COMMERCE DEPARTMENT

Minnesota Thermal Energy Network Site Suitability Study

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Minnesota Department of Commerce, Division of Energy Resources
85 7th Place East, Suite 280
Saint Paul, MN 55101
https://mn.gov/commerce/energy/
ilana.percher@state.mn.us
651-539-1496
1-800-657-3710

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Prepared by:

Buro Happold Consulting Engineers, Inc.
633 West 5th St, 68th FL
Los Angeles, CA 90071

In collaboration with:

Building Decarbonization Coalition
116 Front St., PO Box 642
Lewes, DE 19958

Slipstream, Inc.
431 Catalyst Way
Madison, WI 53719

Thermal Energy Insights
35 Eastview Rd
Hopkinton, MA 01748

Authors:

Eric Bosworth, Thermal Energy Insights

Noah Cordoba, Building Decarbonization Coalition

Nada Haddad, Buro Happold

Laura Helmke-Long, Slipstream

Miles Ingraham, Buro Happold

Connor Jansen, Slipstream

Alex Nutkiewicz, Buro Happold

With support from:

Haider Attiq, Slipstream

Ashley Besic, Building Decarbonization Coalition

Ania Camargo, Building Decarbonization Coalition

Adam Friedberg, Buro Happold

Scott Hackel, Slipstream

Grady Haffrey, Buro Happold

Jon Koliner, Slipstream

Andrew Lick, Slipstream

Jason Masters, Buro Happold

Lily Matthews, Buro Happold

Ian Nicholson, Buro Happold

Jess Silber-Byrne, Building Decarbonization Coalition

Mauricio Vasquez, Buro Happold

David Vigliotta, Slipstream

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Contents

Executive Summary

To meet Minnesota's greenhouse gas reduction targets – 50% by 2030 and net-zero by 2050 – the state must decarbonize building heating and cooling at scale. Legislation passed in 2024 supports the development of thermal energy networks (TENs), which use shared water-filled pipes and heat pumps to transfer heat between buildings and other thermal energy-producing resources. When strategically deployed, TENs reduce neighborhood emissions, alleviate grid stress, and provide an equitable, affordable alternative to Minnesota's gas system.

This analysis evaluates the suitability of TENs across the state. Through a combination of geospatial suitability mapping, stakeholder interviews, and site-specific evaluation, this study has identified opportunities and barriers for TENs deployment in Minnesota. This analysis includes:

- A review of the current technical, policy, regulatory, and market landscape and motivations driving TENs in the United States.
- A GIS tool that describes conducive conditions for TENs across Minnesota.
- A comprehensive overview of challenges and opportunities for TENs in Minnesota, including statutory, regulatory, market, and technical barriers, workforce and supply chain readiness, and community and stakeholder perceptions and feedback.
- A quantitative and qualitative scoring mechanism that evaluates 16 example sites for TENs development in Minnesota.

This multi-phase, mixed-methods analysis reveals several key findings for the state.

TENs are most technically feasible in dense, mixed-use areas and neighborhoods with recoverable thermal energy sources.

Urban centers such as those found in downtown Mankato, Rochester, and Alexandria scored highest due to their high density and co-location with thermal resources of municipal, commercial, and residential buildings, which provide balanced thermal loads. These sites also encompass several “anchor tenants” – large buildings or key neighborhood sites embedded in a community that, when deciding to join a TEN, can drive broader interest in participation and further drive network viability. These tenants include municipal buildings, hospitals, schools, and community centers, and they consistently emerged as critical indicators of site suitability. These types of anchor tenants represent large and stable energy demand for a TEN, providing the potential source of long-term revenue needed for specific ownership and business models.

Thermal resource accessibility is also a major advantage to the performance of TENs. Proximity to thermal resources, which can include buildings such as data centers, ice rinks, industrial facilities, or natural resources such as geothermal boreholes and large bodies of water, significantly improves system performance and economic feasibility.

New developments present strategic opportunities to build and integrate TENs infrastructure alongside building HVAC systems. Planned mixed-use projects in areas like Brooklyn Park and The Heights in St. Paul can enable concurrent installation of TENs with other infrastructure and building systems, lowering costs and improving efficiency.

Ownership and permitting complexity represent the largest challenges to TENs.

To unlock opportunities for TENs, there is a need for regulatory clarity, financially backed business certainty, and owner, user, and broad community support.

Addressing environmental, utility, land ownership, and legal requirements is critical for TENs deployment. Sites with single or municipal ownership, such as universities and municipally owned properties, streamline logistics and reduce the barriers associated with gaining approval for system construction. Developing TENs for these sites can serve as foundational projects, generating operational data, building workforce skills, and increasing stakeholder confidence for future systems in more complex ownership contexts.

State support is needed for timely and equitable development of TENs.

As one stakeholder noted: "Anything the state can do to facilitate this, they should do." Key actions to catalyze the development of TENs include de-risking projects through financial support, offering multilingual resources for workers and communities, streamlining licensing and permitting, and initiating projects in state-owned buildings. These strategies will build workforce capacity, strengthen community and investor confidence, and enable equitable scaling of TENs.

Equity and environmental justice should also guide TEN development projects, particularly in energy-burdened communities that may qualify for enhanced incentives and targeted support. Appropriate ownership and business models can and should advance goals beyond revenue, including affordability, community benefit, and long-term resilience, which is especially important in energy-burdened communities. State and local officials should actively pursue state and federal funding, including environmental justice grants and infrastructure programs, to reduce upfront costs, fund feasibility work, support customer-side retrofits, and resource multilingual community engagement.

Minnesota is a leader in showcasing the opportunity for TENs.

Minnesota's characteristics – an abundance of thermal resources, diverse building typologies, local support for clean energy systems, existing local drilling knowledge, and precedent projects featuring innovative designs and business models – position the state to lead the nation in TENs implementation. Successful TENs deployment will require targeted strategies that prioritize and address the barriers and opportunities outlined here and throughout the remainder of this analysis.

1 Introduction

The State of Minnesota has passed ambitious greenhouse gas (GHG) reduction targets. By 2030, the state has committed to reducing their statewide GHG emissions by 50%, and, by 2050, reach net-zero emissions. This legislation was supplemented by passing successive budget and policy bills that support developing utility electrical transmission capacity and facilitating grants and working groups dedicated specifically to the advancing thermal energy networks across the State of Minnesota.[1]

Thermal energy networks (TENs) are increasingly understood to be key solutions towards reducing energy consumption and GHG emissions from heating and cooling buildings across the United States. TENs circulate fluids through underground pipes carrying non-combustible thermal energy to heat and cool a network of interconnected buildings. Heat pumps located within these individual buildings utilize this stable source of thermal energy (supported through geo-exchange with the earth, groundwater, surface water, wastewater, or other heat sources) for heating and cooling with coefficients of performance (COPs) that can exceed 6.[2] TENs represent an opportunity to transform the energy landscape of entire communities – improving their resilience while also reducing the health and safety risks associated with fossil fuel-based systems. While these systems are the most efficient methods available for delivering decarbonized thermal energy to neighborhoods, the lack of precedent projects across a diverse stock of communities has slowed their widespread deployment. Identifying priority geographical zones and socio-economic opportunities for the development and expansion of TENs represents a key initiative for the State of Minnesota in working to enable this transformative energy technology.

To accomplish this objective, Buro Happold, Slipstream, the Building Decarbonization Coalition, and Thermal Energy Insights developed a mixed methods approach to evaluating the suitability of communities across Minnesota for TENs deployment. First, a comprehensive data collection process identified quantitative and qualitative data sources describing the geologic, hydrogeologic, energy, infrastructure, and socio-economic conditions across the state. This data was complemented by extensive stakeholder engagement, where interviews were conducted with technical experts and community leaders to understand barriers and opportunities for TENs adoption. Utilizing the insights from stakeholder interviews and geospatial data analysis, “hotspots” were identified to help select specific sites for further comparative study. This study involved the development of a scoring system and accompanying geospatial tool, where sites were evaluated based on their relative suitability for TENs installation based on a set of 8 quantitative and 10 qualitative criteria. The results from these methods are described in more detail throughout the report.

[1] Laws of Minnesota 2024, Chapter 126, May 24, 2024 https://www.revisor.mn.gov/laws/2024/0/Session+Law/Chapter/126/

[2] Colorado Energy Office, Geothermal Heating and Cooling, https://geothermal.colorado.gov/geothermal-heating-and-cooling.

2 Background and Motivation

2.1 Evolution of Thermal Energy Networks

Sharing thermal energy among buildings is not new. TENs represent the one of the latest and cleanest innovations in a lineage of large-scale heating and cooling technologies known as district energy systems.

District energy systems traditionally rely on a centralized heating source to produce hot water or steam. The heated water then flows through pipes to provide space or water heating to buildings. Long-standing district energy systems exist in New York (established 1881), Denver (1880), Philadelphia (1889), and Boise (1891); a 2018 report by the International District Energy Association (IDEA) reported 660 systems in the U.S.[3] [4] [5] [6] [7] District energy systems also serve campuses, military barracks, industrial complexes, and hospitals.[8]

Minnesota is familiar with district energy systems as well. Since 1917, municipalities with fewer than 10,000 residents have had the right to install district systems referred to as "central heating plants"; in 1988, this was extended to cities of all sizes, and the terminology "district heating systems" was used.[9] Duluth's district heating

[3] ConEdison, The Evolution and Future of the Con Edison Steam System, PowerPoint presentation, October 21, 2022, https://www.nyiso.com/documents/20142/33938587/20221021%20-%20Steam%20Future%20Overview_NYISO%20(002).pdf.

[4] Xcel Energy, Denver's Steam System (2019), https://www.xcelenergy.com/staticfiles/xe/PDF/2019DenverSteamFacts.pdf.

[5] Jeannie Morris, "Our History and Future: Vicinity Energy in Philadelphia," Vicinity Energy, May 9, 2024, https://www.vicinityenergy.us/blog/our-history-and-future-vicinity-energy-in-philadelphia/.

[6] Kenneth Neely, Gerry Galinato, and Kent Johnson, "City of Boise Geothermal District Heating System," GRC Transactions 30 (2006): 229–33, https://www.idahogeology.org/pub/Geothermal/References/GRC/Neely_etal_2006_GRC_Trans.pdf.

[7] U.S. Energy Information Administration, U.S. District Energy Services Market Characterization (Washington, DC: U.S. Energy Information Administration, February 2018), https://www.eia.gov/analysis/studies/buildings/districtservices/pdf/districtservices.pdf.

[8] Building Decarbonization Coalition, Neighborhood-Scale Building Decarbonization Map, accessed December 5, 2025, https://buildingdecarb.org/neighborhood-scale-projects-map.

