

Boston Green Ribbon Commission

Boston Area Clean Thermal Project 9.26.25

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Basic Information

Organizational Applicant

- The proposal applicant is the Innovation Network for Communities (INC), on behalf of the Boston Green Ribbon Commission (GRC).
- The GRC is a voluntary CEO network whose mission is to accelerate the implementation of the City's Climate Action Plan by convening, organizing, and enabling leaders from Boston's key sectors.
- INC serves as the fiscal agent for the GRC. INC is a 501(c)3 charitable organization.

Other Organizations Receiving This Proposal

- None

Contact Information

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Proposal Purpose

This study will explore the technical, regulatory and economic feasibility of using thermal energy from Boston-area water sources to support a transition away from the use of natural gas. The resulting report will provide needed information for policy makers to select the best method(s) for further investigation and potential enactment.¹

The targeted thermal sources will include water in the Charles River, Mystic River, Boston Harbor, and Fort Point Channel, and bedrock below the Charles and Mystic Rivers that can be accessed by inclined boring.² The study will seek to address five key questions for these thermal reservoirs:

1. **Thermal Supply.** How much thermal energy can be reliably extracted from or stored in the targeted thermal reservoirs?
2. **Thermal Distribution.** How can this energy be cost-effectively distributed to potential users?
3. **Thermal Demand.** What is the potential phased demand of large energy users for the delivered thermal energy and is this demand sufficient to justify capital investment for extraction/storage, distribution and consumption?
4. **Investment Opportunities.** For those new thermal opportunities where feasibility is validated by the technical, economic and regulatory analysis, what next steps will help convert those opportunities into projects ready for investment?
5. **Regulatory and Permitting Barriers.** What are the regulatory and permitting barriers to new clean thermal development?

The Clean Thermal project will be done in partnership with a portfolio of large thermal energy users – higher education, health care, commercial real estate, governmental and quasi-governmental entities – who could potentially serve as early stage off takers for new thermal energy networks. These partners will anchor the analysis with detailed building data that can be extrapolated to create a menu of technical and financial options applicable to many sites for both installation and growth.

Additional core project stakeholders will include governmental entities (cities of Boston, Cambridge, Medford and Somerville, and the Commonwealth of MA), regulated utilities (Eversource and National Grid), and district energy providers (Vicinity Energy).

¹ Attachment 1 includes additional detail on the rationale for the proposal, as well as additional detail on the operation, benefits and challenges of thermal energy networks.

² Attachment 2 includes additional detail on the Boston area targeted thermal reservoirs.

Note that this project will address the potential for deep geothermal in the limited way by making recommendations on a future process for stakeholders to collaborate on a commercial viability assessment for this emerging technology.

Alignment with MassCEC Objectives

The mission of the Massachusetts Clean Energy Center (MassCEC) is to accelerate a transition to clean energy, while driving job creation, environmental benefits, and long-term economic growth.

This study will explore affordable ways to shift buildings and infrastructure in the Boston area to non-combusting thermal sources, utilizing the finances, size and status of some of the largest institutions in the Boston area. The study's goal is to create a statewide model that is practical, equitable, affordable and can be enacted now.

Advancement of thermal energy networks could also have a positive impact on another important Commonwealth priority. The Everett Marine Terminal allows natural gas to be shipped into the Boston area, primarily to meet peak heating needs during the winter. Closing the Everett Marine Terminal is a priority for the Commonwealth, both to reduce emissions and for energy affordability as the terminal costs gas customers \$1 billion every six years. The aggregate gas use of the participating GRC member organizations is 5.8 million MMBtus. This is enough to reduce peak gas load in the Boston area such that the Everett Marine Terminal could be closed.

Partners

Governmental Partners

Governmental partners, whether at the state or city level, play a key role in enabling, planning for, and potentially funding TENs. In this project, the governmental partners will:

- Share pertinent information as necessary about the local underground infrastructure and local planned development.
- Identify regulatory barriers and share ideas for regulatory reform to remove those barriers.
- Identify key funding needs, strategies, and sources to support thermal energy development.
- Identify adjacent communities as candidates for expansion of existing networks.

The following government partners have been approached for participation. In many of these cases, key contacts serve on the GRC.

- The Commonwealth Executive Office of Energy and Environmental Affairs
- The Department of Public Utilities
- The City of Boston
- The City of Cambridge
- The City of Somerville
- The City of Medford

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A special focus of government partners will be those organizations that control regulatory access to thermal sources. The project will work closely with these players on Deliverable 5 – Regulatory and Permitting Analysis.

Anchor Institution Partners

The Clean Thermal project will ground its feasibility assessment in actionable data from large property owners from the higher education, health care, commercial real estate and government sectors. All these sectors are represented in the GRC network. Many of these organizations have their own district energy systems that they are in the process of upgrading and decarbonizing. They will be able to “ground truth” the viability of new clean thermal services for large property owners.

The role of property owner partners will be to:

- Advise on business models for delivering clean thermal that would most appeal to them as potential consumers/producers.
- Advise on the barriers and challenges to retrofitting their buildings and district systems to accommodate new thermal supplies.
- Estimate their projected future demand for new clean thermal supplies in terms of needed peak, base load and annual cumulative thermal load.³
- Identify potential backup supplementary local heating and cooling assets (such as boilers or chillers) that could be connected to new thermal sources,⁴ Including costs to interconnect and run the assets, heating/cooling capacity, emissions, water use, and estimated lifetime.

