3.57 million in grants to 20 entities for TEN scoping, design, and installation. Nearly half (48%) was allocated to projects serving disproportionately impacted, low-income, or just transition communities, as defined in Colorado Statute. Additionally, Office staff regularly engage in office hours and community events to educate the public about the technology and funding opportunities. Through these efforts, the Office has gathered a deep understanding of community needs and preferences for geothermal pilots and projects (e.g., balancing cost savings, energy independence, carbon reduction, or other goals).

31 *For example:* Colorado Mesa University Geo-Grid System and University Taps "The Heat Beneath Our Feet" Geothermal Energy.

32 *For example:* Whisper Valley Project Description, Frequently Asked Questions, and "Geothermal Tech Weathers Texas Ice Storm; Home Batteries Provide Resiliency."

33 Colorado House Bill 23-1252 (2023). *Concerning the Implementation of Measures to Advance Thermal Energy Service.*

34 Colorado Energy Office resources include: Geothermal Energy Tax Credit Offering, Geothermal Energy Grant Program, and list of Geothermal Energy Grant Program Round 1 Awardees.

Costs and Customer Acceptance on the Path to Adoption

While case studies and technical potential analyses show that TENs provide many benefits and could be used more widely, our research for this brief also identified a variety of barriers that proponents will need to overcome to realize that potential. This section highlights cost and customer experience factors that are the focus of utility demonstrations.

Project Cost Categories

Construction and equipment drive the cost of geothermal heating and cooling projects, with operation and maintenance comprising a smaller share of the cost.[35] Core cost categories include:

- **Participant Equipment:** The individual heat pump equipment that converts network heat to space conditioning costs $2,500-$5,000 per ton of capacity, resulting in upwards of $15,000 for residential customers requiring a 3-ton unit (not including other associated building weatherization, energy efficiency, structural upgrade, or installation costs).[36] The equipment lasts around 25 years.[37] Utilities may choose to pay for some or all of these costs during demonstrations. At scale, ratepayer-funded energy efficiency programs, state and federal incentives, or inclusive financing are other potential avenues to help customers manage costs.
- **Utility Infrastructure and Equipment:** Key equipment shared by all customers on the TEN includes multiple geothermal wells per TEN (boreholes), a ground loop (network of geothermal mains and service lines that connect wells with premises), and network pumps to circulate the fluid in the pipes. The equipment is long-lived; the pipes, for example, are expected to last for 50 years. As with more traditional utility capital investments, the costs of infrastructure that serves customers could be recovered in utility rates, and the fair allocation of these costs across customers is being discussed. Integrated gas and electric system planning may be a vehicle to clarify project impacts across relevant utility systems.
- **Installation:** Skilled labor and equipment availability contributes to project cost and timelines. Natural gas pipeline staff bring transferable skills that can be applied to installing and maintaining shared pipelines.[38] However, stakeholders note that there is a shortage of geothermal drillers and drill rigs needed for deployment. Workforce education and training are underway to increase the number of qualified contractors capable of supporting increased TENs deployment.[39,40]
- **TEN Operations:** So far, utilities with TEN demonstrations are recovering or planning to recover the costs of ongoing operation and maintenance using a fixed participant geothermal heat charge.

Utilities and stakeholders exploring TENs are looking for good cost data as they plan projects. A National Renewable Energy Laboratory review of four operational geothermal-based district energy systems at college campuses provides a starting estimate of total installation costs, which ranged from $10 million to $20 million.[41]

35 HEET & Buro Happold (2019). Geothermal Networks.

36 U.S. DOE (2011). Guide to Geothermal Heat Pumps.

37 Ibid.

38 Energy & Environmental Economics (2021). Philadelphia Gas Works Business Diversification Study: Identifying Opportunities for Philadelphia Gas Works to Thrive in a Lower-Carbon Future.

39 Geothermal Market Capacity Coalition (2024). A National Network of Geothermal Drilling Centers of Excellence: Supporting an Equitable Transition to Clean Energy.