[9] Doug Presley and Kate Moore, Accelerating Thermal Energy Network Deployment in Minnesota – Policy Barriers and Opportunities (Midwest Building Decarbonization Coalition, September 2024), https://static1.squarespace.com/static/6548fa466239d21eee818ad3/t/66e0a2dd0bd49504e456aa6c/1725997790857/Thermal+Enery+Network+Policy+Opportunities+and+Barriers+in+Minnesota+-+2024-09+%281%29.pdf.

system has operated since 1932, Minneapolis' since 1972, and St. Paul's district energy system has provided heating since 1983 and cooling since 1993.[10] [11]

District energy systems have evolved over decades to reduce emissions, improve efficiency, and provide cooling (Figure 2-1). These evolutions created distinct generations of systems, with the emerging fifth generation marking the transition to today's TENs.[12] The definition of a TEN varies by state, but Minnesota statute defines TENs as "projects that provide heating and cooling to multiple buildings connected via underground piping containing fluids that, in concert with heat pumps, exchange thermal energy from the earth, underground or surface waters, wastewater, or other heat sources."[13]

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[10] Duluth Energy Systems, "What Is District Energy?," Duluth Energy Systems website, accessed December 5, 2025, https://www.duluthenergysystems.com/how-it-works/.

[11] Trey Harsch and Sophie Nikitas. Thermal Energy Network Deployment Work Group Report." Minnesota Public Utilities Commission accessed December 15, 2025. https://www.lrl.mn.gov/docs/2025/mandated/251873.pdf

[12] Zeyneb Magavi, Angie Alberto-Escobar, and Isabel Varela. "A Definitional Taxonomy for (Geo)Thermal Energy Networks." Geothermal Resources Council Transactions 48 (2024): 2089–2110. https://www.geothermal-library.org/index.php?action=view&mode=pubs&record=1035205.

[13] Minnesota Statutes, § 216B.2427 (2025). "Natural Gas Utility Innovation Plans."

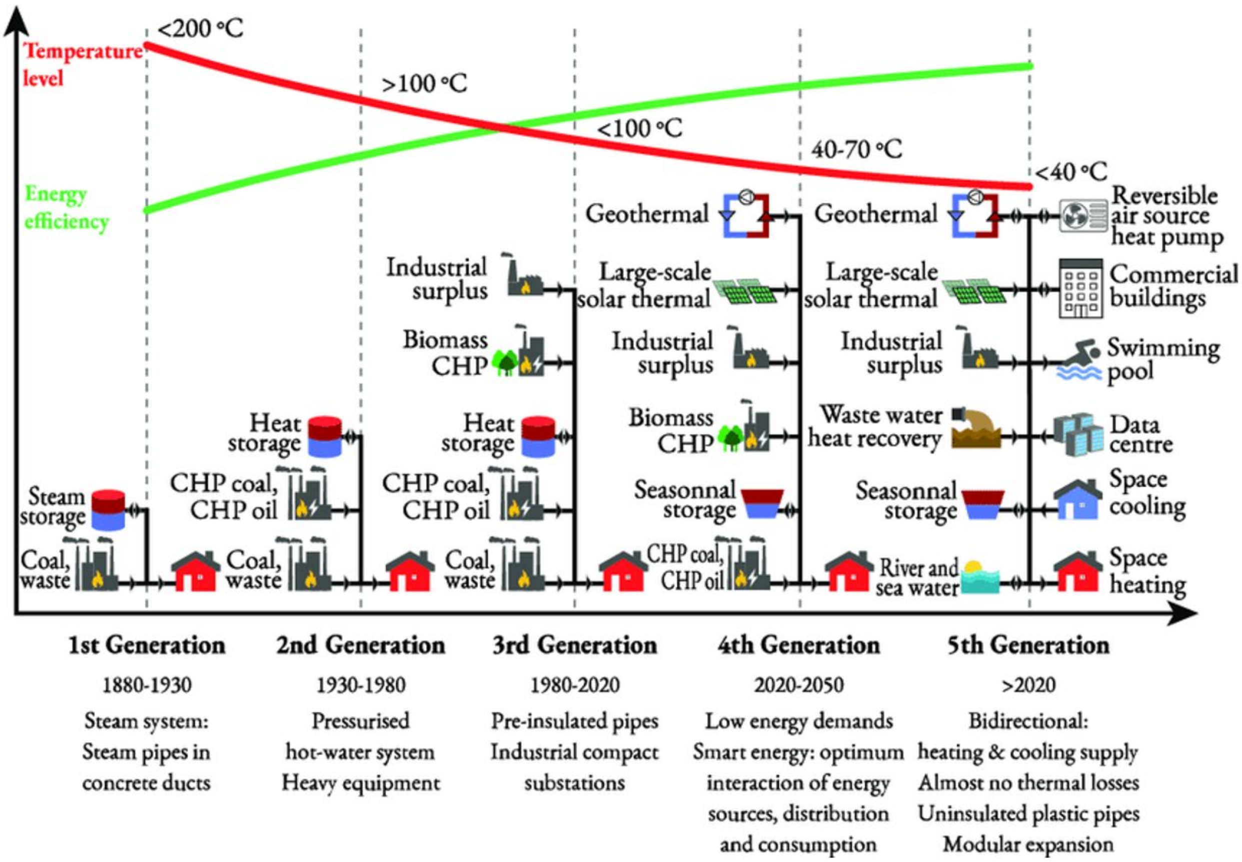

***Figure 2-1**. Evolution of district energy systems.*[14]

While early district energy systems enabled efficient, safer heat distribution in growing cities, TENs address today's energy challenges: reducing emissions, downsizing gas systems, lowering energy bills, supporting union labor in the clean energy transition, and managing electric grid demand.[15]

TENs build on decades of district energy engineering expertise, but their characteristics, applications, and drivers for adoption differ significantly from earlier district systems. Most importantly, TENs deliver efficient heating and cooling without onsite combustion. Ground-source heat pumps (GSHPs) connect each building to the TEN's thermal infrastructure, running on electricity to provide both heating and cooling without burning fuel.

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[14] Marwan Abugabbara, Modelling and Simulation of the Fifth-Generation District Heating and Cooling (Lund: Division of Building Services, LTH, Lund University, May 2021).

[15] Charles G. Gertler, Timothy M. Steeves, and David T. Wang, Pathways to Commercial Liftoff: Geothermal Heating and Cooling (Washington, DC: U.S. Department of Energy, January 2025), https://igshpa.org/wp-content/uploads/LIFTOFF_DOE_Geothermal_HC.pdf.

Unlike early district energy systems that relied on central heat or chilled water production, fifth-generation TENs are decentralized, meaning they connect multiple clean thermal energy sources, sinks, and storage resources into a single network. This enables energy sharing, balanced heating and cooling loads, improved efficiency, and potentially reduced overall costs compared to a system that relies on a central heating or cooling plant. As district energy systems have evolved, new designs have enabled the temperature of the circulating fluid within the pipes to decrease. The innovation of the single-pipe, ambient temperature loop (ATL) allows water to circulate between 45-95°F, reducing thermal losses and working ideally with market-ready ground-source heat pumps (GSHPs).

2.2 Motivation for TENs Adoption

Emissions Reduction

TENs are critical technology for Minnesota's decarbonization goals. By networking non-combusting GSHPs at campus, district, or utility scales, TENs significantly reduce emissions. Existing systems prove this impact: Missouri S&T University reduced campus CO_2 emissions by 25,017 tons in its first year of operations, while Colorado Mesa University's geothermal network cuts 17,742 tons of CO_2 annually.[16] [17]

This matters for Minnesota, where economy-wide emission reduction goals are set out in statute, including specifically the goal to reduce statewide greenhouse gas emissions across all sectors to net-zero by 2050.[18] Achieving this requires reducing fuel combustion in buildings, yet Minnesota's gas system continues to grow. Natural gas fuels approximately 72% of end uses (e.g., space and hot water heating, cooking) in residential buildings and 57% in commercial buildings.[19] Residential and commercial gas deliveries have increased 24% from 2010-2022 and are projected to continue growing. Filings by CenterPoint, Xcel, MERC, and Great Plains Natural Gas project growth in gas deliveries through 2038 – three years past the state's 50% emissions reduction goal.[20]

Gas System Transition

Minnesota is not alone in the trend of investing in and expanding gas infrastructure at the time when the state must reduce fuel use and should instead be contracting its gas system. According to the American Gas Association, annual utility capital spending on gas infrastructure has tripled over the past decade, reaching

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[16] Missouri S&T, "S&T's Geothermal Energy System," Facilities Operations, accessed December 12, 2025, https://facilitiesoperations.mst.edu/geothermal/.

[17] Colorado Mesa University, "Geo-Grid System," Sustainability, accessed December 12, 2025, https://www.coloradomesa.edu/sustainability/initiatives/geo-grid.html

[18] Minnesota Statutes, § 216H.02 (2025). "Greenhouse Gas Emissions Control."

[19] Fresh Energy, Hidden Beneath Our Feet: Minnesota's Growing Decarbonization Challenge, white paper, April 8, 2024, accessed September 17, 2025, https://fresh-energy.org/wp-content/uploads/2024/04/White-Paper-Minnesotas-Decarbonization-Challenge-040824.pdf.

[20] Ibid.

approximately $21 billion in 2022.[21] This spending is partially driven by the need to replace aging gas pipelines. Based on 2024 data, more than one-third of gas mains in the United States were installed before 1980, and approximately one-quarter of gas mains were installed before 1970.[22] [23] As this infrastructure nears or passes the end of its useful life, it must be replaced. Without a clear alternative or technological pathway for a managed transition away from gas at this critical juncture, utilities will continue investing in gas pipelines that contradict state climate goals, forcing ratepayers to cover these investments for years.[24] [25]

TENs offer a clean, scaled alternative to gas infrastructure investments. When granted legal or regulatory authority, as described in Section 2.3, gas utilities can use TENs to provide customers with alternative heating and hot water sources while leveraging gas utilities' existing workforce, customer base, legal rights-of-way, and administrative and billing expertise. Ratepayers benefit when gas utilities finance clean energy infrastructure instead of future stranded gas assets.[26] Utility adoption of TENs also advances equitable building decarbonization by providing clean heating and cooling to every network customer, regardless of income level or homeownership status.