The GRC has had preliminary discussions with the following large property stakeholders affiliated with the GRC. They have expressed interest in participation. Participating organizations will be contributing substantial amounts of staff time as in-kind contributions to the project. It is expected that additional property owners will join as partners as we move forward on the project.⁵

- Boston University
- Harvard University
- Northeastern University
- Tufts University
- MIT

³ The estimated total thermal load of the buildings is added up, with the estimated simultaneous load cancellation, the thermal capacity of the water in the network, and the top 10% of the peak subtracted from that total. This of course would be approximated as best as possible without a full engineering study.

⁴ These pre-existing assets could have in the past been used exclusively to heat or cool a building, or to heat or cool a district system. Assets will be selected by the utility to interconnect with the TEN so that it can then function with a dual purpose of serving the building/district system, as well as the TEN.

⁵ Identification of additional large property owners will be driven by which properties are within a feasible geographic reach of the targeted thermal reservoirs.

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- Boston Properties (BXP)
- Mass General Brigham

These institutions are some of the largest in the Boston area. They are the largest customers of the local utilities and collectively can play a key role in local gas and electric utility collaboration. They are unlikely to relocate and thus any distribution system installed beneath them is likely to be used and useful far into the future, making the investment very secure.

The initial installations are the most expensive portion of any new energy infrastructure since they:

- Drive down the learning curve⁶ of future installations per customer served by developing the necessary workforce, technical expertise and supply chains.
- Install the expensive infrastructure needed for expansion, such as water pumps and thermal reservoir infrastructure, reducing the cost of adding new customers (including adjacent enighborhoods).⁷

If these initial networks are installed in these major institutions across the Boston area, the Commonwealth will develop the knowledge, workforce and supply chains to grow them (and others) for the least cost and at the greatest speed.

Utility Partners

Utilities are key partners in the natural gas transition and will need to play leadership roles in the transition for it to occur in the time required by state law and regulation. Enormous progress has been made in the last several years in creating a legal and regulatory framework that can enable gas utilities to transition to help the state meet its emissions mandates by 2050. The GRC has engaged as partners National Grid and Eversource, as well as Vicinity Energy, the local district energy system. All three are members of the GRC. The role of these organizations will be to:

- Share any plans for investing in clean thermal energy in the participating cities.
- Provide estimates of the costs and potential speed of the installation of any proposed thermal distribution systems.
- With the Department of Public Utilities' approval, calculate an estimated customer energy bill for the proposed installation, assuming the costs are amortized over the lifetime of the distribution system.
- Provide input on potential business and financing models.
- Identify regulatory barriers to thermal network development, with suggested regulatory reforms.

⁶ An [80% learning curve](#) is standard. It means that with every doubling of a company's output, the cost of the new output is 80% of the prior output.

⁷For instance, according to HEET, Eversource's new proposed additon to the Framingham network will cost approximately half as much per customer as the initial installation. The budget for this work has been submitted to and approved by the US Department of Energy.

Deliverables

The Clean Thermal project will produce the following specific deliverables to address each key question.

Deliverable 1 – Thermal Supply

Key Question 1: How much thermal energy can be reliably extracted from or stored in the targeted thermal reservoirs?

The project will conduct the following analysis for the targeted thermal sources (Charles/Mystic River water/bedrock and Fort Point Channel and the Boston Harbor):⁸

- Estimate of peak and annual cumulative capacity of each thermal reservoir.
- Assessment of the available and most economical technology to extract thermal energy from each thermal reservoir.
- Comparison of thermal reservoir capacity with estimated thermal demand.
- The willingness of the organizations that own and control each thermal reservoir to consider its use.
- Installation timeline for required infrastructure.
- The projected cost installed per MMBtu of thermal energy supplied to the distribution system.
- Potential regulatory, technical, and other implementation challenges.
- Emission reductions over time if the phased thermal network plan is enacted.

Deliverable 2 – Thermal Distribution

Key Question 2: How can energy extracted and stored from thermal reservoirs be cost-effectively distributed to potential users?

The project will perform an assessment of:

- Options for design of thermal distribution systems that can connect with potential early stage off takers. This will identify the key infrastructure challenges of transporting thermal supplies from the source to the user, including the inherent difficulties of installing new underground infrastructure in a dense urban setting.
- The distribution system installation speed and costs for each network, in ways that meet anticipated future load demands from potential off takers.
- Identification of specific locations for distribution infrastructure location, especially exit points from water bodies.
- The key challenges of installing the needed distribution systems.

⁸ Note that waste heat from buildings will be automatically included in the anchor institutions analysis in terms of synchronous load cancellation and the thermal storage of the water in the network.

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- With the permission of the Department of Public Utilities, the local utilities will also calculate an estimated delivered cost of energy from the proposed distribution system(s), assuming the costs are amortized over the lifetime of the system(s).

Deliverable 3 – Thermal Demand

Key Question 3: *What is the potential phased demand of large energy users for the delivered thermal energy and is this demand sufficient to justify capital investment for extraction/storage, distribution and consumption?*

Large energy users will provide in-kind services to assess their current and potential future demand for new clean thermal services. The work produced by each potential customer will include:

- A hypothetical plan showing how the institution’s applicable buildings could connect to a new local thermal network in phases, including the timing and cumulative cost of the needed building retrofits.
- The calculated total thermal demand (in terms of needed peak, base load and annual cumulative thermal load) of the connected buildings over those phases.
- Identification of the potential pre-existing local heating and cooling assets that could be connected to the local thermal network as backup supplemental assets, including costs to interconnect and run the assets, heating/cooling capacity, emissions, water use, and estimated lifetime.
- Identification of the owner real estate that is likely not appropriate for being serviced by a thermal network.
- Identification of adjacent communities that would be candidates for network extensions and expansions.

