The Future of Heat: Thermal Energy Networks as an Evolutionary Path for Gas Utilities Toward a Safe, Equitable, Just Energy Transition

Ana Maria Camargo, Building Decarbonization Coalition
Jessica Silber-Byrne, Building Decarbonization Coalition
Audrey Schulman, HEETLabs
Zeyneb Magavi, Home Energy Efficiency Team (HEET)

ABSTRACT

Thermal energy networks (a.k.a. TENs, utility thermal energy networks or UTENs, clean thermal energy networks or CTENS, geothermal energy networks or GENs, community geothermal, networked geothermal, district geothermal, and fifth-generation heating and cooling district or 5GHCD) of varying designs have proven their efficiency as clean sources of heating and cooling in private and municipal contexts in the United States for decades. However, most of the existing systems are designed and deployed as campus-based systems rather than utility systems, limiting their widespread use as a decarbonization solution. This paper highlights the potential for UTENs, designed specifically for utility-scale growth, to contribute to multiple clean energy transition goals. These include emissions reductions, equitable delivery of heating and cooling, a safe transition away from the methane gas system, reduced grid buildout, and cost savings. We recommend legal and regulatory innovations needed to develop UTENs. When aided by knowledge sharing, collaborative planning, and prudent legislation, TENs provide a viable path for gas utilities to evolve into thermal energy utilities.

Introduction: An Overview of Building Decarbonization in the U.S.

The United States has a federal goal of net-zero emissions by 2050 (DOS and the United States Executive Office of the President 2021). Twenty states have commitments to reduce greenhouse gas emissions, and thirteen of those states have specifically committed to reduce emissions by 75% or more by 2050 (NARUC 2022). Buildings represent approximately 30% of our nation's emissions and about half of those emissions derive from on-site combustion (EPA 2021). To meet state and federal mandates, we must change how we heat and cool buildings.

The prevailing market model for decarbonizing buildings entails upgrading individual home appliances, primarily by replacing gas furnaces with air-source heat pumps (ASHPs), one house at a time. This appliance-by-appliance electrification process has already begun: more United States residents are purchasing heat pumps than gas furnaces (AHRI 2024). But this model can exacerbate inequity and increase safety risks (Tepper, Bodemer, and Boecke 2020). Households with the financial means to do so will migrate away from the gas system as gas bills increase and non-gas alternatives offer health, cost, and efficiency advantages (Walsh and Bloomberg 2023). A declining customer base for gas service results in higher rates for customers that remain on the gas system; these customers are often the households that are least likely to be able to afford an increase and the most vulnerable to energy burdens (Walsh and Bloomberg 2023, Aas et al. 2020). Data from Massachusetts projects that this approach, if it continues through 2050, will more than double the energy burden on low-income households who rely on the gas system and cannot afford new electric equipment (E3 and Scott Madden Management Consultants 2022, 104).

This unmanaged transition harms utilities in addition to their customers: a declining ratepayer base leaves gas utilities vulnerable to insolvency, which limits their ability to provide safe, continuous, reliable service to the remaining remaining customers (Gridworks 2019). Under these circumstances, gas utilities are at a critical juncture. The past decade has seen a large increase in utility capital spending on gas distribution infrastructure—nearly $21 billion in 2022, according to the American Gas Association (Seavey 2024). Gas utilities must continue to prioritize safety in their operating budgets, but rather than make large capital investments each year on new gas infrastructure that contradicts federal and state climate goals, utilities should invest in non-gas-pipeline, neighborhood-scale, and non-hybrid alternatives.

Neighborhood-scale building decarbonization, an "emerging strategy that focuses on transitioning street segments, developments, or even entire neighborhoods to decarbonized energy sources and electric appliances," has the potential to accelerate building decarbonization while also structurally integrating equity, by providing access for any customer independent of ownership, prioritizing environmental justice communities and providing a career transition pathway for fossil fuel workers (George Bagdanov, Halbrook, and Rider 2023, 8). State legislation and utility strategic plans are increasingly incorporating neighborhood-scale decarbonization approaches (Building Decarbonization Coalition n.d.; Lalakea Alter et al. 2024).[1] Gas utilities have a key role to play in a neighborhood-scale approach, as they have the resources and power to mobilize a multi-block transition toward clean energy.

Thermal energy networks, or TENs, present an opportunity for gas utilities to invest in neighborhood-scale decarbonization solutions. TENs circulate water through underground pipes, carrying non-combustible, non-emitting thermal energy for heating and cooling among a network of connected buildings. As a system-scale solution that requires large infrastructural investment, TENs can take advantage of gas utilities' existing workforce, customer interface and billing systems, legal rights-of-way, and access to capital financing. Utility-owned TENs (UTENs) also present a promising avenue for states, utilities, workers and unions, and ratepayer and environmental advocates to work together. They allow utilities to adapt their business model in a clean-energy economy. Workers who currently install and repair gas pipes may transfer their skills to the similar thermal energy pipes. Ratepayers benefit when gas utilities avoid the costs of continuous investment in soon-to-be-obsolete gas infrastructure and when a planned transition mitigates cost burdens shouldered by remaining customers. Finally, legislation and regulation can strengthen equity by requiring these utilities to prioritize historically marginalized neighborhoods in deploying TENs installations.

State legislation that allows or mandates regulated utilities to operate TENs unlocks the potential of high-reward, at-scale, rapid building decarbonization. Currently, seven states (Massachusetts, New York, Colorado, Minnesota, Washington, Maryland, Vermont) have passed such legislation. This paper examines the opportunities and obstacles regarding utility ownership of TENs, and recommends policy pathways that can accelerate UTENs.