Utility TENs can also protect vulnerable and low-income customers. An unmanaged, household-by-household transition away from gas results in households with financial means electrifying their homes; a declining customer base will drive higher gas rates for remaining customers, increasing their overall energy burden.[27] By prioritizing the equitable installation of TENs in disadvantaged or environmental justice neighborhoods, utilities

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[21] Dorie Seavey, Leaked & Combusted: Strategies for Reducing the Hidden Costs of Methane Emissions & Transitioning off Gas (HEET, 2024), https://cdn.prod.website-files.com/649aeb5aaa8188e00cea66bb/663a27270c0fa4fffcfe447d_Leaked-and-Combusted-May-2024.pdf.

[22] U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, "Gas Distribution Mains by Decade Installed," accessed December 15, 2025, https://portalpublic.phmsa.dot.gov/analytics/saw.dll?Dashboard

[23] Note: Percentages here exclude the miles of gas mains with unknown installation dates. Of the 1,298,028.52 miles with known installation dates in 2024, 34.1% (442,327.07 miles) were installed before 1980, and 24.6% (319,858.51 miles) were installed before 1970.

[24] Andy Bilich, Michael Colvin, and Timothy O'Connor, Managing the Transition: Proactive Solutions for Stranded Gas Asset Risk in California (Environmental Defense Fund 2019), https://www.edf.org/sites/default/files/documents/Managing_the_Transition_new.pdf.

[25] Sol deLeon et al., Minnesota Building Decarbonization Analysis: Equitable and Cost-effective Pathways Toward Net-Zero Emissions for Homes and Businesses (Clean Heat Minnesota, June 2024), https://www.synapse-energy.com/sites/default/files/MN%20Decarbonization%20Report_June%202024%2023-074.pdf.

[26] Ana Maria Camargo et al., The Future of Heat: Thermal Energy Networks as an Evolutionary Path for Gas Utilities Toward a Safe, Equitable, Just Energy Transition (Washington, DC: ACEEE, August 2024), https://buildingdecarb.org/wp-content/uploads/The-Future-of-Heat-Thermal-Energy-Networks-as-an-Evolutionary-Path-for-Gas-Utilities-Toward-a-Safe-Equitable-Just-Energy-Transition.pdf.

[27] Ibid.

can ensure that these customers are protected from increased energy burdens as they transition their gas system to clean alternatives.

Grid Relief and Infrastructure Affordability

As buildings in Minnesota move away from gas and toward electrification, electrification technologies and approaches matter. Inefficient building electrification will increase electric grid demands, requiring more investment in generation, transmission, and distribution infrastructure during peak heating and cooling seasons.[28] In the United States, seasonal electricity demand is currently greatest in the summer months, when electricity is used to provide cooling. However, by electrifying space heating in buildings, especially in a heating-dominant state like Minnesota, [29] this seasonal peak electricity demand will shift towards the winter – requiring an electric grid buildout that can meet that new, increased peak. This concept is visualized through what is called the “Falcon Curve” (Figure 2-2) which shows the potential change in Minnesota’s electric demand profile throughout the year.

Ground-source heat pumps, when networked in a TEN, have efficiency advantages over other individual building-scale electrification technologies. As shown in Figure 2-2, when all heating energy demand is electrified with technologies having a COP of 1 (e.g., baseboard or other electric heating, shown on the left plot), the new electricity demand, represented by the purple line, spikes dramatically in the winter months. However, the Falcon Curve, under an electrification scenario with a COP of 6 – a typical reported COP for TENs – shows a significantly lower demand curve with flattened peaks (right plot), closer to the existing business-as-usual (summer electrical peak) scenario.[30] This relative shift in demand represents an enormous opportunity for grid flexibility and resiliency during peak periods – translating into substantial reductions in grid infrastructure buildout.[31]

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[28] Jonathan J. Buonocore et al., "Inefficient Building Electrification Will Require Massive Buildout of Renewable Energy and Seasonal Energy Storage," Scientific Reports 12 (2022): 11931, https://www.nature.com/articles/s41598-022-15628-2.

[29] Brian Sousa et al., “Understanding Seasonal Variations of U.S. State Energy Demand.” 2022 AGU Fall Meeting, Chicago, IL, December 12–16, 2022. https://ui.adsabs.harvard.edu/abs/2022AGUFMGC42Q0927S

[30] Jonathan J. Buonocore et al., "Inefficient Building Electrification Will Require Massive Buildout of Renewable Energy and Seasonal Energy Storage," Scientific Reports 12 (2022).

[31] Xiaobing Liu, et al., 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, TN: Oak Ridge National Laboratory, 2023), https://info.ornl.gov/sites/publications/Files/Pub196793.pdf.

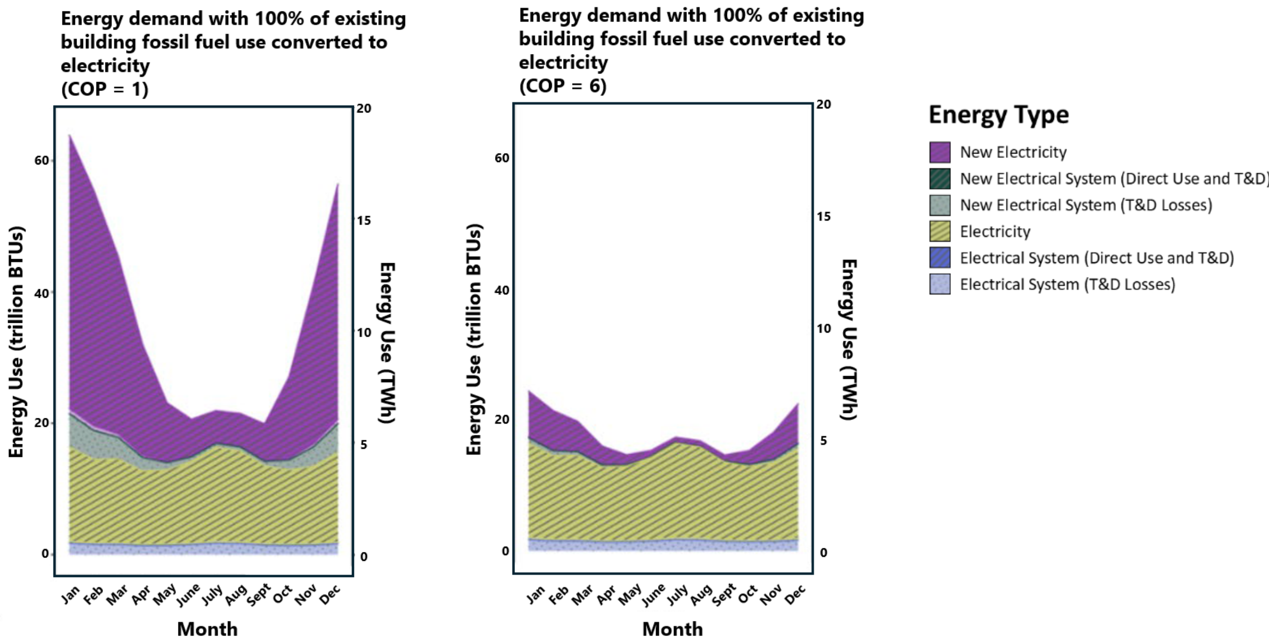

***Figure 2-2**. Minnesota's "Falcon Curve" plots present modeled seasonal fluctuations in peak electricity demand when space heating shifts from gas or delivered fuel-based sources to electricity.[29] [32] If building heat is supplied universally by low-efficiency electrified technology, (e.g. resistance heating with COP ≈ 1), wintertime peak demand will far exceed today's electrical system capacity. Alternatively, when highly efficient technologies are used to heat buildings, (e.g., TENs with COP ≈ 6), this seasonal shift to winter peak demand is mitigated - reducing the need for major electrical grid upgrades.*

2.3 TENs Policy in the United States

College campuses in the U.S. were early adopters of TENs. As institutions that own their infrastructure and can make large capital expense decisions relatively quickly, campuses were well-positioned for early implementation. TENs enabled them to meet decarbonization and affordability goals by reducing or eliminating fuel commodity expenses, lowering maintenance costs, decreasing electricity and water consumption, and stabilizing energy costs. Municipal TENs and systems in master-planned communities followed.[33] In 2021, the Massachusetts Department of Public Utilities became the first state regulatory commission to approve an investor-owned utility building and operating a TEN within its gas service territory.

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[32] Zeyneb Magavi, "Untitled, MN May 2025", Minnesota Public Utilities Commission Thermal Energy Network Deployment Workgroup Informational Workshop #4, Docket 24-275, May 29, 2025, https://efiling.web.commerce.state.mn.us/documents/%7B20B42197-0000-C913-BC69-38D96EAC6BA0%7D/download?

[33] Ana Maria Camargo et al., The Future of Heat: Thermal Energy Networks as an Evolutionary Path for Gas Utilities Toward a Safe, Equitable, Just Energy Transition (Washington, DC: ACEEE, August 2024), https://buildingdecarb.org/wp-content/uploads/The-Future-of-Heat-Thermal-Energy-Networks-as-an-Evolutionary-Path-for-Gas-Utilities-Toward-a-Safe-Equitable-Just-Energy-Transition.pdf.

State policy, regulation, and legislation have since accelerated interest in TENs. States primarily pass TENs legislation to meet climate or greenhouse gas emission reduction mandates established by state law.[34] State Clean Heat Standards and "Future of Gas" regulatory proceedings also serve as policy vehicles for TENs consideration.[35] Massachusetts and Minnesota were the first states to pass explicitly TENs-enabling legislation in 2021. Minnesota's Natural Gas Innovation Act (NGIA) mandated that gas utilities with over 800,000 customers include district energy pilots in their innovation plans, with subsequent amendments requiring at least 15% of NGIA budgets to be spent on TENs.[36]

As of 2025, 13 states have passed TEN-related legislation.[37] Eight of these states explicitly enable or mandate investor-owned gas or dual-fuel utilities to pilot TENs, resulting in 26 utility-owned pilots progressing through state utility commissions. Several states have introduced or are considering new legislation to advance TENs beyond a pilot phase and enable them to be regulated as long-term infrastructure. Depending on the state, this may require amending a regulated utility’s “obligation to serve,” allowing utilities to meet their customer service obligations via thermal energy rather than gas.[38] Reforming the obligation to serve is in process in California, Washington, and Massachusetts.[39]

Legislation accelerating utility-scale transition has also addressed environmental justice and equity. New York's Utility Thermal Energy Network and Jobs Act (UTENJA) require a proportion of UTEN pilots be deployed in disadvantaged communities.[40] Minnesota's NGIA requires utilities to include steps “ensuring that low- and moderate-income residential customers benefit from innovative resources included in the plan.”[41]

Gas utility transition is not the only reason states adopt TENs legislation. Energy affordability, market transformation, and job creation also motivate states to incorporate TENs into policy. Texas amended its local

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[34] Ania Camargo Cortes et al., Thermal Energy Networks (TENs) Legislative Guidebook (Building Decarbonization Coalition and Vermont Law & Graduate School, March 2025), 31, https://docs.google.com/document/d/1rB9OR6xL9EHBtFYFV-2nXHeZ4xOKlj_PaWb66xdTQT8/edit?tab=t.0#bookmark=id.x87m1lor1duz.