The GRC will work in collaboration with the project engineering lead and the participating municipalities to facilitate the development of these property owner data sets. The resulting data will be shared in aggregate form only, to protect the confidentiality of the owners.

Deliverable 4 – Investment Opportunities

Key Question 4: *For those new thermal opportunities where feasibility is validated by the technical, economic and regulatory analysis, what next steps will help convert those opportunities into projects ready for investment?*

The project will recommend a framework for assessing the cost effectiveness of thermal networks in a way that quantifies avoided costs and anticipated future reductions in marginal costs due to improvements in engineering know-how, technology, supply chains and other production factors. The goal will be to have a standardized way of comparing the “Levelized Cost of Energy” (LCOE) for thermal networks with other forms of energy that can meet our state’s emissions mandates while providing heating and cooling services. This framework will

help private and public investors make informed decisions about how and when to invest in thermal network projects.

The cost effectiveness framework will be used by the project to assess the economic feasibility of each of the identified opportunities to connect users to targeted thermal sources. For the new thermal supply opportunities where feasibility is validated, the project will make recommendations on what next steps will help convert those opportunities into investment opportunities.

Deliverable 5 – Regulatory and Permitting Barriers

Key Question 5: What are the regulatory and permitting barriers to new clean thermal development?

The project will identify regulatory and permitting challenges to the design, location, construction, and operation of thermal energy networks, and will recommend changes that can support accelerated clean thermal supplies without compromising safety or environmental impacts.

Project Management and Personnel

Advisory Board

Partners and other experts will be invited to participate in an Advisory Board. The Advisory Board will be composed of staff and academic personnel from the different project partners, outside technical experts (including organizations that operate thermal networks in other cities); the key governmental entities (Boston, Cambridge, Somerville, Medford, and the Commonwealth of Massachusetts); and local utilities (Eversource, National Grid and Vicinity Energy).

Project Management Team

As project grantee, the GRC (in the form of its fiscal sponsor, the Innovation Network for Communities – INC) will be responsible for overall project management, including management of the budget and the hiring of contractors to perform work. John Cleveland, Strategic Advisor to the Green Ribbon Commission, and Johanna Partin, Principal of Transformative Strategies will convene the teams, drive forward the process, share information and solve problems to weave together a cohesive report.

Project Timeline

- 12 months
- 3 meetings with all project personnel, (at the start, middle and end of the project)

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- Each of the teams will meet as regularly as needed

Contractor Selection

The technical and economic analysis needed for Deliverables 1-4 will be combined into a single RFP-based solicitation that includes a lead engineering firm with practical experience with water-based thermal energy networks. The selected firm will serve as the prime technical contractor on the project. The GRC will issue the RFP and manage the contractor selection process.

A separate subcontractor will be selected to conduct the in-depth permitting/regulatory analysis described in Deliverable 5.

An additional contractor will be selected for the final report writing and production, which will incorporate the findings and recommendations from the lead engineering firm.

Project Budget

The project budget is summarized below. The proposal requests \$500,000 of funding from MassCEC. The MassCEC funding will be matched by in-kind contributions from project partners.

Boston Area Clean Thermal Project Budget	
Expense Item	Amount
Deliverables	
Deliverable 1 -- Thermal Supply	\$300,000
Deliverable 2 -- Thermal Distribution	
Deliverable 3 -- Thermal Demand	
Deliverable 4 -- Cost Effectiveness Framework	
Deliverable 5 -- Regulatory and Permitting Analysis	\$20,000
Project Management	
Lead Project Manager	\$75,000
Report Writing and Production	\$30,000
Indirect Costs	
Innovation Network for Communities Indirect (15%)	\$75,000
Total Budget Request	
	\$500,000
In-Kind Contribution Analysis	
Partners	15
Person days per partner	25
Person hours per partner	200
Total person hours	3,000
Average cost per person hour	\$200
Total in-kind contribution	\$600,000

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The anchor institution partners participating in this project will be providing substantial in-kind support involving the documentation and analysis of their existing and projected thermal demand. We estimate that this contribution will be at least equal to, and likely more than, the requested project budget of \$500,000. The budget shows the calculation of the in-kind support, assuming 15 anchor partners (seven of which have already been identified and agreed to participate).

Requestor Background

The Green Ribbon Commission (GRC) is a voluntary CEO network whose mission is to accelerate the implementation of the City's Climate Action Plan by convening, organizing, and enabling leaders from Boston's key sectors. The City of Boston is committed to achieving net zero carbon by 2050, climate equity, and climate resilience, even as the city grows. The GRC provides a forum for representatives of the private sector and the City to discuss, plan and act on the opportunities, challenges, ideas, and requirements of preparing Boston to meet the imperatives of climate change.

The GRC's 40 CEO-level Members represent the spectrum of Boston's major economic sectors and industries, including the City of Boston, the Commonwealth, commercial real estate, education, health care, utilities, renewable energy, finance, consulting, and not-for-profit.

From the 2016 Climate Ready Boston research that comprehensively detailed the likely impacts of climate change on Boston, to the 2019 Carbon Free Boston study that outlined the city's options for strategic electrification, to the 2023 Our Shared History report that encourages policy makers and developers to avoid the mistakes of the past during a time of fundamental urban transformation, the GRC has set the table for cooperation and action. Along the way we have helped shape and encourage participation in the ambitious agenda that puts Boston in the vanguard of U.S. cities addressing the challenges of climate change. The GRC is committed to positioning Boston and Massachusetts as national leaders in the transition to a clean energy economy while creating a more equitable and vibrant city.