---

[1] For example, seven states have passed legislation authorizing or mandating that utilities initiate neighborhood-scale projects by installing thermal energy network pilots in their territories; one pilot in Massachusetts is already operational (Building Decarbonization Coalition, n.d.). In California, Pacific Gas & Electric has initiated neighborhood-scale "zonal electrification" projects (Building Decarbonization Coalition, 2022) while National Grid is exploring neighborhood-scale non-gas-pipeline alternative projects in its territories in Massachusetts and New York (Lalakea Alter et al. 2024).

What Are TENs?

TENs, when designed for utility-scale deployment, can replace existing gas infrastructure with clean energy infrastructure that uses a non-combustible, non-emitting thermal energy medium: water. Water is pumped through underground pipes, capturing and exchanging heat between connected buildings and heat sources (Figure 1).

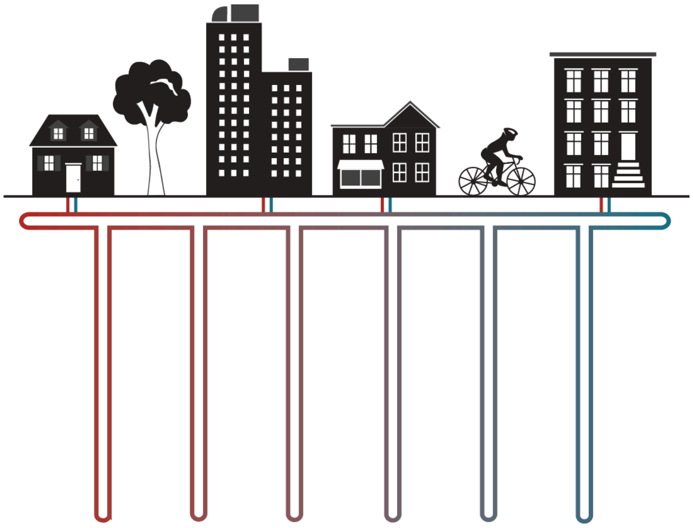

Figure 1. Representation of TEN infrastructure. *Source*: HEET.

TENs are designed opportunistically to draw from the thermal resources at the location, which may include energy-intensive buildings that shed waste heat, sewer systems, and the subsurface ground temperature, which is always available. There are several design approaches in operation today, with varying numbers of pipes and design temperature ranges for the water. Given the focus on utility-scale deployment, however, the single pipe with an ambient temperature range (~40-90°F) is the assumed design in this paper. This allows for the efficiencies, simultaneous heating and cooling, and the flexibility of interconnection and scalability described below (HEET & BuroHappold Engineering 2019).

Geothermal networks (GENs) are an important and common subcategory of TENs that use the relatively constant temperature of the earth below the frostline to assist with heating in winter and cooling in summer (Kalogirou and Florides 2004). Many GENs are optimized by using arrays of vertical, shallow boreholes of roughly 100 to 750 feet depth (HEET & BuroHappold Engineering 2019) which allow excess thermal energy to be stored in the bedrock (Skarphagen et al. 2019). As we grow a thermal grid composed of interconnected TENs, a critical mass of GENs is essential to ensure the long duration storage and distributed energy generation needed to maintain and manage a utility-scale system. This paper uses the name TENs with the assumption that a significant percentage of any regional deployment are GENs in order to achieve the outcomes described.

TENs, with or without vertical boreholes, have similar basic components. A horizontal pipe loop is installed underground below the frostline. This is a closed-loop pipe system: it is filled just once with water that then continuously circulates thermal energy (Dandelion Energy

2020). Ground-source heat pumps (GSHPs), powered by electricity, draw thermal energy from the pipe loop into connected buildings, or move it out of buildings and into the loop. Single-pipe ambient temperature TENs and GENs can be designed at different scales, and the system can grow, allowing more buildings and streets to connect over time.

TENs provide multiple benefits to a building. Because the system does not use combustion to create heat, it has no on-site emissions. The only emissions derive from the electricity used to power a building's heat pump, and those will logically reduce as the grid generates electricity from more renewable sources. By replacing gas furnaces and water heaters with heat pumps, home occupants also reduce their exposure to pollutants including carbon monoxide and benzene. Replacing a home's gas system by connecting it to a TEN has potential financial benefit compared to heating a home with gas (Castigliego et al. 2021). For example, gas utility bills reflect the commodity cost of gas as well as costs of operation, maintenance and capital expenditures of pipelines and infrastructure ("How to Read Your Natural Gas Bill" 2022). Because TENs are highly efficient compared to gas furnaces, the fuel commodity cost would be replaced by a minimal amount of electricity; studies have thus projected a lower cost of home heating (E3 and Scott Madden Management Consultants 2022).

Multiplying Benefits at Neighborhood Scale

These individual household benefits are multiplied when a neighborhood connects to a TEN. TENs benefit from economies of scale, with the *networked* aspect contributing to greater efficiency, affordability, and emissions reduction potential (Buonocore et al. 2022). Neighborhood-scale deployment of TENs, particularly GENs, will help states reduce emissions and avoid surplus expansion of the electric grid.[2]

Utilities can confer their expertise, experience, and considerable resources to neighborhood-scale deployment. Modern utilities were formed in the early 20th century to maximize the benefits of economies of scale in power generation and distribution (Tomain and Cudahy 2004). Utilities are "natural monopolies" because the infrastructure required to produce and deliver a public good, such as electricity, is expensive to build, and additional competing infrastructure would not benefit residents; regulated monopolies can instead spread the cost of infrastructure buildout among their ratepayer base (Tomain and Cudahy 2004). The economies of scale that benefited gas and electric utilities are transferable to the context of UTENs.