[35] Johanna Partin et al. Thermal Energy Networks in the United States: Emerging Challenges, Opportunities, and Needs (Transformative Strategies and Common Spark Consulting, May 2025).

[36] Minnesota Statutes, § 216B.2427 (2025). “Natural Gas Utility Innovation Plans.”

[37] Building Decarbonization Coalition, Thermal Energy Networks State Legislation (accessed December 6, 2025), https://buildingdecarb.org/resource-library/tens-state-leg.

[38] Kristin George Bagdanov, Decarbonizing the Obligation to Serve (Building Decarbonization Coalition, 2024), 20, https://buildingdecarb.org/wp-content/uploads/FINAL_Decarbonizing-the-Obligation-to-Serve_Oct2024.pdf.

[39] Ania Camargo Cortes et al., Thermal Energy Networks (TENs) Legislative Guidebook (Building Decarbonization Coalition and Vermont Law & Graduate School, March 2025), 33, https://docs.google.com/document/d/1rB9OR6xL9EHBtFYFV-2nXHeZ4xOKlj_PaWb66xdTQT8/edit?tab=t.0#bookmark=id.x87m1lor1duz.

[40] N.Y. S.B. 9422, 2021-2022 Leg. Sess. (2022), § 11, p. 6, lines 23-24, https://legislation.nysenate.gov/pdf/bills/2021/S9422.

[41] Minnesota Statutes, § 216B.2427 (2025). “Natural Gas Utility Innovation Plans.”

government code to allow municipalities to finance TENs through bonds, while Illinois' Clean and Reliable Grid Affordability Act included TEN funding as a solution for grid relief and clean energy job creation.[42] [43]

Federal policy has also spurred interest in TENs. In 2023, the Department of Energy (DOE) awarded $13 million in grants to 11 communities to explore community-scale thermal energy systems. Three of these projects were awarded additional DOE grant funding in 2025 and are proceeding. The Clean Electricity Investment Tax Credit (ITC) of the Inflation Reduction Act (IRA), passed by Congress in 2022, provided TENs owners and investors with a crucial financial tool by covering up to 50% of an eligible TEN project's tax liability.[44] The ITC for commercial installations remained intact during the 2025 reconciliation for H.R.1, affirming bipartisan Congressional support for geothermal systems. H.R. 1 also enables new ownership and business models, including third-party ownership and leasing for GSHPs and TENs, presenting opportunities for scalable adoption and replicable business models.

Combined local, state, federal, and private support has created tailwinds for GSHPs and TENs. Opportunities to use available funding for capital projects have motivated many stakeholders to explore integrating TENs into existing infrastructure priorities, which has introduced new opportunities for TENs ownership and business models.

2.4 TENs Ownership Models

TENs incorporate shared thermal production and distribution infrastructure and individual customer appliances, and different aspects of a system may be owned by different entities. This introduces unique ownership configurations and challenges. In this stage of rapid adoption and development, current and prospective TENs owners are testing models of private, public, and community ownership, as well as variations of public-nonprofit and public-private partnerships.[45] Evolving regulatory frameworks, increased participation, and third-party ownership and leasing opportunities will likely generate even more adaptations of ownership and business models.[46] These frameworks highlight the fluidity and flexibility of various ownership models, demonstrating

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[42] Building Decarbonization Coalition, Thermal Energy Networks State Legislation, accessed December 6, 2025, https://buildingdecarb.org/resource-library/tens-state-leg.

[43] Building Decarbonization Coalition, "Illinois Passes the Clean and Reliable Grid Affordability Act, Unlocking Affordable Energy Bills with Thermal Energy Network Investment," Building Decarbonization Coalition, October 31, 2025, https://buildingdecarb.org/illinois-passes-the-clean-and-reliable-grid-affordability-act-unlocking-affordable-energy-bills-with-thermal-energy-network-investment.

[44] Internal Revenue Service, "Clean Electricity Investment Credit," accessed December 15, 2025, https://www.irs.gov/credits-deductions/clean-electricity-investment-credit.

[45] Johanna Partin et al. Thermal Energy Networks in the United States: Emerging Challenges, Opportunities, and Needs (Transformative Strategies and Common Spark Consulting, May 2025).

[46] Ibid.

that existing systems have adapted to fit their own financial and community contexts.[47] In Minnesota, established district energy operators and energy-as-a-service (EaaS) providers, such as Cordia and Ever-Green Energy, have adapted their experience operating district energy systems into new and innovative ownership models. In communities where district systems are not established, community organizations and energy leaders have begun ideating on structures to advance TENs through community cooperative ownership.

Insights from specific case studies across the U.S. capturing these models are discussed in the following subsections.

The Heights, St. Paul, Minnesota

Located on the greater east side of St. Paul and owned by the St. Paul Port Authority, The Heights is a 112-acre master-planned community in development on land previously maintained as a golf course. The site will have 1,000 units of affordable housing and 1,000,000 square feet of light industrial space. A TEN will heat and cool a portion of the development following years of support from community organizers, the City of St. Paul, Ramsey County, and private TEN developer District Energy St. Paul (DESP), which owns and operates downtown St. Paul's district energy system through its subsidiary Ever-Green Energy.

The Heights Community Energy, Inc., a nonprofit incorporated by DESP, will own and operate the TEN. The system's projected $12 million cost includes about $6.8 million from grants and utility tax-exempt financing and a $4.7 million bridge loan from the Minnesota Climate Innovation Finance Authority (MnCIFA). The project anticipates repaying this loan through a minimum $4.8 million federal investment tax credit (representing 40% of project costs).[48] The project has succeeded, in part, due to being a new development where champions secured construction financing to align TEN distribution piping with new roadway construction timelines.

West Union, Iowa

West Union, Iowa, began constructing its municipal TEN in 2010.[49] The project emerged from planned downtown street repaving converging with the state's interest in demonstrating sustainable urban planning solutions. The City Council initially disagreed with moving forward but ultimately approved the TEN after confirming full grant funding without requiring new debt or tax increases. The $2.2 million system began operation in 2014. The city now leases the boreholes and distribution piping to West Union District Energy (WUDE) – a user group that manages maintenance and operation, sets rates, and handles billing.[50]

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[47] Building Decarbonization Coalition, TENs Ownership Models, accessed December 6, 2025, https://buildingdecarb.org/tens-ownership-models.

[48] Minnesota Climate Innovation Finance Authority, Special Board Meeting Agenda, March 26, 2024 (St. Paul: Minnesota Department of Commerce, 2024), PDF, accessed December 4, 2025, https://mn.gov/commerce-stat/pdfs/MnCIFA-march-26-board-meeting-info%20Packet.pdf

[49] Building Decarbonization Coalition, Case Study: West Union, Iowa, accessed December 6, 2025, https://buildingdecarb.org/resource/case-study-west-union-iowa.

[50] Building Decarbonization Coalition, TENs Ownership Models, accessed December 6, 2025, https://buildingdecarb.org/tens-ownership-models.

The network has capacity to serve 70 downtown businesses and buildings, but only 12 buildings are current users. Adoption has been gradual partially because individual building owners must fund their own building retrofits, heat pump installations, and connection fees, although grants and utility incentives may be available to assist with these expenses. As new users join, system-wide costs fall for all users. Customer costs decreased each year, from $14 per ton of heating and cooling capacity in 2021 to $10 per ton in 2024.

Ann Arbor, Michigan

Ann Arbor has goals of carbon neutrality by 2030 and strong constituent support for climate initiatives.[51] The city has prioritized decarbonization in the Bryant neighborhood, where more than one-third of households are energy-burdened.[52] After modeling decarbonization scenarios for Bryant, a TEN emerged as the most affordable option.

In 2022, the city secured a Department of Energy (DOE) Community Geothermal grant to study the feasibility of a TEN. Extensive engagement, in partnership with the local nonprofit Community Action Network, yielded community support and helped inform ownership and operation models. Once the TEN is fully constructed, the city will own the boreholes and distribution piping. Ownership of individual heat pumps is still under discussion, but Bryant residents will not be required to purchase their own equipment. The TEN will be operated by Ann Arbor's new Sustainable Energy Utility (SEU), an opt-in supplemental energy utility that Ann Arbor voters approved in 2024.

In December 2024, the DOE announced that Ann Arbor would receive a further $10.8 million grant to support TENs construction.[53] The SEU is currently exploring financial models and rate proposals for its future services, including the TEN.

Framingham, Massachusetts

The geothermal network in Framingham, Massachusetts is the nation's first investor-owned utility TEN. HEET, a Boston-based nonprofit, first proposed this model as a way for regulated gas utilities to replace leak-prone gas pipelines with utility-scale geothermal heating and cooling. Motivated by state climate mandates, Eversource Energy proposed a ratepayer-funded geothermal network pilot in 2020, which the Massachusetts Department of Public Utilities (DPU) approved in 2021.

The City of Framingham emerged as an ideal site for a pilot due to its technical feasibility, ongoing clean energy outreach and education, and the City's knowledge of building stock and neighborhood energy needs. City staff

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[51] Ann Arbor Office of Sustainability and Innovations, Carbon Neutrality Home, accessed December 6, 2025, https://www.a2gov.org/sustainability-innovations-home/carbon-neutrality-home/.

[52] Building Decarbonization Coalition, Case Study: Ann Arbor, Michigan, accessed December 6, 2025, https://buildingdecarb.org/resource/case-study-ann-arbor-michigan.

[53] U.S. Department of Energy, District-Scale Geothermal Energy Pilots, accessed December 6, 2025, https://www.energy.gov/eere/geothermal/district-scale-geothermal-energy-pilots.

first gauged interest from key anchor tenants (large buildings or key neighborhood sites embedded in a community that, when deciding to join a thermal energy network, can drive broader interest in participation and further drive network viability) in a specific neighborhood and then conveyed that interest to Eversource. After its own site selection process, Eversource chose the neighborhood as the official pilot site in 2022. Construction began in 2023, and customers joined the network in stages through late 2024. The pilot will continue operating and collecting data for two full heating and cooling seasons.