The GRC is currently leading two signature projects in partnership with the City, the first to advance coastal resilience governance and finance structures, and the second to advance Boston Grid Modernization to assure that there are adequate electricity supplies to support building and transportation electrification.

The Green Ribbon Commission 2025-2030 Strategic Plan includes a goal to: *"Facilitate transition away from natural gas, leading with the private sector."* As a contribution to this goal, the GRC Higher Education Working Group (HEWG)⁹ has launched three project teams focused on innovations to accelerate thermal decarbonization on higher education campuses.

⁹ The institutions participating on the HEWG include Harvard, MIT, Boston University, Northeastern, University of Mass Boston, Tufts and Emerson.

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One of these project teams advocated the development of a Boston area “Clean Thermal Plan” to accelerate the natural gas transition. The plan would build on, and in turn support, the strategies that many large energy users (particularly the campuses of higher education and health care organizations) are already actively developing and implementing to decarbonize their thermal services. It would complement the many city and statewide policy initiatives designed to accelerate the natural gas transition. The project team developed a proposed framework for developing municipal clean thermal plans.

Through conversations with GRC member Melissa Lavinson, the GRC was encouraged to submit an unsolicited proposal to the MassCEC to the initial feasibility assessment analysis to support a Clean Thermal Plan for the Boston area.

Key Staff Bios

John Cleveland

John Cleveland serves as Strategic Advisor to the Boston Green Ribbon Commission (GRC), a network of business and civic leaders supporting the implementation of the City of Boston’s Climate Action Plan. John is also President and a co-founder of the Innovation Network for Communities, a nonprofit focused on supporting cities in responding to climate change by reducing GHG emissions and strengthening resilience.

Prior to founding the Innovation Network for Communities, John served as Vice President of IRN, Inc., a market intelligence firm located in Grand Rapids, Michigan that provided strategic planning, market research, automotive forecasting and merger and acquisition due diligence to mid-sized manufacturing companies. Before IRN, John worked as a private consultant; as director of Continuous Improvement for Grand Rapids Community College; and as director of the State of Michigan’s industrial extension service.

John received a B.A. in City Planning from Yale University. He is the co-author of three books related to social impact and climate change: *Life After Carbon – The Next Global Transformation of Cities*, *In Harm’s Way – How Communities Are Addressing Key Challenges of Building Climate Resilience*, and *Connect, Innovate, Scale Up – How Networks Create Systems Change*.

Joanna Partin

Partin was the Founder and Director of the Carbon Neutral Cities Alliance, the world’s leading international network of ‘climate vanguard’ cities pioneering and scaling urban carbon neutrality innovations. She was Senior Policy Advisor on Climate and Sustainability to San Francisco Mayors Gavin Newsom and Edwin Lee, where she spearheaded many of the city’s groundbreaking climate, clean energy, and sustainable mobility policies and initiatives.

As the North America Regional Director for C40 Cities Climate Leadership Group, she managed the North America region for the world’s largest network of cities working to advance climate

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action and sustainability. As the Deputy Director at the Building Decarbonization Coalition, she led the organization's strategic growth into 10 new states and led the effort to center equity across the organization's programs and operations. She has also served as a Fellow at the Grameen Bank, structuring renewable energy microfinancing programs to power women's enterprises.

Currently working as the Founding Principal of Transformative Strategies, Partin has written two reports on TENs and worked closely with HEET.

Dennis Carlberg

Dennis Carlberg, AIA, LEED AP BD+C is the [Chief Sustainability Officer & Associate Vice President for Climate Action](#) at Boston University where he focuses on building the programs necessary for mitigating BU's impacts on climate change, preparing its campuses for climate change, and supporting the integration of sustainability into the curriculum including the creation and administration of the [BU Campus Climate Lab](#). Prior to joining BU in 2009, Carlberg was a principal at Arrowstreet, a Boston-based architectural firm where he focused on sustainable design. He began his career at the Solar Energy Research Institute (now the National Renewable Energy Lab) conducting daylighting research to reduce building energy consumption and improve the indoor environment.

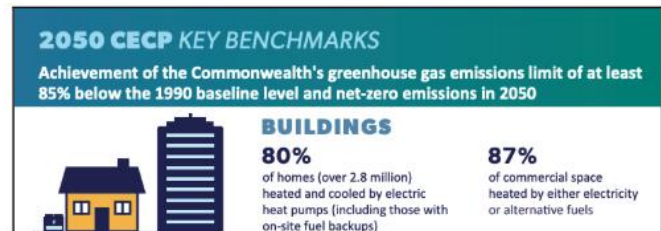
Dennis co-chairs the Boston Green Ribbon Commission Higher Ed Working Group Executive Committee with Jacob Glickel from Northeastern University. He is the University's Liaison to the University Climate Change Coalition, a group of 23 of the world's leading research universities and university systems committed to accelerating climate action on campus, in communities, and at a global scale. Dennis co-founded the Urban Land Institute Climate Resilience Committee in Boston for a decade and served on many sustainability committees for ULI and Technical Advisory Groups for the City of Boston, the Commonwealth of Massachusetts, and the Association for the Advancement in Higher Education.

At BU he served on the Climate Action Plan Task Force and the advisory boards of the Institute for Sustainable Energy, City Planning and Urban Affairs, BU URBAN, and led development of the Sustainable Operations section of the BU Strategic Plan.