40 *For example:* Northeast Energy Efficiency Partnerships' involvement in the Ulbrich Heights Community Geothermal Project, includes a Connecticut Geothermal Industry Workforce Needs Assessment and Proposed Geothermal Heat Pump Workforce Development Plan for Connecticut (July 15, 2024).

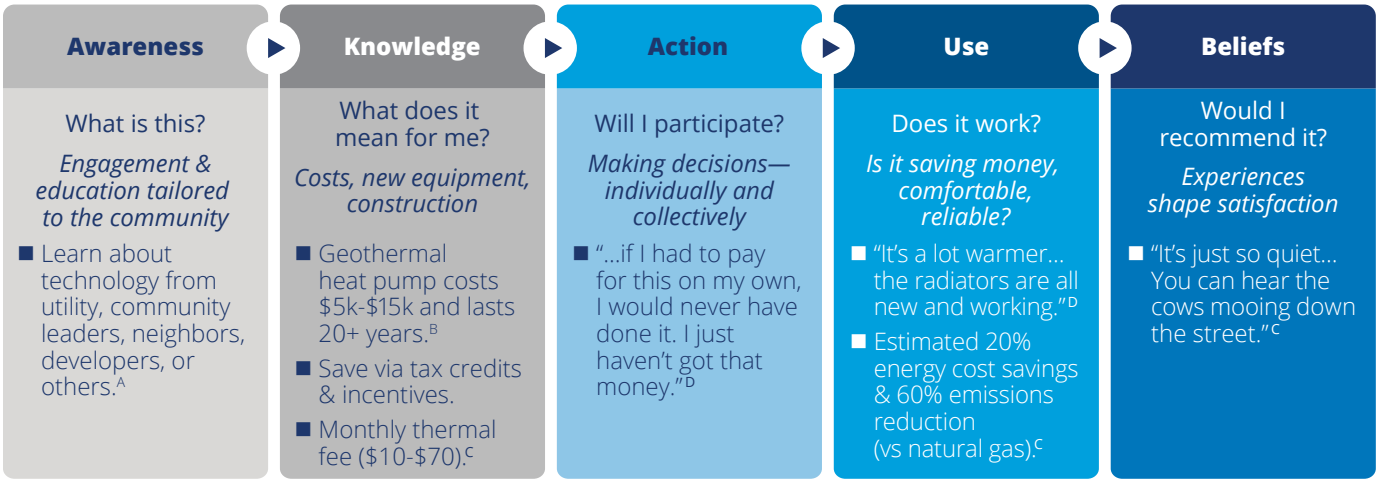
41 Installed between 2008 and 2017, each serving 6 to 1,728 acres / 10 to 47 buildings, and using unique engineering specifications such as number of boreholes, depth, number of ground loops, geothermal heat pump capacity. National Renewable Energy Laboratory (2023). Cost and Performance Analysis for Five Existing Geothermal Heat Pump-Based District Energy Systems in the United States. (NREL/TP-5700-86678).

However, early-moving utilities have found that TENs costs do not necessarily scale linearly with system size, and rather reflect the complexities of converting the unique existing buildings present at each site. Preliminary total cost estimates for utility-proposed TENs were available at the time we wrote this brief, but may change as projects are approved and constructed. Costs that we reviewed appear to reflect the unique mix of many factors, including heat source, engineering specifics, TEN size, development density, building stock, and others. Once multiple utility TENs have been constructed and final cost data are available, it will be beneficial to provide a cross-cutting analysis that relates costs to specific contextual factors. Such analysis can also explore efficiencies of scale and cost reductions as experience increases.

Customer Experience

Translating the policy interest in TENs to consumer acceptance and deployment involves uncovering community priorities and designing projects around them. This is a prime opportunity for comprehensive community engagement and inclusive consumer incentives. Community engagement can build on the work of advocacy coalitions supporting TENs for environmental justice (e.g., Grist profile of Blacks in Green geothermal grant funding from DOE) and workforce development (e.g., AFL-CIO). Utilities also can leverage long standing customer energy program best-practices to plan and deliver participant outreach. Eversource, for example, sees its extensive and in-depth community outreach leading up to its Framingham TENs demonstration as a key driver in securing agreement from 100% of site customers.[42] Separate experience from Great Britain indicates that prospective TENs participants want to understand logistical issues like construction, how they can finance upgrades, and how billing will work after the conversion.[43] Figure 5 shows the potential customer journey.