Public project update filings with the Massachusetts DPU estimate the ~375-ton pilot's costs at roughly $22 million, with costs expected to fall after applying the Investment Tax Credit. The highest proportion of costs are building retrofits and appliance installation, which were included in this pilot at no cost to the homeowners. In 2025, HEET, in partnership with Eversource Energy, received a Department of Energy grant to roughly double the network's size, with the expansion projected to cost roughly 60% of the initial installation.[54]

Colorado Mesa University, Grand Junction, Colorado

Colorado Mesa University (CMU) began developing its TEN in 2007 while constructing a building that needed to meet specific efficiency requirements to receive state capital funding.[55] The new building's ground-source heat pump system formed the foundation for one of the nation's earliest single-pipe, ambient temperature loops using geothermal boreholes. University leadership supported the project despite investing in a large capital construction project when these systems were relatively rare.

The initial $20 million system has proven extremely cost-effective. CMU reports annual energy savings of $1.5 to $1.6 million, equaling initial system payback within 12 years without federal tax credits.[56] These energy savings transfer to students in the form of lower tuition and fees. CMU is now expanding its system with strong state support. The university received $6 million from the state in 2023 for additional underground infrastructure, as well as two grants totaling approximately $400,000 in 2024 to pursue full campus connection to the TEN. Current construction will connect nine more buildings, and the university is exploring future partnerships with the City of Grand Junction to connect civic buildings and Grand Junction High School facilities to the network.[57] [58]

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[54] Building Decarbonization Coalition, Case Study: Framingham, Massachusetts, accessed December 7, 2025, https://buildingdecarb.org/resource/case-study-framingham-massachusetts.

[55] U.S. Department of Energy, Geothermal Heat Pump Case Study: Colorado Mesa University, accessed December 6, 2025, https://www.energy.gov/eere/geothermal/geothermal-heat-pump-case-study-colorado-mesa-university.

[56] Colorado Mesa University, Geo-Grid System, "Sustainability Initiatives," accessed December 6, 2025, https://www.coloradomesa.edu/sustainability/initiatives/geo-grid.html.

[57] Colorado Energy Office, Geothermal Energy Grant Program: Round 1 Awardees, https://drive.google.com/file/d/1E9W_GQhtgWaKxO1CyCEf7Vr42tslxYrz/view.

[58] Colorado Mesa University, Geo-Grid System, "Sustainability Initiatives," accessed December 6, 2025, https://www.coloradomesa.edu/sustainability/initiatives/geo-grid.html.

2.5 Legal Considerations for Deployment and Suitability

Minnesota has already passed two laws that specifically advance or enable TENs. The 2021 Natural Gas Innovation Act (NGIA) granted the state's large gas utilities the legal authority to pilot TENs. In 2024, H.F. 5257, which authorized this statewide site suitability study, modified the NGIA to require a proportion of TENs pilots in future gas utility innovation plans, appropriated funds for a GSHP system in Minneapolis, funded a local government geothermal planning grant program, and created a TEN Deployment Work Group (Work Group) within the Minnesota Public Utilities Commission ("Commission").[59]

The Work Group aimed to identify barriers and opportunities for TENs deployment among Minnesota's regulated gas utilities and provide a reference point for legal and regulatory considerations consistent with considerations from other states advancing TENs. The Work Group's six key recommendations to accelerate TENs development are:[60]

1. Amend definitions of "district energy" and "thermal energy networks" in statute.
2. Modify or clarify definitions of "public utility" and "service" in Minnesota Statute 216B.02 Subdivisions 4 and 6, to authorize utilities to invest in and recover costs for TENs as an alternative to natural gas while exempting existing non-utility TENs from becoming regulated public utilities, affirming Tribal authority to self-regulated thermal energy services on tribal lands, and ensuring consumer protections.
3. Prioritize TENs in communities that meet specific environmental justice or project viability criteria, including those deemed suitable in this study.
4. Provide financial and programmatic support to customers transitioning onto a TEN.
5. Establish a framework for a utility to meet service requirements via a TEN and transition existing gas infrastructure as a result.
6. Expand opportunities for TEN developments in existing programs like gas integrated resource plans (IRPs) and NGIA.

From a legal perspective, Recommendations 1, 2, and 5 are particularly critical to enable TENs expansion. Minnesota statute currently defines "district heating," "district energy," and "thermal energy networks" differently and applies these definitions to different ownership contexts.[61] For example, municipal utilities may operate "district heating systems" and "heat plants," but not specifically "thermal energy networks." While a TEN would likely be permissible, its characteristics could also be interpreted to fall outside this definition.[62] Clear

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[59] Building Decarbonization Coalition, Thermal Energy Networks State Legislation (accessed December 6, 2025), https://buildingdecarb.org/resource-library/tens-state-leg.

[60] Minnesota Thermal Energy Network Deployment Work Group. Roundtable 4 Summary, June 13, 2025. Great Plains Institute, 2025. Accessed December 4, 2025. https://app.smartsuite.com/shared/s4ibn4qz/kZMTD0QWTl

[61] Doug Presley and Kate Moore, Accelerating Thermal Energy Network Deployment in Minnesota – Policy Barriers and Opportunities (Midwest Building Decarbonization Coalition, September 2024), https://static1.squarespace.com/static/6548fa466239d21eee818ad3/t/66e0a2dd0bd49504e456aa6c/1725997790857/Thermal+Enery+Network+Policy+Opportunities+and+Barriers+in+Minnesota+-+2024-09+%281%29.pdf.

[62] Ibid.

legal definitions for TENs and supporting statutes should guide ownership and operation outside NGIA and investor-owned utility contexts. This clarity would make proposed TEN sites more suitable when municipalities are the proposed owners, increasing the navigability of system ownership.

Recommendation 2 addresses expansion of utility-owned TENs. Current Minnesota law is unclear regarding utilities' ability to build and recover costs for TENs beyond NGIA-approved pilots. The recommendation authorizes both gas and electric utilities to recover costs for future TENs through rates subject to Commission approval, exempts non-utility TENs from public utility regulation, and affirms that Tribes retain authority to operate and regulate their own thermal infrastructure on tribal lands.[63] Although statute does not expressly restrict utility cost recovery for TENs, certainty would increase project suitability by improving access to adequate financing.

Recommendation 5 outlines that states, including Minnesota, must reform regulated utilities' service requirements to permanently authorize utility-owned TENs. This would decouple service obligations from delivering specific fuels like natural gas and allow utilities to meet customer energy needs through electrification and TENs.[64] Regulated utilities routinely cite this obligation as a barrier to effective TENs deployment despite varying legal interpretations. Addressing the service requirement would benefit all utility led TEN projects by increasing potential customer numbers within proposed systems and enabling utilities to propose TENs where gas investments were previously planned.

2.6 Existing Regulatory Frameworks

Many state regulations and regulatory bodies present opportunities for TEN projects as well as potentially impact project design, costs, and ultimately suitability as future sites are evaluated under evolving regulations.

Utility Planning Dockets

As TENs become a recurring topic on the desk of the Commission, two active regulatory dockets require attention. The first is the gas Integrated Resource Planning (IRP) docket (23-117). Gas IRPs require the three largest gas utilities in Minnesota – CenterPoint, Xcel Energy, and Minnesota Energy Resources Corporation – to submit plans every three years outlining how they will reliably and affordably meet customer gas needs over the next 10 years.[65] These plans must compare resources on a level playing field across different fuel types and technologies and treat energy efficiency as an equal resource. Xcel Energy will file the first IRP on July 1, 2026,

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[63] Trey Harsch and Sophie Nikitas. Thermal Energy Network Deployment Work Group Report." Minnesota Public Utilities Commission, accessed December 15, 2025. https://www.lrl.mn.gov/docs/2025/mandated/251873.pdf

[64] Ania Camargo Cortes et al., Thermal Energy Networks (TENs) Legislative Guidebook (Building Decarbonization Coalition and Vermont Law & Graduate School, March 2025), 33, https://docs.google.com/document/d/1rB9OR6xL9EHBtFYFV-2nXHeZ4xOKlj_PaWb66xdTQT8/edit?tab=t.0#bookmark=id.ugnwvkdcnw3w.

[65] Minnesota Public Utilities Commission. Order Clarifying and Expanding Framework for Natural Gas Integrated Resource Planning, Docket 23-117. October 28, 2024.

which must include an expansion alternative analysis (EAA) of two to three planned gas expansion projects to evaluate alternatives to gas system expansion. IRPs are a crucial area for evaluating TENs as a competitive resource.

The second active docket (07-1199), aimed at defining the appropriate regulatory cost of carbon for use in these IRPs, might make TENs even more competitive compared to traditional gas system expansion. The regulatory cost of carbon is a dollar-per-ton value set by the Commission and used by utilities in their IRPs to attribute a cost to CO_2 generated by resource options. A regulatory cost of carbon could affect TEN economics compared to traditional gas system expansion by making TENs routinely cheaper on a levelized basis and more likely to appear in IRPs. Minnesota has already adopted regulatory costs of carbon for electric utilities' electricity generation, but the outstanding question is whether these same values will apply to gas IRPs.[66]

Waste Heat Regulation

Management of thermal energy resources, including human-made waste heat and environmental geothermal sources, requires guidelines for TEN owners to leverage thermal opportunities while stewarding public and environmental health. Current Minnesota statute defines "district energy" systems to include solar thermal resources, the temperature of the earth, or underground resources. In 2024, legislation empowered the Pollution Control Agency to encourage recovery of wastewater heat resources.[67] [68] This excludes other waste heat sources, such as heat emitted by data centers, industrial processes, schools, or breweries. Minnesota also has abundant natural surface resources that may serve as appropriate thermal resources for TENs, including lakes and rivers.

Groundwater and Surface Water Regulation

Minnesota’s robust groundwater protections limit construction materials, which in turn affect project costs. Every borehole – whether used for TENs, GSHPs, water wells, or other purposes – falls under the oversight of the Minnesota Department of Health (MDH). Ten local boards of health also have delegated authority over wells in their jurisdictions, where borehole drilling may require additional fees, permits, and inspections.[69] Surface water is included as a thermal resource in Minnesota’s statutory definition of TENs.[70] Surface water use is regulated by

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[66] Minnesota Public Utilities Commission. Order Addressing Environmental and Regulatory Costs, Docket 07-1199. December 19, 2023

[67] Doug Presley and Kate Moore, Accelerating Thermal Energy Network Deployment in Minnesota – Policy Barriers and Opportunities (Midwest Building Decarbonization Coalition, September 2024), https://static1.squarespace.com/static/6548fa466239d21eee818ad3/t/66e0a2dd0bd49504e456aa6c/1725997790857/Thermal+Enery+Network+Policy+Opportunities+and+Barriers+in+Minnesota+-+2024-09+%281%29.pdf.

[68] Building Decarbonization Coalition, Thermal Energy Networks State Legislation (accessed December 6, 2025), https://buildingdecarb.org/resource-library/tens-state-leg.