Efficiency at scale. A TEN is optimally designed when it connects buildings with diverse heating and cooling needs, such as homes and offices, gymnasiums and community centers, data centers, ice arenas, hospitals, or food storage facilities. Even in winter, buildings that need to stay cool will reject heat back into the network, where it is carried by the water in the loop to the many homes or other buildings in the area that need that heat. In New York City, the utility ConEdison is following these principles in its proposed pilot in Chelsea, where excess heat from

---

[2] As the United States electrifies, there is an urgent need to build electricity generation and transmission infrastructure (GDO 2023). Switching homes from heating with gas to electricity in winter, for example, could require a 28x increase in January wind generation or a 303x increase in January solar generation (Buonocore et al. 2022). Transmission is another challenge, with estimates that the United States must build 75,000 miles of transmission lines by 2035 (Jenkins 2023). An efficient approach to building decarbonization mitigates the scale and urgency of this buildout. Highly efficient building electrification can shrink winter peak demands, while mass deployment of ground-source heat pumps, coupled with building weatherization, could potentially erase the need for up to 43,500 miles of transmission lines (Buonocore et al. 2022; Liu et al. 2023, xix).

a single data center will be transferred to four New York City Housing Authority residential buildings (Consolidated Edison Company of New York, Inc. 2023).

GENs provide particularly substantial efficiency benefits by storing thermal energy in vertical boreholes underground (HEET and BuroHappold Engineering 2019). Thermal energy stored underground during winter can benefit the system overall as the seasonal swing shifts back to cooling in the summer; a percentage of deferred building heat stays stored in the geothermal system, where it can be retrieved months later when it is needed (Skarphagen et al. 2019, Simpson and Zhu 2024).

GSHPs are already a highly efficient technology, but their performance can improve in a networked system. Their efficiency is expressed through a formula called the coefficient of performance (COP), which measures the ratio of energy needed (input) to produce heat (output). A higher COP reflects a higher efficiency. A study of cold-climate ASHPs found them to have an average COP of 2.5 during the heating season, meaning one unit of energy produces 2.5 units of heat (Winkler and Ramaraj 2023). In contrast, individual GSHPs have an average heating COP of 4 (Liu et al. 2023), and a case study of GSHPs (not networked) in Germany found those heat pumps achieved a consistent year-round performance that maintained a minimum seasonal COP of 3.8 even after 20 years (Meng et al. 2019). Networked heat exchange within the TEN boosts this efficiency: equipment at Colorado Mesa University has achieved an annual average COP of nearly 6, with a winter peak COP of 8.9 (Xcel Energy 2022).

This efficiency means widespread TEN and GEN adoption can guide appropriate investment into the buildout of the electric grid, with potential savings in the billions or even trillions of dollars (Liu et al. 2023). As the United States electrifies, electricity generation, transmission, and distribution infrastructure must expand to meet increased demand, particularly during summer and winter (Buonocore et al. 2022). If buildings are decarbonized using inefficient technology, the electric grid must be built to accommodate high peak demand, with a commensurate need for an extensive upgrade to system-wide and local grid capacity—e.g., greater electricity generation, added transmission capacity, and more (or higher capacity) substations and feeder lines. GSHPs can help reduce demand: a study by the Department of Energy's Oak Ridge National Laboratory and National Renewable Energy Laboratory examined the impacts of widespread deployment of individual (non-networked) GSHPs into the majority of existing and new buildings in the United States by 2050 (Liu et al. 2023). Because of their efficiency compared to other electrification technologies, the most ambitious modeled results predict significant savings in grid buildout costs (greater than USD 1 trillion), grid buildout materials (a 33% reduction in transmission wires) and building fuel consumption (resulting in consumer savings of USD 19 billion each year). Due to networked energy-sharing efficiency, geothermal networks have the potential to increase these savings further: GENs emerge as the most efficient electrification method compared to electric baseboard heating and ASHPs, with the highest potential to flatten seasonal peak demands (Buonocore et al. 2022).

Scaling affordability and equity. Installing a TEN requires an upfront investment that, when undertaken by a regulated utility with access to capital financing, can be recovered by ratepayers over a span of 50-60 years, similar to current investments in the gas system. An engineering analysis for a community-wide geothermal network system in Colorado found that despite higher upfront installation costs compared to community-wide installation of ASHPs, the community's savings from maintenance, energy, and replacement costs would equal approximately $195 million over 30 years (Anderson 2022).

Affordability may also be achieved through a utility's street-scale approach to infrastructure projects and equipment. A project in which a utility drilling rig is mobilized to drill 100 boreholes for 100 buildings will logically cost less per borehole than if the equipment had to be mobilized for just a single borehole and building. UTENs can further provide market stimulus for geothermal energy equipment manufacturers; the supply chain responds to market signals and thus far has moved relatively slowly, with utilities National Grid and Eversource observing from their geothermal network pilots (GENs / UTENs) in Massachusetts that drill rigs, drilling expertise, and critical components for operation are a constraint to industry growth (The Geothermal Market Capacity Coalition, 2024). Utility-scale investment in the supply chain could provide stability and certainty to the market.