Attachment 1 – Thermal Energy Network Background

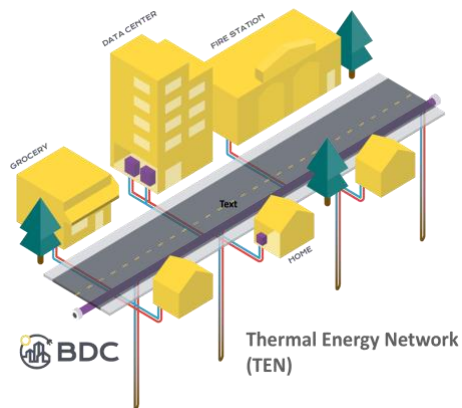
To meet its net zero emissions mandate, the Commonwealth’s Clean Energy Climate Plan has declared that by 2050 over 80% of all buildings must be upgraded to efficient electric heat pumps by 2050.

It is a mammoth task to retrofit over two million homes and businesses in 25 years to electric heat pumps, as well as to enact the associated changes to our energy infrastructure: rightsizing our natural gas system while modernizing the electric system to meet the increased future need.



Massachusetts Clean Energy Climate Plan

To meet the scale of the challenge, while minimizing stranded assets and maintaining affordable customer energy bills, the Commonwealth must shift from an exclusive focus on building-by-building decarbonization to adding in the ability to transition whole street-segments at a time. Understanding this, the Department of Public Utilities has already mandated that the state is moving beyond gas and overlapping gas and electric utilities must perform Integrated Energy Planning to ensure a smooth and least-cost transition of our energy infrastructure.



One of the most promising methods of transitioning whole street-segments to electricity is Thermal Energy Networks (TENs).¹⁰ TENs can benefit both electric and gas utilities, while delivering affordable energy in an equitable manner.

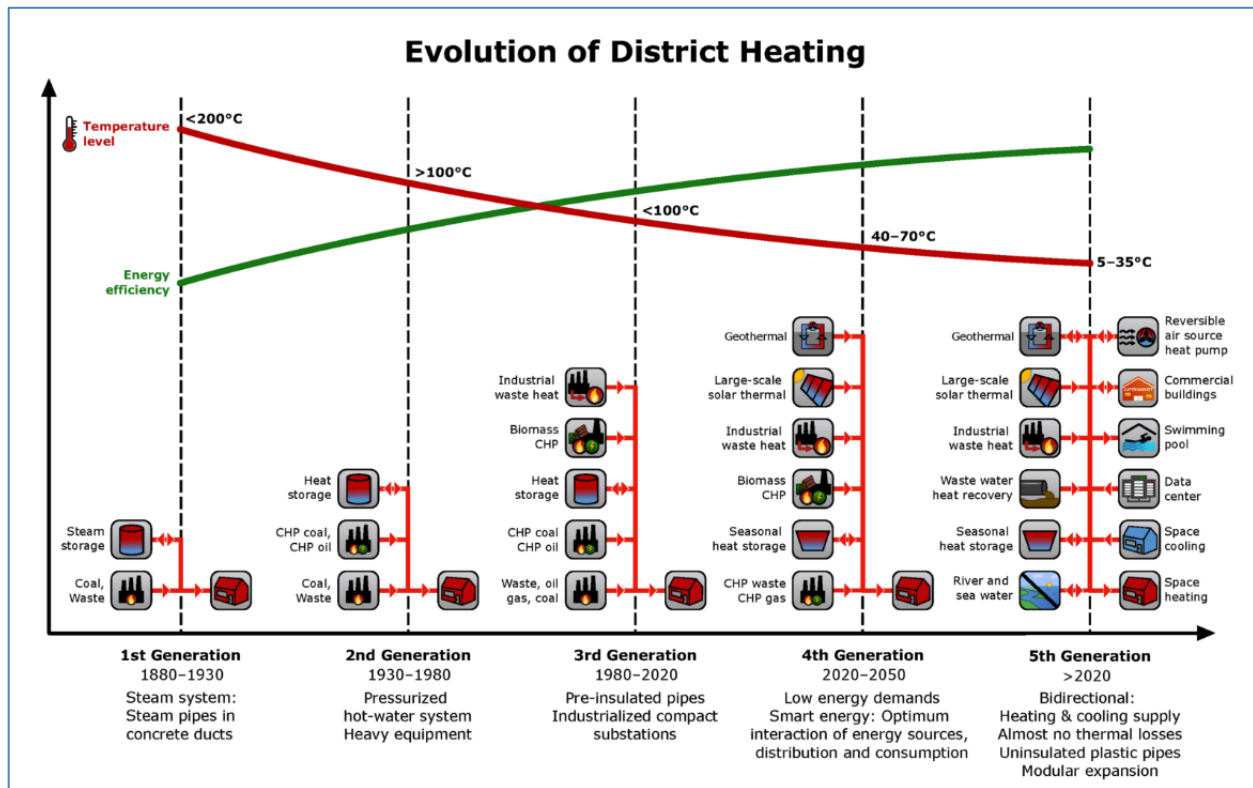
We use the term Thermal Energy Networks to describe “Fifth Generation District Energy Systems” or “5G District Heating and Cooling – 5GDHC” systems. The graphic below from the Building Decarbonization Coalition (BDC) describes the evolution of district energy systems over time. A thermal network taxonomy paper authored by HEET¹¹ explains the attributes that distinguish 5G systems from predecessor systems, including the fact that they are: “...non-linear, bi-directional energy flow, and decentralized. They provide ambient temperature fluid to decentralized water-source heat pumps in the buildings on the loop, which deliver the required thermal energy for heating and cooling the building space. Bi-directional energy flow results in

¹⁰ TENs are also known as geothermal networks, fifth-generation district energy systems, and many other names. For more information, see <https://buildingdecarb.org/resource-library/ten-definitions>.