[69] Minnesota Department of Health, "Delegated Well Programs," accessed December 15, 2025, https://www.health.state.mn.us/communities/environment/water/wells/delegated.html.

[70] Minnesota Statutes, § 216B.2427 (2025). “Natural Gas Utility Innovation Plans.”

the Minnesota Department of Natural Resources (DNR). "Once-through" cooling systems, which extract water from one source and discharge it elsewhere, are specifically regulated: expansion of existing once-through systems is prohibited, and systems that use more than 5 million gallons annually must be terminated (with some exceptions).[71]

While water appropriation is regulated by the MDH and DNR, thermal appropriation from water is not currently regulated. Cooling systems may extract groundwater at a temperature of 49-50°F and return it at a higher temperature; a threshold for this temperature is not established by statute. Currently, state officials have an established practice of deferring to 86°F as the maximum discharge temperature, but this is not codified.[72]

Permitting and approval depends on the type of system. Closed-loop systems, which do not remove any water but simply transfer heat through enclosed pipes, engage only with the MDH. "Consumptive" systems that extract groundwater require additional approval from the Minnesota Department of Natural Resources (DNR). An exception is Darcy Solutions' technology, which is considered non-consumptive because it withdraws water from a lower stratum, moves it up a column, and discharges it at the same rate. Per- and Polyfluoroalkyl Substances (PFAS) contamination is widespread in Minnesota, and drilling within a contaminated area triggers a more intensive approval process.[73] Because brownfields are potential redevelopment sites for geothermal heating and cooling technologies, a growing workforce must understand the regulations required to drill in contaminated areas, and TENs owners must accommodate the potential cost implications on their project budgets.

2.7 Market and Technical Capacity

Minnesota's climate, with cold winters and warm summers, makes the state an excellent market for GSHPs and TENs. While modern cold-climate air-source heat pumps have improved, ground-source systems and TENs remain substantially more efficient in cold climates, requiring less electricity and managing grid stress as space heating electrifies during extreme temperatures.[74]

TENs rely on market-ready components, including GSHPs and high-density polyethylene pipes nearly identical to those used in modern gas distribution pipelines. Despite the technology's maturity, GSHP market share represents just 1% of residential heating nationally compared to 13% for air-source heat pumps.[75] This is partly

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[71] Minn. Stat. § 103G.271, subd. 5 (2024), https://www.revisor.mn.gov/statutes/cite/103G.271.

[72] Information collected from interviews with stakeholders (Section 4).

[73] Fawkes Char et al., PFAS Monitoring Plan: Initial Findings and Next Steps, rev. ed. (Minnesota Pollution Control Agency, May 2024), https://www.pca.state.mn.us/sites/default/files/p-gen1-22h.pdf.

[74] Jonathan J. Buonocore et al., "Inefficient Building Electrification Will Require Massive Buildout of Renewable Energy and Seasonal Energy Storage," Scientific Reports 12 (2022): 11931, https://www.nature.com/articles/s41598-022-15628-2.

[75] Charles G. Gertler, Timothy M. Steeves, and David T. Wang, Pathways to Commercial Liftoff: Geothermal Heating and Cooling (Washington, DC: U.S. Department of Energy, January 2025), https://igshpa.org/wp-content/uploads/LIFTOFF_DOE_Geothermal_HC.pdf.

due to higher GSHP installation costs and minimum lot size requirements, specifically related to borehole drilling, for single building applications. Industry leaders also note that lingering COVID supply chain challenges have delayed projects or impacted design. Previously shelf-ready components now have wait times spanning months to over a year, exacerbated by market uncertainty from rapidly changing tariffs.[76]

As neighborhood-scale infrastructure, TENs present an opportunity to downsize the gas system and employ the state's existing skilled workforce on clean energy infrastructure. Installation and maintenance of TENs require the same skills as unionized tradespeople currently employed in gas system construction, maintenance, and operation, such as pipefitters and operating engineers.[77]

Geothermal drillers and drilling are needed nationwide to boost ground-source heating and cooling technologies, including TENs. Industry leaders estimate Minnesota has a shortage of active geothermal drilling firms statewide, and a state-of-the-art drilling market will be required to scale TENs. Recruiting new drillers from other sectors can create year-round employment and address capacity needs, as further discussed in Section 4.6.

Geothermal drillers operate under water well licensing requirements in Minnesota. Drilling companies must employ licensed drillers who oversee the installation of wells. Employees such as laborers or apprentices do not require individual licenses. Minnesota does not require additional certification, such as that obtained through the International Ground-Source Heat Pump Association (IGSHPA), for geothermal drillers. However, commercially-sized or utility-sized system owners or contractors almost always require that their drilling subcontractors do possess IGSHPA certification or equal training.

Most drilling contractors in Minnesota are not unionized. However, prevailing wage requirements under the Davis-Bacon Act apply when required for drilling projects.[78] Additionally, customers or clients (i.e., potential TEN owners) with project labor agreements with unions may require additional fees from the contracting driller.

TENs development offers the state an opportunity for job creation, economic growth, and family-sustaining wages. Current statute requires TENs receiving state funding, including those on university campuses, to meet prevailing wage requirements.[79] The NGIA requires utility innovation plans to project local job impacts and describe steps taken by utilities to maximize local construction employment.[80] Strengthening workforce

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[76] Information collected from interviews with stakeholders (Section 4).

[77] Reyna Cohen, Lynda Nguyen, and Dylan Correll Smith, Understanding Thermal Energy Networks: A Building Decarbonization Approach to Good Union Jobs (ILR Climate Jobs Institute, 2024), https://www.ilr.cornell.edu/sites/default/files-d8/2024-12/understanding-thermal-energy-networks.pdf.

[78] Information collected from interviews with stakeholders (Section 4).

[79] Information collected from interviews with stakeholders (Section 4).

[80] Ania Camargo Cortes et al., Thermal Energy Networks (TENs) Legislative Guidebook (Building Decarbonization Coalition and Vermont Law & Graduate School, March 2025), 25, https://docs.google.com/document/d/1rB9OR6xL9EHBtFYFV-2nXHeZ4xOKlj_PaWb66xdTQT8/edit?tab=t.0#bookmark=id.ugnwvkdcnw3w.

transition to TENs may require establishing similar wage or labor standards for all TEN projects, particularly those above a certain size.[81]

Minnesota has the technical capability and climatic conditions ideal for TENs using market-ready components, and TENs present a strategic opportunity for utilities to keep their workforce employed on clean-energy projects. Deliberate workforce development programs and increased implementation will be needed to help the TENs industry scale beyond pilots.

[81] Doug Presley and Kate Moore, Accelerating Thermal Energy Network Deployment in Minnesota – Policy Barriers and Opportunities (Midwest Building Decarbonization Coalition, September 2024), https://static1.squarespace.com/static/6548fa466239d21eee818ad3/t/66e0a2dd0bd49504e456aa6c/1725997790857/Thermal+Enery+Network+Policy+Opportunities+and+Barriers+in+Minnesota+-+2024-09+%281%29.pdf.

3 State-Wide Evaluation Approach

To understand the wide-ranging suitability of TENs across the State of Minnesota, this study leveraged stakeholder interviews and desktop research to identify a set of priorities needed to develop a successful TEN project. Then, a two-stage screening process aimed to identify a short list of example sites to score as proxies for the whole of Minnesota. Finally, the scorecard – which evaluates site suitability on both quantitative and qualitative aspects – is applied to these selected "neighborhood typologies" to determine the relative suitability of various sites that are commonly found across the state. This methodology, illustrated in Figure 3-1, is described in further detail in the Appendix.

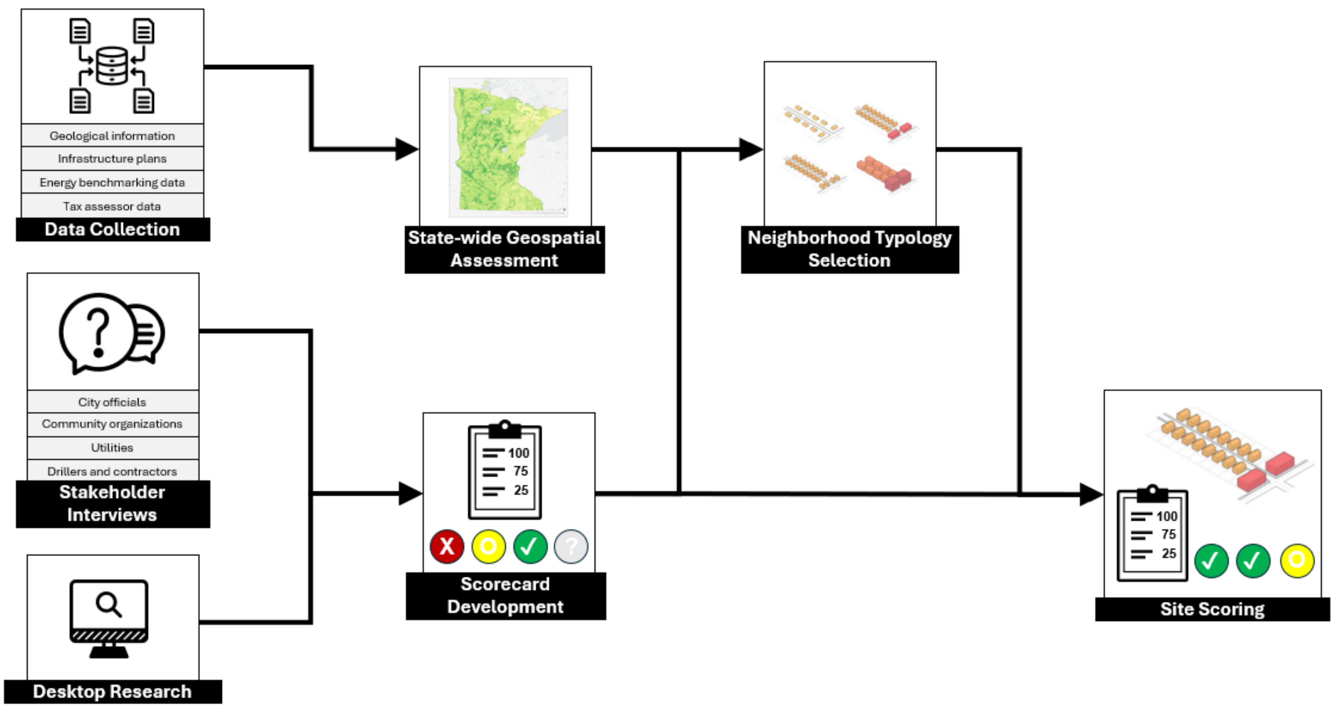

Figure 3-1. *Methodology for site suitability study.*

3.1 Quantitative Scoring Approach

To objectively evaluate the suitability for TENs across Minnesota, a list of criteria to inform a scoring methodology was developed:

- Borehole Accessibility and Construction
- Geologic Conditions and Thermal Conductivity
- Load Characteristics
- Environmental Constraints
- Behind-the-Meter Costs and Complexity
- Opportunistic Thermal Resources
- Disadvantaged Communities

- Viability for Future System Expansion

Each of these criteria were measured by a set of quantitative indicators to objectively score each site selected for detailed review. Due to the varied levels of importance of each criterion and indicator, relative weightings and a scoring rubric were developed to reflect holistic suitability. These criteria, indicators, and relative weightings are provided in Table 3-1, with detailed summaries of the scoring rubric provided in Appendix Table D-1 and the accompanying Site Suitability Scorecard.