In terms of equity, TENs provide clean heating and cooling to every building on the network, regardless of the residents' income level or homeownership status (both of which can influence their ability to electrify their homes). A regulated utility can be mandated to prioritize pilots in environmental and social justice communities. New York's Utility Thermal Energy Network and Jobs Act (UTENJA) requires a proportion of UTEN pilots to be placed in disadvantaged communities (Senate Bill S9422 2022, §66-t). Massachusetts' Act Creating a Next-Generation Roadmap for Massachusetts Climate Policy expands the mandate of the Department of Public Utilities by incorporating equity into its existing priorities (Bill S.2995 2021).

Emissions reductions en masse. The systemwide efficiency of TENs has the opportunity to reduce emissions en masse, accelerating state and national progress toward climate goals. Existing TENs have yielded large reductions in CO_2 emissions and improved air quality. For example, S&T University in Missouri reports that their TEN reduced campus CO_2 emissions by 25,017 tons in its first year (Missouri S&T, n.d.) while Colorado Mesa University's geothermal network has reduced campus emissions by 17,742 tons of CO_2 each year (Colorado Mesa University, n.d.).

An Evolution for Gas Utilities

By evolving from gas to thermal energy providers, system benefits accrue to utilities as well as neighborhood residents and businesses.

Safe, managed gas pipeline decommissioning. There are nearly 3 million miles of gas pipelines in the United States (Sevier 2023). Utilities across the United States currently spend billions of dollars on capital investments to the gas system—close to $21 billion annually, a sum that has tripled in the last decade alone (Seavey 2024). Many of these investments involve the costly replacement of aging or leak-prone pipes with new pipelines; calculations using utility-filed data in Massachusetts suggest that replacing all leak-prone pipes in that state by 2039 would exceed USD 34.4 billion (Seavey 2023). Similarly, in New York in 2019, gas utilities identified pipe replacement plans that would cost a minimum of USD 28 billion by 2043 (Walsh and Bloomberg 2023). Given that many states have climate mandates to reduce emissions above 75% by 2050, replacing an aging cohort of gas distribution pipelines with new pipelines is an enormous investment in infrastructure that the public is unlikely to use much longer (Gridworks 2019). Yet without a clear pathway and framework for a managed transition away from gas, utilities will continue to invest in gas infrastructures that are doomed to become "stranded assets;" and ratepayers, investors, and taxpayers will be paying for these for years to come (Bilich, Colvin, and O'Connor 2019; Synapse Energy Economics, Inc. 2023).

Safely transitioning this colossal system requires utilities to continue using their maintenance and operations budgets for critical repair work to prevent system failure, while balancing the realities of pending gas pipeline obsolescence (Sevier 2023, Seavey 2024). Utilities' participation in a managed transition ensures that customers who remain connected to gas continue to receive reliable heat. Utilities in California, Colorado, New York, and Massachusetts are making progress on various neighborhood-scale strategies, which may include UTENs, to convert gas customers to clean heating and cooling systems while balancing the crucial need for safe, reliable service (Lalakea Alter et al. 2024).

Better business model. Current UTEN pilots demonstrate the feasibility of transferring utility business models from gas to thermal energy. Eversource Gas has paid the upfront costs of equipment installation and retrofitting in their pilot in Framingham, Massachusetts; customers will pay a monthly fee to Eversource for their heating and cooling, and will cover the cost of the geothermal equipment installation over time through their rates (Eversource, n.d.). Additional benefits may accrue to gas utilities that adapt their business model to provide thermal energy. For example, because TENs provide cooling *and* heating, they are a potential source of year-round revenue, not just in the winter. Utilities may also qualify for Inflation Reduction Act investor tax credits between 30-50% and state and local incentives for inside-the-house upgrades and equipment, particularly for low-income households (GeoExchange 2022).

The shifting of expense from fuel to infrastructure shifts dollars from the pass-through cost of gas to an infrastructure asset cost: the geothermal borehole. In the existing utility finance model, the infrastructure asset earns a return on equity, whereas the fuel earns the utility no income. Currently, gas utilities must transport that fuel from a wellhead to its furthest end point, a journey that could stretch thousands of miles with multiple opportunities for single-point failure (Brown 2024). The closed-loop system of a TEN removes these vulnerabilities from the utility's business, while the risks involved in long-distance fuel transport are also eliminated. Furthermore, this inherently resilient decentralized design can better withstand growing energy security threats including cyber attacks.

High-road jobs and job growth. UTENs allow gas utilities to bring their existing workforce and contractor relationships to the clean energy transition. Installing TENs requires the skills of pipefitters and pipe layers. While the technology is not an exact one-to-one transition, workers already understand how to install and fix similar gas mains, services, and HVAC equipment (George Bagdanov, Rider, and Halbrook 2023); because gas pipes and TENs' horizontal loops are constructed of the same high-density polyethylene plastic, existing gas workers are already certified to maintain and operate the horizontal loops. Eversource Gas' pilot installation in Framingham has demonstrated the transferability of skills from gas main installation to TEN main installation (Eversource, n.d.). Gas utility workers are understandably concerned about the effects of a clean energy transition on their livelihoods, and legislation in New York, Colorado, and Maryland has responded through the inclusion of provisions for labor involvement and protection (Building Decarbonization Coalition n.d.). Massachusetts has legislation pending to address the same concerns, ensuring that the workers today are prioritized for the good jobs of the future. There is also potential to increase the number of available jobs, as more workers are needed for drilling and heat pump installations; the DOE predicts that (non-networked) geothermal heat pump installation will generate “significant” jobs (Liu et al. 2023).