¹¹ https://cdn.prod.website-files.com/649aeb5aaa8188e00cea66bb/671b0629c6bc4b994c041c9c_2024_GRC_Taxonomy_Magavi_Alberto_Varela.pdf

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more efficient systems. Because of this, 5G systems are more efficient than previous generations of DHC systems. The bi-directional energy flow from the main loop to the buildings and vice-versa makes 5GHDC systems well suited for urban environments with a high diversity of thermal load profiles.”



This project will focus on opportunities for Thermal Energy Network expansion or new development because of their efficiency advantages and capacity for flexible, modular expansion, but acknowledges that many anchor institution customers have legacy systems that are not TENs and those legacy systems could also benefit from access to new clean thermal sources. The right solution for thermal energy decarbonization will need to be determined on a case by case basis.

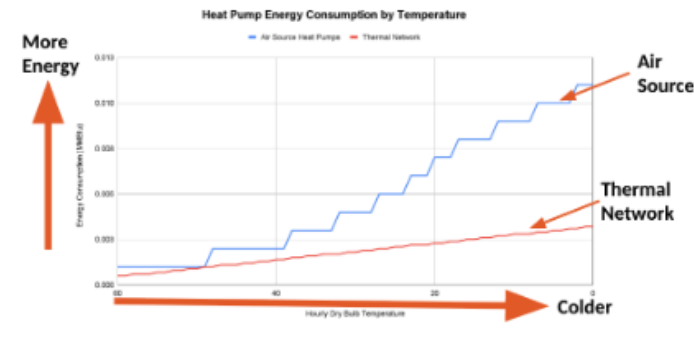
How a Thermal Energy Network (TEN) Functions

A TEN connects heat pumps in buildings using a network of pipes filled with ambient-temperature water. These heat pumps add unwanted heat or pull needed heat from the piped water to keep each building at the desired temperature.

The water in the underground pipes is maintained within a temperature range (approximately 40 to 90 degrees Fahrenheit), which allows heat pumps to work at their peak efficiency, no matter what the temperature of the outside air. This narrow temperature range is one of the

reasons that TENs can deliver heating or cooling at roughly twice the efficiency of air source heat pumps.¹²

Thermal Networks are Ultra-Efficient



To maintain the temperature of the water with renewable energy, an adequate thermal reservoir is needed. A thermal reservoir is defined as a permanent and abundant source of naturally occurring temperature that can be used to keep the water in the desired temperature range. These reservoirs include wastewater, waterways, the sea and the bedrock beneath our feet.

Phased for Success and Scale

The most cost-effective method of installing a TEN follows these principles:

- **Base Load Sizing:** Calculate the net thermal load of the buildings (i.e. subtract the simultaneous heating load from the cooling). Install thermal-reservoir infrastructure to meet the net non-peak load; this is generally about 90% of the hours each year.
- **Peak Load Management:** Address the peak load with local thermal assets, such as pre-existing boilers, heat pumps or chillers. These assets can store heating or cooling in the network's water long before that temperature is needed. These pre-existing local assets can also function as emergency backup assets to decrease worries about the new technology.
- **Planned Obsolescence:** As these assets reach end-of-life, they can be replaced with non-combusting heat pumps (which can store the needed thermal energy during electric off-peak hours).

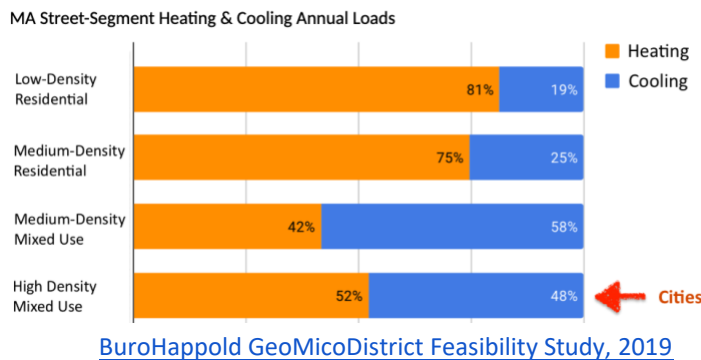
This phased approach significantly reduces the size and cost of the initial infrastructure, allowing the network to scale at speed, while enabling it to become completely non-emitting over time as the local combustion assets are systematically replaced.

Thermal Energy Network Benefits

The high efficiency levels of TENs have multiple benefits as a decarbonization strategy:

¹² See the Appendix for Xcel Energy's case study of Colorado Mesa University's TEN.

- **Ability to leverage load balancing.** TENS can reuse shed thermal energy between buildings. In Massachusetts, portions of cities can be ideal sites for TENS because they have a nearly perfectly balanced use of heating and cooling (see graph).¹³ This balanced energy-use increases the efficiency of the network –for instance, a lab or office building that predominantly needs air conditioning will reject heat into the water (rather than into the atmosphere) in the network, allowing buildings down the street to utilize that heat. The balanced heating and cooling use cancels each other out, decreasing the size and cost of the infrastructure needed to support the energy use.