Figure 5. Utility TENs Customer Journey Includes Comprehensive Engagement



Source: SEPA (2024).

Notes:

A: *For example:* Eversource (2024). Geothermal Pilot Project Updates.

B: Cost range reflects 2-ton and 4-ton units at $2,500 per ton of capacity based on U.S. DOE (2021) Consumer Guide to Geothermal Heat Pumps. Actual costs may vary by system type, size, site conditions, and, if applicable, any other retrofit costs.

C: Range is illustrative, using a residential fee ($10) from Eversource's Framingham pilot and the residential rate in the Whisper Valley, Texas community. *See* Canary Media (June 4, 2024) "Massachusetts kicks off first pilot to shift gas utilities to clean heat." and Wall Street Journal (April 21, 2024) "Underground Thermal Energy Networks May Be About to Have Their Moment." Actual rates may vary by customer type and project design.

D: Energy Systems Catapult (2023). Heat the Streets: Project summary for householders.

42 Eversource (2024). *Clean Technologies – Geothermal Pilot.* Presentation to National Association of Regulatory Utility Commissioners (NARUC) Innovation Webinar "Unearthing Opportunities: Advances in Networked Geothermal Systems to Meet Today's Customer Heating Needs." Presented August 2022.

43 Catapult Energy Systems (2023). Heat the Streets: Summary for Policymakers.

Future Directions

There is an ambitious vision for scaling up all forms of geothermal heat in the U.S. today, including ground source heat pumps and TENs. **What will thermal energy networks (TENs) ultimately mean for natural gas and electric utility decarbonization?**

For decades, a small number of community leaders and developers around the U.S. and abroad have used the technology to effectively heat and cool their neighborhoods, campuses, and business districts. Early-moving utilities and their stakeholders now see potential to use the technology to help meet carbon reduction goals but are just starting to explore how and where best to deploy it, as well as what other benefits its usage offers to project participants and utility ratepayers at large. Today, these utilities' efforts are targeted, street-by-street demonstrations and pilots, and most are still in the scoping or engineering phase or awaiting regulatory approval and funding. Customer education and in-depth engagement have been key to the very first efforts, encouraging customers to participate in a utility-led effort to transform the way they and their neighbors heat and cool their homes and businesses.

Throughout the anticipated next wave of deployment, it will be crucial to track progress and share emerging best-practice procedures and field-validated impacts. Gathering and sharing these experiences will help stakeholders assess what else it would take to expand usage and how best to utilize this technology alongside the array of other decarbonization technologies available today.

To help increase the opportunity for TENs in states *not yet* enabling TENs, staff at utilities, utility regulators, state energy offices, consumer advocates, and nonprofits can:

- **Explore whether TENs could provide benefits aligned with state and local goals**, as well as which types of entities (private developers, utilities, communities, others) are positioned to help manage the costs and infrastructure to deliver those benefits.
- **Explore approaches to enable broader TENs deployment**, including potential changes to state legislation, state energy policy, public or private funding or technical assistance programs, utility regulation, workforce development, and/or community engagement.
- **Explore pathways to finance TENs and fairly distribute costs** across participants and, if applicable, other utility customers that benefit from TENs deployment.

To facilitate industry learning and growth in areas *already* enabling TENs, staff at these same organizations can:

- **Form or participate in TENs consortia and working groups** to keep pace with and integrate learnings among early-movers. Groups that bridge multiple perspectives will be key to build trust, share expertise and best practices, and refine strategies to reduce barriers and maximize benefits for all stakeholders.
- **De-risk future TENs deployment through data sharing**, including engineering and design best practices, project costs, and resulting quantifiable benefits to project proponents and investors, participants, the electric grid, and the environment.
- **Share learnings across the power sector to broaden peer understanding.** If gathered and shared on a timely basis, the learnings from individual projects, as well as consortia, working groups, and data sharing initiatives can be used to help design more efficient, effective utility TENs in real time.



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