Status of Utility-Scale Installations

UTEN installations are progressing. Leadership at the federal level includes the Department of Energy’s USD $13 million initiative to support feasibility studies for “Community Geothermal” projects nationwide, many of which are geothermal networks (GENs); two of the eleven initial projects to receive funding include utility involvement (DOE 2023). The Inflation Reduction Act also includes a maximum of 50% investor tax credit for geothermal networks (GeoExchange 2022). At the state level, seven states—Massachusetts, Minnesota, New York, Colorado, Washington, Maryland, and Vermont—have passed legislation that either mandates or allows utilities to begin to install and operate UTEN pilots (Building Decarbonization Coalition, n.d.) Nationally, there are 19 utility pilots underway in Massachusetts, Minnesota, and New York.

Knowledge-sharing and research between and among utilities and advocacy groups is increasing, with utilities taking proactive steps even absent federal or state directives. A utility networked geothermal collaborative, comprising 28 gas and electric utilities, has convened to share learnings and research (HEET 2023).

Overcoming Obstacles: What’s Needed Next

Scaling UTENs requires planning, coalition-building, and knowledge sharing to optimize design, overcome obstacles, and craft enabling legislation and regulation.

Legislation that removes barriers to decarbonization. Legislative requirements must allow gas utilities to install and operate TENs and sell thermal energy. Depending on the state’s legal context, this may require amending a utility’s “obligation to serve.” The obligation to serve is the utility’s legal requirement to offer service to any customer who requests it in their territory (Payne 2022). Originally intended to protect customers from discrimination at the hands of a monopoly, this legal principle has emerged as a barrier to decarbonization, as utilities have argued that it requires them to continue delivering gas to any customer who wants it. This can stall a neighborhood’s decarbonization on the basis of a single customer’s request (California Energy Commission 2021; George Bagdanov 2024). Legally reforming this obligation means permitting gas utilities to serve alternative sources of energy, including thermal energy, rather than gas specifically. Legislation that seeks to reform the obligation to serve has been proposed in New York, California, and Massachusetts; Washington state amended their obligation to serve to include thermal energy in their 2024 session (Senate Bill S2016A 2023; Senate Bill 1221 2024; Bill S.2105 2023, Washington H.B. 2131).

Coordinated planning and mapping. Gas and electric utilities, municipalities, and states must collaborate on comprehensive planning to prioritize feasible, safe pathways for replacing gas pipelines with non-emitting thermal infrastructure including TENs. This will demand substantial time and effort as multiple actors consider factors including the age and quality of the gas system; community energy burden disparities; electric grid constraints; plans for concurrent improvements to roads or other infrastructure; and a system’s potential thermal energy sources and sinks (Sevier 2023; Building Decarbonization Coalition 2024).

While existing gas utility ownership of TENs offers advantages, these utilities are receptive to multiple types of ownership. Indeed, there is growing interest in municipal or community ownership models, which can take the form of cooperatives, community trusts, and housing associations (George Bagdanov, Halbrook, and Rider 2023; DOE 2023). Gas utilities still must cooperate with communities or municipalities that initiate financing and construction of their own TENs-based utilities, as the existing gas utilities must help plan a safe and managed transition off of the gas system.

Leveraging the innovation curve. Regulators and utilities alike must learn from ongoing pilot installations and demonstration projects. The Home Energy Efficiency Team (HEET), a Massachusetts nonprofit that pioneered the concept of utility-owned TENs, has previously proposed regulators abet a "period of innovation" in which utilities can safely experiment with, and report on, possible technologies that could allow gas distribution companies to transform into thermal delivery companies (HEET 2022). As utilities in Massachusetts and New York learn from their ongoing installations and early demonstration projects, there will be an innovation cost reduction curve as they improve their systems and designs. The external design costs of the first utility geothermal network were nearly three times the cost of the design for the second loop (D.P.U. 19-120 2020, HEET 2023). As utilities gain in-house knowledge, such expertise can build over time. Even regulatory permitting and investment approvals moved more quickly for the second installation compared to the first in Massachusetts (HEET 2021).

Clear, consistent, and transparent sharing of data and learnings will accelerate cost and performance optimization. HEET has initiated the Learning from the Ground Up (LEGUp) research team, aimed at collecting such data and sharing insights from the first utility-led geothermal network pilots in the United States (HEET 2022). This research team supplements utilities' existing project evaluations by developing an open-source digital model of the technology based on the data collected at the project sites. This model will inform and improve ongoing and future projects and allow for non-site-specific detailed potential and impact studies on technical, economic, health, equity, and environmental aspects of utility-led GENs.

A Regulatory Innovation Stage. The nature of a TEN—shared infrastructure delivering a necessary public service to diverse customers—lends itself to a natural monopoly model that would require regulation. Regulatory decisions will determine the success or failure of scaling UTENs.

Rate design is the primary mechanism for regulators to ensure reliability and affordability. Rate design strives to balance needed system investments with avoiding excess cost burdens to ratepayers. A key decision is the duration of depreciation of high up-front infrastructure costs. Several economic projections, which matched a TEN's depreciation time to that of gas infrastructure, resulted in a monthly energy bill lower than gas (Castigliego et al. 2021, E3 and Scott Madden Management Consultants 2022). As state regulators discuss the possibility of accelerated depreciation for gas infrastructure (RAP 2023), which would raise the energy bill for those gas customers, the cost advantage of TENs might even improve over time.