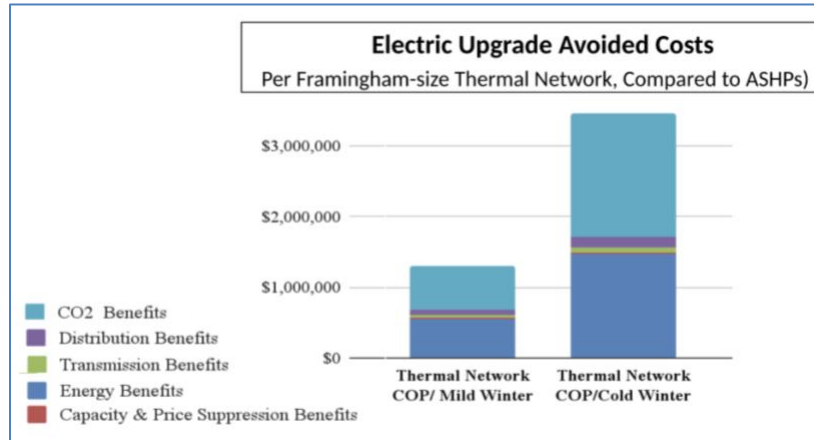
- **Reduced demand on the electricity grid.** The ultra-efficiency of a TEN can benefit the electric system by significantly reducing the cost of the local electric-grid modernization work in comparison to those buildings using air source heat pumps. This “non-wires alternative” can thus reduce customer electric bills¹⁴ and potentially speed up the decarbonization transition.¹⁵

¹³ [Buro Happold GeoMicroDistrict Study](#), pg 30

¹⁴ A recent study by Black Swan Lab and Synapse, found that each TEN installation the size of the installation by Eversource in Framingham, would result in the average avoided costs to the local electric system of \$1.3 to 3.5 million in comparison to air source heat pumps, depending on the severity of the winter and the assumed COP of the TEN.

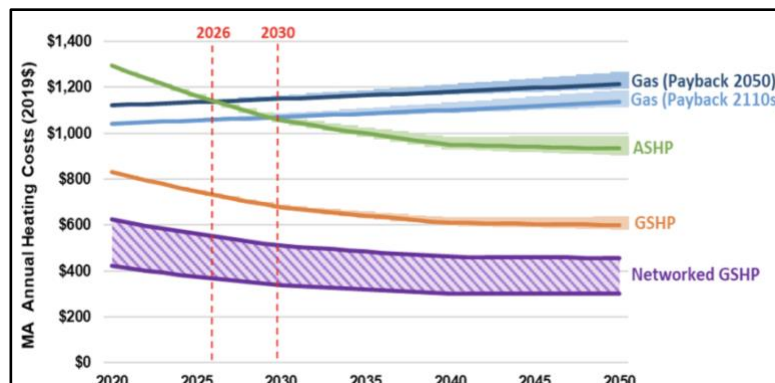
¹⁵ Much of the supply chain for parts for the electric distribution system is currently overwhelmed nationally. Electric transformers, for instance, can take more than two years to be delivered.

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[Synapse 2025 analysis](#), sponsored by Black Swan Lab

- Compatibility with gas utility business models.** TENS also benefit gas utilities as an alternative non-combusting business model that uses the gas utilities' (and their workforce's) core expertise of pumping thermal energy through pipes underground, as well as their long-term financing methods for expensive shared infrastructure. With TENS, gas utilities can become thermal utilities, existing and flourishing in our low-emissions future.
- Long-term affordability.** Next generation TENS are at an early stage of development in the US market and as a result have not yet benefited from the cost reductions that will inevitably come from technology innovation, increased engineering know-how, workforce development, improved supply chains, reduced material costs, etc. State regulators will, of course, make the final determination on the actual costs and structure of a utility TEN rate structure, and this decision will be based on the local installation costs, the cost of capital and the payback period. However, TENS have been predicted by multiple economists to be likely to result in heating bills as low or lower than gas. With TENS, although the initial infrastructure costs more than the existing gas distribution system, it requires no fuel beyond that of electricity to pump the water around the network and to run the heat pumps. Because it is ultra efficient, it only requires a minimal amount of electricity.



Inflection Point: When Heating with Gas Costs More, [Applied Economics Clinic](#), 2021

Thermal Energy Network Challenges

This project will help clarify the multiple “unknowns” that need to be addressed to effectively utilize TENS as part of a region’s decarbonized future.

- **What locations are most appropriate for TENS?** Strategies for TENS start at the building scale to first optimize building energy performance, divert waste heat from cooling towers and from steam condensate. TENS are most efficient and financially attractive when there is a density of thermal demand; some diversity of cooling and heating needs; a local thermal reservoir that can be accessed easily; and where there is room to install the thermal exchange infrastructure. As city-scale clean thermal planning develops, cities will increasingly be differentiating their urban areas according to areas:
 - Already served by a TEN
 - Appropriate for the expansion of an existing TEN
 - Appropriate for a new stand-alone TEN
 - Appropriate for decentralized building-scale solutions
- **How can thermal reservoirs be best accessed and distributed in dense urban environments?** Thermal reservoirs beyond the building include removing heat from overheated waterways, heat exchange with wastewater, harbor water, bedrock, and potentially deep geothermal heat. TENS require affordable access to local thermal reservoirs that can keep the network’s water in the required temperature range. In urban centers, a significant challenge is enough underground space to locate the infrastructure, such as boreholes, heat exchangers, and distribution systems.
- **What is the most accurate way to compare the cost of TENS to other decarbonization options?** The front-end infrastructure investments required to get a TEN in place can appear high compared to moving those buildings to air source heat pumps, if the incremental costs of the impact on the electric grid and transmission, and equipment lifecycle are not factored in. How can we get an accurate “full cost accounting” of both building retrofits and shared infrastructure costs, especially as those infrastructure costs are still being developed – for TENS, the Electric Sector Modernization Plans (ESMPs) and the transmission system?
- **How can we minimize disruptions during installation?** The installation of TENS infrastructure can be disruptive to the residents of the building and to the people who use the streets. Cities have found ways to manage this disruption during the installation of new natural gas lines and other under-ground infrastructure. Similar practices need to be adapted to TENS infrastructure installations.
- **How can we build the skilled workforce to manage TENS?** Designing and running TENS comes with a set of engineering and operational challenges, some unique to these low-

temperature, bidirectional networks. Organizations operating TENs need experienced managers and engineers to take full advantage of their efficiencies.