Table 3-1*. Scoring criteria and indicators used in site suitability evaluation.*

Criteria	Criteria Weight	Indicator	Description	Indicator Weight
Borehole / Borefield Accessibility and Construction	15%	Availability of area for borefields	Accessibility is needed to locate the drill rigs, support equipment and material storage, and to perform the work safely and efficiently.	4.8%
		Concentration of utilities (buried and overhead)	Drilling and installation of the geothermal system piping is complicated and slowed down by the presence of buried and overhead utilities, which can increase costs.	4.8%
		Traffic density	TEN development is likely to be impeded by a large amount of disruption to existing pedestrian and vehicular traffic.	0.8%
		Complexity of stakeholder coordination for open space access	Complex processes surrounding the procurement of necessary easements can create challenges for TEN developers.	4.7%
Geologic Conditions and Thermal Conductivity	10%	Bedrock suitability	Higher thermal and hydraulic conductivity improves the efficiency of the geothermal system and reduces well count, potentially reducing capital and operating costs.	10%

Criteria	Criteria Weight	Indicator	Description	Indicator Weight
Load Characteristics	18%	Load balance	If heating and cooling demands are not balanced, then the temperature of the ground surrounding the borefield can begin to change year over year until the location is no longer viable.	9%
		Load density	Higher density of thermal demand results in greater cost-effectiveness in delivering thermal energy. Buildings within proximity to the TEN may opt-out of interconnection. A large and diverse building stock helps maintain the viability of the system over long periods as the load profile shifts.	9%
Environmental Constraints	5%	Proximity to wetlands / permitted jurisdictions	Land adjacent to a wetland can create restrictions on where TENs are able to be developed.	2.5%
		Proximity to subsurface environmental contamination	Proximity to hazardous contamination may void a project area from consideration.	2.5%
Behind-the-Meter Costs and Complexity	27%	Building stock quality	Proxy to measure expected need for weatherization, other potential service improvements beyond HVAC conversion.	9%
		Existing HVAC system	HVAC systems in use within existing buildings represent a significant barrier or opportunity depending on their condition and compatibility with a ground loop.	9%

Criteria	Criteria Weight	Indicator	Description	Indicator Weight
		Capacity for electrical demand	TENs reduce peak electrical demand during the summer and are the most energy efficient method of electrified heating during the winter. As such, capacity constraints represent high impact sites and planned construction around utilities is a strong opportunity to align with TENs construction.	9%
Opportunistic Thermal Resources	10%	Opportunistic thermal resources	Capturing thermal energy traditionally discharged to the atmosphere or surface water represents a cost-effective and sustainable strategy to supplement the network with additional thermal capacity.	10%
Disadvantaged Communities	10%	Development within a priority community	Underserved communities are often furthest behind in terms of infrastructure conditions and ability to fund capital projects and therefore should be emphasized as pilot sites for modern community systems such as TENs.	10%
Viability for Future System Expansion	5%	Physical potential for expansion	Given the characteristic ability for TENs to scale geographically from their initial build out, this indicator evaluates the opportunity for the system to grow over time.	5%

3.2 Qualitative Scoring Approach

The scoring breakdown presented in Table 3-1 shows the quantitative aspects of considerations needed to identify TENs suitability. However, there are many nuanced qualitative aspects that also indicate project suitability. Stakeholder interviews indicated that community support, social and institutional readiness, market and financial readiness, and infrastructure alignment could not be reliably evaluated through a quantitative system. Thus, ten qualitative criteria were developed during the literature review and engagement process and are summarized in Table 3-2. Site scores, reported in traffic light colors rated green (✓), yellow (O), or red (X), are presented in Sections 5.2 and 5.3.

Applying these qualitative criteria differs from technical feasibility scoring because assessing neighborhood support, viable project economics, and workable ownership structures requires local context and dialogue. These criteria should only be applied after in-depth discussions with community leaders or by stakeholders assessing their own communities.

Table 3-2. *Checklist of qualitative site context.*

Criteria	Description	Method for Evaluation
Neighborhood / User Support	TENs development is more achievable in neighborhoods where building owners, residents and/or system users are interested and optimistic about the technology.	Stakeholder and community engagement; letters of commitment; offtake agreements.
Project Champion	The local government, community organization, cooperative, utility, or other entities have committed leadership to see the project through.	Champion(s) in organizational staff or in elected offices for the project with some level of decision-making capability.
Capacity for Financial Risk	TENs implementation depends on the ability to secure financing, potentially through debt, which may require issuing bonds, hiring grant writers, or assuming financial risk.	Bonding capacity, grant writers on staff.
Project Economics / Anchor Customers	Successful long-term projects need viable business models, such as a revenue base underpinned by a stable customer pool and/or anchor customers who stable long-term revenue into the system.	Demonstrated large users who can/are contracted as customers to the systems.
Broader Community Support	TENs development is more achievable in communities in which community-based organizations, stakeholder groups, and the wider public are interested and optimistic about the technology.	Stakeholder and community engagement.
Alignment with Population and Growth Trends	Placing TENs in communities where population and urbanization are likely to continue to grow presents an opportunity for network growth and longevity, improving the long-term viability of TEN systems.	Map of population and urbanization growth factors.

Criteria	Description	Method for Evaluation
Sustainability Goals	Local government or organizational leadership has sustainability goals and capacity to provide support for 3-5 years of cooperation, inter-agency coordination, outreach and education, and (if necessary) financing or funding.	Municipal/organizational sustainability or net-zero goals; publicly stated leadership goals or voter-approved plans; staff capacity in the form of sustainability officers.
Navigable System Ownership	Ownership of system infrastructure, participating buildings, and equipment can be relatively straightforward with a single entity, or increase in complexity with multiple users.	Initial project bounds with single entity or multiple entities.
Planned Infrastructure Alignment	TEN projects are most cost-effective and minimize community resistance (minimally disruptive?) if they can be aligned with existing planned infrastructure upgrades like water main replacements or other underground utilities.	Upcoming municipal, utility, or agency plans for street repairs, paving, infrastructure upgrades.
Workforce Availability	Sufficient skilled workforce that meets the needs of the system being available and willing to take on the project is crucial.	Expressed interest from union labor; local workforce training centers; stakeholder and community engagement.

3.3 Geospatial Mapping

To address the physical and environmental aspects of TENs feasibility, publicly available data was mapped in an ArcGIS Online webtool. This data included bedrock geology, groundwater flow, thermal energy resources (e.g., surface water bodies, industrial or commercial facilities that produce waste heat), demographics, and existing building energy performance. The full list of data collected for analysis is discussed in greater detail in Appendix A. The data was processed, aggregated, and standardized into individual raster layers to represent both suitability and constraint factors – reflecting key physical or regulatory parameters influencing the technical feasibility of TENs.

3.4 Stakeholder Engagement

To understand factors influencing TENs implementation in Minnesota, 26 interviews were held with 35 individuals from diverse stakeholder groups and organizations. These interviewees represented local governments, campuses, union workers and other individuals involved in professions associated with TENs, geothermal technology, contractors, utilities, and community organizations. Interviewees had ranging experience with TENs, and were either involved with existing TEN projects, considering TEN projects, or represented a stakeholder group in the community known for their involvement in studying the barriers and opportunities around TENs development. A full list of the individuals and organizations who were interviewed is provided in Appendix Table E-1.

Most of the interviews were conducted online via Zoom or Teams platforms, lasted approximately one hour, and involved primarily two interviewers to guide the discussion. In some cases, only one interviewer was present. The interviews were recorded, except for two which were done in person and had hand-taken notes that were transcribed using Teams or TurboScribe. Interview questions focused on how the person or organization was involved with existing or planned TEN projects or influencing TENs development in the areas of renewable energy, economic and ownership models, community and stakeholder relations, or workforce development. Unique interview guides were developed for interviewees involved in existing projects, considering projects, and for other stakeholders, which can be found in Appendix F. Interviews were tailored for the specific interviewees to understand their experiences with TEN projects, economic and ownership considerations, community and stakeholder relations, and technical and workforce considerations. Permission to quote interviewees was obtained, and requests for anonymity were respected.

Interview transcripts were reviewed and analyzed for themes. The findings from these interviews informed the qualitative factors assessed in the scoring of TENs and are further described in Section 4.

4 Stakeholder Insights and Community Perspectives

As discussed in Section 3.4, 26 interviews among 35 individuals were conducted to understand the barriers and opportunities around TENs development. When interviewees provided explicit consent to be quoted in this report, their names and affiliations were included in the text. Otherwise, they are referred to as “interviewees” or “stakeholders.”

Stakeholders were excited about the potential for TENs in the state and shared insights and advice based on their experiences. Common themes emerged, revealing several significant challenges to address, especially regarding ownership and financing. However, there are also many opportunities where Minnesota seems well-positioned to be a leader on TENs. Section 4 discusses key themes stemming from the stakeholder and community interviews.

4.1 Geologic Diversity

Some of the more fundamental considerations with TENs involve potential owners wanting a network, but facing uncertainty about where to locate the project and where specifically to drill. Many interviewees with TENs development or drilling experience spoke to this concern, with one mentioning that there was highly variable geology in Minnesota, ranging from easy sand and gravel to hard-to-drill rock, and another stressing that site-specific testing is required since broad assumptions about regions can be misleading. Minnesota’s varied geology means specific areas are easier for new drillers to navigate than others; per Brock Yordy (Co-Founder, Geothermal Drillers’ Association), a driller learning program could focus on areas with sand and gravel, rather than hard rock. This would essentially allow licensed drillers to divide the state into geological training “quadrants” and train their employees on the easiest to the hardest.