As ratemakers consider all customers throughout the clean energy transition, there is an opportunity to address affordability, reliability, and safety with new approaches. A gas utility that evolves into a thermal utility will have a consistently declining number of gas ratepayers and an increasing number of thermal ratepayers; when held separately, this will result in rising costs and safety concerns for those remaining on the gas network. HEET has proposed a solution in which both gas and geothermal customers are merged into a single ratepayer base, stabilizing costs and ensuring continued maintenance and workforce availability for the declining gas system (Karp and Klavens 2022). Importantly, even within a proposed single ratepayer base, there can be multiple ratepayer classes for both customer and technology type; in other words, ratepayers do not necessarily pay the same rate for energy, despite sharing some costs. Innovative rate design is also a potential mechanism to address an existing gap in regulation between the deployment of utility GENs and the subsequent benefits to the electric grid, electric utilities and electric ratepayers. In other words, thermal ratepayers' investments in TENs that include geothermal boreholes will likely accrue additional benefits to electric ratepayers (Liu et al. 2023), but a cross-subsidization will also require some regulatory innovation.

Finally, regulatory innovation must resolve questions regarding the boundaries of ownership between customer, utility, and thermal energy sources. For example, if the thermal utility owns the TEN and delivers thermal energy, do they also own all or just some of the thermal sources? Regulation can create a thermal market that allows local municipalities and property owners to turn their thermal energy sources into value streams—a potential boon to communities—and regulators are also likely to require that the utility provide or ensure baseload thermal energy, likely through geothermal boreholes, in the interest of reliability. Getting this balance right will take time and careful experimentation.

All this regulatory innovation will require a clear regulatory framework, such as Massachusetts' recent "Beyond Gas" framework (D.P.U. 20-80-B 2023). As data is collected from initial utility pilots that allows for scaling studies, and as legislation passes to unleash that scaling, regulators must balance between immediate, rational ratepayer protections and a period of learning during which novel regulatory mechanisms are tested. This innovation period will allow regulators to align effective mechanisms with society's priorities for emissions, equity, affordability, safety, security and reliability during a time of energy system transformation.

Conclusion

TENs have proven their efficiency and effectiveness in reducing emissions under a variety of ownership contexts, including university and college campuses, private housing developments, and municipal business districts. Although comparatively new, UTENs present a valuable solution for both utilities and the public to safely and rapidly achieve building decarbonization at scale. Adopting TENs is a pathway for gas utilities to evolve their business model to the clean energy transition, maintain their workforce, and protect their most vulnerable consumers and ratepayers. By leveraging their existing expertise and resources, utilities can also accelerate the transition to cleaner heating and cooling systems and help states meet emissions reduction goals faster.

Coordinated legal, political and multi-stakeholder efforts are required to overcome existing barriers to UTENs. Cross-sector collaboration and advocacy for supportive policies will be essential to realizing the system's full potential in combating climate change and improving affordability, reliability and safety for all residents, not just those who can afford to make early investments in their home's electrification.

References

Aas, D., Mahone, A., Subin, Z., Mac Kinnon, M., Lane, B., & Price, S. (2020, April). *The Challenge of Retail Gas in California's Low-Carbon Future*. California Energy Commission. https://www.ethree.com/wp-content/uploads/2021/06/CEC-500-2019-055-F.pdf

AHRI (Air-Conditioning, Heating and Refrigeration Institute). (2024). *Monthly Shipments*. AHRI. Retrieved July 8, 2024, from https://www.ahrinet.org/analytics/statistics/monthly-shipments

Anderson, D. (2023, January 14). Geothermal system at Brown Ranch could cost twice as much up front, but might save residents big bucks over time. *Steamboat Pilot*. Retrieved March 1, 2024, from https://www.steamboatpilot.com/news/geothermal-system-at-brown-ranch-could-cost-twice-as-much-up-front-but-might-save-residents-big-bucks-over-time/

Bilich, A., Colvin, M., & O'Connor, T. (2019). *Managing the Transition: Proactive Solutions for Stranded Gas Asset Risk in California*. Environmental Defense Fund. https://www.edf.org/sites/default/files/documents/Managing_the_Transition_new.pdf

Bill S.2105. (2023). Commonwealth of Massachusetts One Hundred and Ninety-Third General Court (2023-2024). https://malegislature.gov/Bills/193/S2105

Bill S.2995. (2021). Commonwealth of Massachusetts One Hundred and Ninety-First General Court (2019-2020). https://malegislature.gov/Bills/191/S2995

Brown, K. (2024, January 30). Why a natural gas storage climate 'disaster' could happen again. *Energy News Network*. Retrieved March 1, 2024, from https://energynews.us/2024/01/30/why-a-natural-gas-storage-climate-disaster-could-happen-again/

Building Decarbonization Coalition. (n.d.). *Thermal Energy Networks (TENs)*. Building Decarbonization Coalition. Retrieved March 1, 2024, from https://buildingdecarb.org/resource-library/tens

———. (n.d.). *Thermal Energy Networks (TENs) Examples*. Building Decarbonization Coalition. Retrieved March 1, 2024, from https://buildingdecarb.org/resource-library/thermal-energy-networks-sites

———. (2022, November 9). *Lunch 'N Learn: PG&E Zonal Electrification*. Building Decarbonization Coalition. https://drive.google.com/file/d/1xL7jzZGGaSI0j8zgltslMYTY2I_PKvG0/view

Buonocore, J. J., Salimifard, P., Magavi, Z., & Allen, J. G. (2022). Inefficient Building Electrification Will Require Massive Buildout of Renewable Energy and Seasonal Energy Storage. *Scientific Reports*, *12*(1), 11931.