- **What is the best way to finance building retrofits for TENs?** Adapting buildings to be able to connect to TENs often requires significant investments, which can include weatherization, electric panel upgrades, and switching gas appliances for electric ones. A recent Building Electrification Institute study found that the cost per Boston home, post-rebate, would range from \$21,000 to \$77,000. Few families can afford that. For the Commonwealth to decarbonize at speed and scale, and in an equitable way, we must find a way to pay for these retrofits, without raising taxes or Mass Save energy bill surcharges.
- **What is the regulatory structure that is needed to support TENs development?** Over the last several years, the State of Massachusetts has implemented a strong policy framework to accelerate the transition away from the use of natural gas. This has included both state legislation as well as several orders from the Department of Public Utilities. The regulatory context for utilities to provide “thermal service” to ratepayers is still in a relatively early stage of development. There is not yet clarity on who will provide thermal services to ratepayers; how thermal services will be regulated; who will lead on clean thermal planning; and how investments will be financed. Advancing clarity on the TENs regulatory structure should be a top priority.¹⁶

¹⁶ A good example is Governor Healy’s Energy Affordability legislation which allows gas companies to own geothermal heat loops that serve individual customers such as universities and hospitals, helping them overcome upfront cost challenges that are a barrier to deploying what is the most efficient heating and cooling technology available. These investments will come at no cost to other customers but will benefit all customers by avoiding the need for costly electric grid upgrades.

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Attachment 2 – Background on Targeted Boston Area Thermal Reservoirs

Seawater

The water in the Boston harbor ranges between 38 and 67 degrees Fahrenheit. This water is completely replaced every four days so there is no chance of depleting the reservoir. A tunnel can pump water in from the harbor, run the water through an evaporator heat exchanger and transfer the thermal energy to a refrigerant to be used in a thermal network. Large seawater heat pumps provide thermal energy in [Stockholm](#), Sweden; [Seward](#), Alaska; and [Esbjerg](#), Denmark. The Environment Dept. of the city of Boston is already actively interested in a seawater heat pump and the University of Massachusetts Boston is planning to install a seawater campus cooling system.



River Water

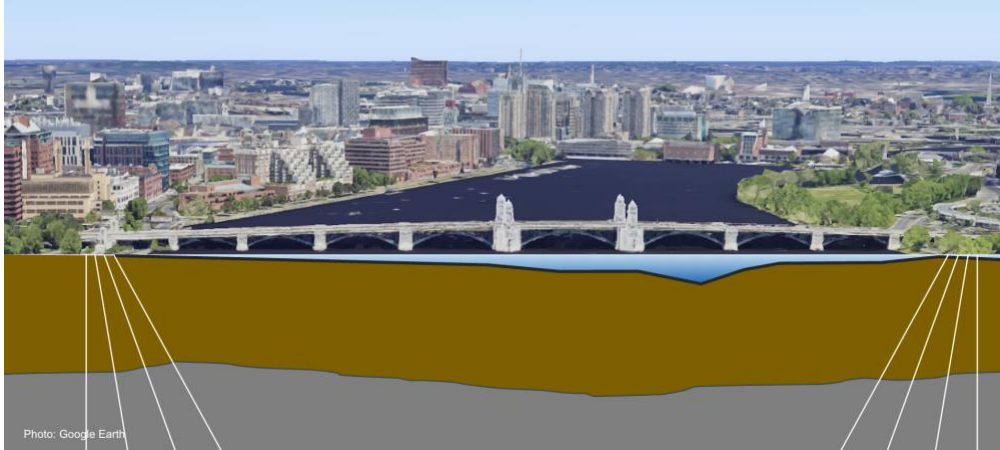
Vicinity already has permits to utilize the thermal services of the Charles River. Heat extracted from rivers can help to restore river temperatures to pre-climate change conditions and can be less capital intensive than geo-exchange. The feasibility of river water thermal reservoirs will depend on a number of factors, including water temperature across seasons; river flow rates; and existing/planned permits for thermal extraction.

Inclined Boreholes

Estimates from drillers and designers suggest that drilling a horizontal array of boreholes into the bedrock of the Charles River or Mystic River from a barge might not be economically worthwhile. Thus, the project will instead explore installing arrays of inclined boreholes from paved areas along the rivers as well as from appropriate areas on property owned by property owner partners.

Inclined borehole arrays can be installed under a surface area the size of a single parking spot, with the boreholes angling out to cover 500' in all directions. Installed in diverse locations along the shore and on campuses, these inclined arrays can maximize the bedrock under the river and under the property of anchor institutions while minimizing surface area disturbance. Each borehole array can be installed in a few weeks. Afterward the surface area is restored and the land utilized as before.

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Potential Inclined Borehole Strategy

Deep Geothermal

Deep geothermal is a technology that is rapidly evolving and could be a potential future option for the Boston area. However, it is not yet a proven thermal technology in the state and it is outside of the scope of this study to do a full assessment of the viability of this technology. The project goal will be to make recommendations on a future process for stakeholders to collaborate on a commercial viability assessment for deep geothermal.