California Energy Commission. (2021). *Strategic Pathways and Analytics for Tactical Decommissioning of Portions of Natural Gas Infrastructure* [Recorded Webinar]. https://energy.zoom.us/rec/play/Ss-dFOWoK-9xslijohhUlbwj0-NwZCJuL1BlPGdI339tTdl8hrzmFa54XMZkvU6itkuKMJrEUti8UP9E.koUYTLhF16jGegd6?canPlayFromShare=true&from=share_recording_detail&startTime=1637172027000&componentName=rec-play&originRequestUrl=https%3A%2F%

Castigliego, J. R., Alisalad, S., Stasio, T., & Stanton, E. A. (2021, January 13). *Inflection Point: When Heating with Gas Costs More*. Applied Economics Clinic.

Colorado Mesa University. (n.d.). *Geo-Grid System*. Colorado Mesa University. Retrieved March 1, 2024, from https://www.coloradomesa.edu/sustainability/initiatives/geo-grid.html

Consolidated Edison Company of New York, Inc. (2023, August). Updated Supplemental Information for Consolidated Edison Company of New York, Inc.'s Utility Thermal Energy Network Pilot Project Portfolio. In *Proceeding on Motion of the Commission to Implement the Requirements of the Utility Thermal Energy Network and Jobs Act, Case 22-M-0429*. State of New York Public Service Commission.

Dandelion Energy. (2020, March 16). *Open Loop vs Closed Loop Geothermal Systems*. Dandelion Energy. Retrieved March 1, 2024, from https://dandelionenergy.com/open-loop-vs-closed-loop-geothermal-systems

DOE (Department of Energy). (2023, April 25). DOE Announces $13 Million to Support Community Geothermal Heating and Cooling Solutions. *Department of Energy*. Retrieved March 1, 2024, from https://www.energy.gov/articles/doe-announces-13-million-support-community-geothermal-heating-and-cooling-solutions

DOS (Department of State) & the United States Executive Office of the President. (2021). *The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050*. https://www.whitehouse.gov/wp-content/uploads/2021/10/us-long-term-strategy.pdf

D.P.U. 19-120. (2020, August 10). https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/12540389

D.P.U. 20-80-B. (2023, December 6). https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/18297602

E3 (Energy + Environmental Economics) & Scott Madden Management Consultants. (2022, March 18). *The Role of Gas Distribution Companies in Achieving the Commonwealth's Climate Goals: Technical Analysis of Decarbonization Pathways*. Energy + Environmental Economics. https://thefutureofgas.com/content/downloads/2022-03-21/3.18.22%20-%20Independent%20Consultant%20Report%20-%20Decarbonization%20Pathways.pdf

EPA (Environmental Protection Agency). (2021). *Sources of Greenhouse Gas Emissions | US EPA*. Greenhouse Gas Emissions. Retrieved March 1, 2024, from https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Eversource. (n.d.). *Geothermal Pilot in Framingham*. Eversource. Retrieved March 1, 2024, from https://www.eversource.com/content/residential/save-money-energy/clean-energy-options/geothermal-energy/geothermal-pilot-framingham

GDO (Grid Deployment Office). (2023, April). *Draft 2023 National Transmission Needs Study*.

GeoExchange. (2022, September). *Geothermal Heat Pump Provisions in the Inflation Reduction Act*. GeoExchange.

George Bagdanov, K., Rider, A., & Halbrook, C. (2023, November). *Neighborhood Scale: The Future of Building Decarbonization*. Building Decarbonization Coalition and Gridworks. https://buildingdecarb.org/wp-content/uploads/BDC_Neighborhood-Scale-Report.pdf

George Bagdanov, K. (2024, March). *Decarbonizing the Obligation to Serve*. Building Decarbonization Coalition. https://buildingdecarb.org/wp-content/uploads/FINAL_Decarbonizing-the-Obligation-to-Serve_March2024.pdf

The Geothermal Market Capacity Coalition. (2024, July). A National Network of Geothermal Drilling Centers of Excellence: Supporting an Equitable Transition to Clean Energy. https://cdn.prod.website-files.com/649aeb5aaa8188e00cea66bb/667f18b3ae775760f2d73cd0_Geothermal%20Drilling%20Centers%20of%20Excellence%20White%20Paper.pdf

Gridworks. (2019). *California's Gas System In Transition*. Gridworks. https://gridworks.org/wp-content/uploads/2019/09/GW_Calif-Gas-System-report-1.pdf

HB23-1252. (2023). Colorado General Assembly Visit & Learn Find My Legislator Watch & Listen.

HEET. (n.d.). *LeGUp Research*. HEET. Retrieved March 2, 2024, from https://www.heet.org/legup

———. (2021, May 25). *National Grid Proposes Networked Geothermal*. HEET Blog. https://www.heet.org/blog-items/national-grid-proposes-networked-geothermal

———. (2022, June 28). What is the Future of Gas? *HEET Blog*. https://www.heet.org/blog-items/what-is-the-future-of-gas-ef-bf-bc

———. (2023, April 17). *Networked Geothermal: The National Picture*. HEET. https://www.heet.org/blog-items/networked-geothermal-the-national-picture

———. (2023, May 3). Department of Energy Awards $715,000 to Plan an Expansion of Networked Geothermal in Massachusetts Neighborhood. *HEET Blog*. https://www.heet.org/blog-items/department-of-energy-awards-715715-to-plan-an-expansion-of-networked-geothermal-in-massachusetts-neighborhood

HEET and BuroHappold Engineering. (2019). *Geothermal Networks: 2019 Feasibility Study*. HEET and BuroHappold Engineering.

House Bill 1084. (2021). State of Washington 67th Legislature. https://lawfilesext.leg.wa.gov/biennium/2021-22/Pdf/Bills/House%20Bills/1084.pdf?q=20230413165345

How to Read Your Natural Gas Bill. (2022, May 5). Elevate Energy. Retrieved May 30, 2024, from https://www.elevatenp.org/publications/how-to-read-your-natural-gas-bill/

Jenkins, J. D. (2023, May). What "Electrify Everything" Actually Looks Like – Mother Jones. *Mother Jones*. Retrieved April 30, 2024, from https://www.motherjones.com/environment/2023/04/electrify-everything-scope-data/

Kalogirou, S., & Florides, G. A. (2004). Measurements of Ground Temperature at Various Depths.

Karp, C. F., & Klavens, J. S. (2022, May 6). *D.P.U. 20-80 Alternative Regulatory Proposal by Home Energy Efficiency Team, Inc.* https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/14922539

Lalakea Alter, A., Billimoria, S., Henchen, M., Barde, K., Eichhorst, C., & Klingler, J. (2024, May). Non-Pipeline Alternatives: Emerging Opportunities in Planning for U.S. Gas System Decarbonization. RMI and National Grid.

Liu, X., Ho, J., Winick, J., Porse, S., Lian, J., Wang, X., Malhotra, M., Li, Y., & Anand, J. (2023). *Grid Cost and Total Emissions Reductions Through Mass Deployment of Geothermal Heat Pumps for Building Heating and Cooling Electrification in the United States*. Oak Ridge National Laboratory. https://info.ornl.gov/sites/publications/Files/Pub196793.pdf

Massachusetts Department of Public Utilities. (n.d.). *Mission Statement*. Mass.gov. Retrieved March 4, 2024, from https://www.mass.gov/orgs/department-of-public-utilities#org-nav-mission

Meng, B., Vienken, T., Kolditz, O., & Shao, H. (2019, November). Evaluating the thermal impacts and sustainability of intensive shallow geothermal utilization on a neighborhood scale: Lessons learned from a case study. *Energy Conversion and Management*, *199*. https://doi.org/10.1016/j.enconman.2019.111913

Missouri S&T. (n.d.). *Geothermal Energy System*. Facilities Operations. Retrieved March 1, 2024, from https://facilitiesoperations.mst.edu/geothermal/

NARUC (National Association of Regulatory Utility Commissioners). (2022). *Clean Energy Policy Tracker*. https://pubs.naruc.org

Payne, H. (2022). Unservice: Reconceptualizing the Utility Duty to Serve in Light of Climate Change. *University of Richmond Law Review*, *56*(2). https://scholarship.richmond.edu/cgi/viewcontent.cgi?article=3329&context=lawreview

RAP (Regulatory Assistance Project). (2023). *Integrating Gas Planning to Modernize Buildings*. Building Modernization Legislative Toolkit. https://toolkits.raponline.org/building-modernization/gas/

Seavey, D. (2023, October 20). *GSEP's cumulative costs*. Groundwork Data. https://www.mass.gov/doc/seavey-gsep-cost-presentation/download

———. (2024, March). *Leaked & Combusted: Strategies for reducing the hidden costs of methane emissions & transitioning off gas*. HEET. https://assets-global.website-files.com/649aeb5aaa8188e00cea66bb/65f36ba611a3ba1f964fc783_Leaked-and-Combusted.pdf

Senate Bill S9422. (2022, May). New York State Senate. https://www.nysenate.gov/legislation/bills/2021/S9422

Senate Bill S2016A. (2023). New York State Senate. https://www.nysenate.gov/legislation/bills/2023/S2016/amendment/A

Sevier, I. (2023, May 17). Blog: Building Decarbonization has a Natural Gas Pipeline Problem. *Climate and Community Project*. https://www.climateandcommunity.org/building-decarb-natural-gas-problem

Simpson, J. G., & Zhu, G. (2024). An Efficient Annual-Performance Model of a Geothermal Network for Improved System Design, Operation, and Control. https://research-hub.nrel.gov/en/publications/an-efficient-annual-performance-model-of-a-geothermal-network-for

Skarphagen, H., Banks, D., Frengstad, B. S., & Gether, H. (2019). Design Considerations for Borehole Thermal Energy Storage (BTES): A Review with Emphasis on Convective Heat Transfer. *Geofluids*, *2019*.

Synapse Energy Economics, Inc. (2023, March 1). *The High Cost of New York Gas Utilities' Leak-Prone Pipe Replacement Programs*. Synapse Energy Economics. https://www.synapse-energy.com/sites/default/files/22-017_High_Cost_NY_Gas_Utilities_LPP_Programs_0.pdf

Tepper, R. L., Bodemer, J. A., & Boecke, D. W. (2020, June 4). *Petition of the Office of the Attorney General, pursuant to G.L. c. 12, §§ 11E, 10*. https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/12255773

Tomain, J. P., & Cudahy, R. D. (2004). *Energy Law in a Nutshell*. Thomson/West.

Walsh, M. J., & Bloomberg, M. E. (2023, March). *The Future of Gas in New York State*. Building Decarbonization Coalition and Groundwork Data. https://buildingdecarb.org/wp-content/uploads/BDC-The-Future-of-Gas-in-NYS.pdf

Winkler, J., & Ramaraj, S. (2023). *Field Validation of Air-Source Heat Pumps for Cold Climates*. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy23osti/84745.pdf

Xcel Energy. (2022). *Evaluating A Community Ground Source Heat Pump System At Colorado Mesa University*. Xcel Energy.