Other concerns relate to the presence of several areas contaminated with PFAS in the state – particularly on brownfield sites – which require extra caution, additional training, and increased costs, including a Phase 3 Environmental Site Assessment (ESA) industry process for drill waste decontamination and disposal. Other interviewees noted that drilling requirements call for cement, not grout, when drilling in bedrock, which can increase the cost of projects. An interviewee in Minneapolis mentioned that in dense urban sites, maintaining a safe distance between wells and navigating water rights is challenging. In response to these concerns, one interviewee mentioned that a tool showing municipally owned land, parking lots, fields, and other surface resources would be helpful to identify potential borefield locations.

4.2 Financing, Cost Recovery, and TENs Valuation

Stakeholders acknowledged that high upfront capital costs are fundamental to TENs adoption. Addressing this requires transparent cost information for budgeting and strategies to organize diverse capital stacks, particularly when owners and lending institutions must also tolerate multi-year recovery periods. Opportunities exist via innovative financing models like leasing arrangements, state leadership in de-risking early projects, and new cost accounting approaches that capture TENs' full value, including deferred grid upgrades and permanent operating cost reductions.

Transparent, accurate, and standardized data from existing pilots and operational TENs is needed to help owners understand their options for cost mitigation strategies and financing tools. Organizations including HEET and the Building Decarbonization Coalition, working alongside community, academic, and industry partners, seek to illuminate costs of TENs through case studies, user-submitted maps, and open-access tools and databases.[82] [83] [84] Distributing these resources is crucial for interested TEN owners. Existing TEN owners and utilities must be willing – or, in regulated utility cases, required by state utility commissions – to provide standardized data that makes these resources accurate and robust.

TENs deliver substantial value to owners over the long term. Carleton College's TEN expansion illustrates a representative project budget. This $42 million project requires approximately a 20-year payback horizon. This payback period is tolerable for TENs owners with institutional permanence, such as colleges, municipal governments, and medical campuses, each of which will benefit from reduced energy costs for years to come. However, it conflicts with established business models in private real estate development, which operate on shorter investment timelines and expectations for faster payback periods. Recent federal tax credit changes now enable geothermal system leasing models that may make TENs compatible with these business models, as discussed in Section 4.3.

Constructing a TEN requires assembling a diverse capital stack. Potential TEN owners in Minnesota may apply for a loan to MnCIFA, but these loans are unlikely to cover entire projects. Interviews with MnCIFA revealed that their largest loan to date has been $5 million – considered a concentration risk – and loans above $10 million are unlikely. Federal grant funding is available for TENs, though changing political priorities may make these grants uncertain. Future state-level grantmaking opportunities can assist with TENs implementation in Minnesota.

Other stakeholders indicated that a financial barrier is not lack of available capital, but comfort with accessing it. Municipalities may access low-interest loans due to lower default risk and access to tax-exempt bonds. However, because credit rating agencies examine debt-to-revenue ratios, a TEN could represent a significant percentage of a city's bonding capacity, resulting in higher interest rates on future borrowing. Prospective municipal TEN owners must balance this with the operational savings that would result from networking city-owned buildings. As Brian Urlaub (Senior Vice President, Salas O'Brien) stated, "We can prove the savings per year; [cities] will get the savings. But cities are afraid to borrow due to credit rating, interest rates, discount rates; it's outside their norm." Potential solutions include the formation of public improvement districts, municipal utility districts, or other vehicles that can finance energy infrastructure.

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[82] Building Decarbonization Coalition, "TENs Ownership Models," accessed December 6, 2025, https://buildingdecarb.org/tens-ownership-models.

[83] Building Decarbonization Coalition, "Neighborhood-Scale Building Decarbonization Map," accessed December 15, 2025, https://buildingdecarb.org/neighborhood-scale-projects-map.

[84] HEET, "Learning From the Ground Up," accessed December 15, 2025, https://heet.org/legup.

The federal Clean Electricity Investment Tax Credit (ITC) is a crucial financial tool for TENs. To make the most of this incentive, stakeholders were clear that they require guidance and definitive explanation of key provisions within the ITC, which will require professional tax advice for each project. Informational resources from the state or other entities may provide basic information for interested TEN owners, supplementing owner-specific tax advice.

At a systems scale, financial innovation and new cost accounting models are needed to unlock financing for TENs and establish their cost-competitiveness. Stakeholders with experience designing and building TENs emphasize that conventional financing does not recognize the unique value proposition of TENs and GSHPs. As Urlaub (Salas O'Brien) explains, a ground-source heating system is valuable because it does not depreciate: "It's a one-time purchase. You don't have to buy energy [after installation] …I think people don't quite understand that. There are costs to operate the pumps, to move the energy, but to get it out of the ground – there's no cost for that, and that's forever. So, what you pay at today's rate actually appreciates, not depreciates, over time."

Another opportunity lies in holistic cost accounting. Incorporating the full social and regulatory cost of carbon into gas integrated resource plans (Section 2.5) would more accurately reflect TENs' comparative value and improve cost-competitiveness against fossil fuel infrastructure. One interviewee suggested evaluating the cost-effectiveness of deferred electric grid and gas infrastructure upgrades enabled by TENs. This general economic framework would quantify grid infrastructure cost avoidance based on load reduction, making it easier to factor these benefits into TENs feasibility assessments without requiring site-by-site analysis. Given the substantial avoided costs to Minnesota's grid infrastructure that could be realized by installing GSHPs and TENs (Section 2.2), a cost framework that incorporates deferred or avoided costs on both the electric and gas distribution networks would capture the actual value of TENs to ratepayers and utilities.

Multiple stakeholders agreed that at this crucial early stage of TENs development, state involvement is essential to establish initial TENs, prove cost-effectiveness, and support financing. In the words of one interviewee, "Anything the state can do to facilitate this, they should do." Another stakeholder emphasized that early government-funded or utility-owned systems could lead by example, setting the foundation for scaling; they referred to government and utility-led pilots as "critical for early success."

Specific stakeholder advice on the role of public leadership varied and included several related or interconnected strategies. In short, these included:

- State grantmaking to fill market gaps in financing.
- Commission requirements toward regulated utilities, redirecting their capital spending from gas expansion to TENs, or from electric grid expansion to demand response solutions including TENs.
- Establishing pilot projects in government-owned buildings, which can lead by example, prove operational savings, help build a workforce, and form anchor systems that can later connect private buildings.

4.3 Revenue Supported Business Models

A stable, revenue-supported business model has long underpinned district energy systems and is a fundamental building block for future TENs development. Many interviewed stakeholders with experience designing, building, owning, or operating traditional district energy systems emphasized this point.

These existing system owners, designers, and operators run systems of many different configurations, including centralized gas- and biofuel-heated hot water systems in urban downtowns, distributed generation steam systems with interconnection and exchange between large users, and traditional campus-style water and steam systems under single ownership. Multiple owners indicated that these systems began from a single large user sizing a steam or hot water system above their own needs and slowly expanded it to neighboring buildings. Other systems launched from clusters of commercial and industrial customers who signed long-term energy contracts, providing operators with secure revenue.

This contract-based model has worked for many existing systems because they exclusively serve commercial or industrial heat customers. As TENs increasingly serve residential single- and multi-family customers, stakeholders expressed concern that some proposed systems – driven by needs to replace aging gas infrastructure, improve environmental justice outcomes, or address other non-revenue goals – may lack the proven business models and revenue base of traditional, commercially-, or privately-adopted systems.

This is especially the case for utility-owned TENs. Utilities will need long-term TENs business models that extend beyond a pilot phase (during which they use their rate base to establish the initial TENs pilot and are not subject to revenue recovery requirements) and take advantage of economies of scale. However, utility business models also have a unique advantage in that early rate-based subsidization of TENs can form the foundation of a new business model that will help support the transition of a waning gas system, preventing revenue collapse as customers depart the gas system for clean energy alternatives (Section 2.2).

While long-term financial sustainability remains essential, TENs serving residential and low-income customers may require revenue structures different from traditional commercial models. Revenue-centric considerations from private developers and traditional district energy operators must be weighed alongside the obligations of regulated and municipal utilities. These utilities have an obligation to serve all customers, including low-income households and residents of environmental justice communities. Utilities must balance efficient, cost-effective system development of TENs with equitable access to service. This tension is already present in utility support programs that are collectively financed through rates.

Beyond revenue models, interviewees highlighted practical uncertainty around contracts and business agreements for TENs. The markets for leasing thermal resources and valuing thermal energy storage and withdrawal are nascent. As one interviewee noted, stakeholders "don't know what to charge and what's allowable to charge" for contributing waste heat or other thermal resources to a TEN. However, stakeholders expressed optimism that while early arrangements will require novel legal advice, standardized approaches will emerge as projects move forward. One interviewee suggested the state establish a commission or designated oversight body to review early contracts and set best practices for thermal markets during this formative stage of TENs development.

4.4 Regulatory Considerations

While economic considerations and financial models ranked highest among interviewees' considerations for TENs deployment, stakeholders also shared regulatory challenges and opportunities that will affect the development of expansion of TENs in the state.

Several stakeholders involved in current TENs and geothermal projects emphasized the need for streamlined permitting across the state and local levels, as delays in permitting slow the projects and cause cost overruns. Yordy (Geothermal Drillers' Association) noted that multiple people currently conduct quality checks, ranging from general contractors and engineers to independent engineers, for assurance and compliance. Certified inspectors with unified standards could decrease project costs. Another stakeholder described excessive bureaucracy and "hoops" for licensing and permitting, particularly in drilling, which discourages workers from joining the workforce, emphasizing the importance of streamlined regulation.

Several interviewees mentioned the Commission's future role in regulating TENs. One stated, "If you're going to scale these things in a meaningful way… you're ultimately going to need to scale it through the Commission. [...] These things are too expensive, too complicated and challenging to be deployed via the private market. At least if you want to have meaningful scale and bend the curve of emissions, you're going to need to have public infrastructure embrace it." One interviewee advocated for regulating non-utility owned TEN systems that use public rights-of-way (e.g., streets) – a concern also expressed by other interviewees – or grow large enough to resemble public infrastructure and potentially exercise market power over captive customers. A design/build firm noted several unknowns regarding which owners and what types of systems would be regulated, emphasizing that existing system owners be part of the conversation.

Another interviewee working on workforce training and standards said, "There is a need for clear regulations around drilling and heat transfer fluids, as some regulators oppose alcohols due to explosivity, making more expensive glycol the required alternative due to National Sanitation Foundation (NSF) drinking water standards."

Early resolution of these regulatory challenges would open the door for more TENs. As one designer/builder noted, a supportive city policy and regulatory environment, including active advocacy, density bonuses for developers, and building codes that favor hydronic systems, can be a major driver of success.

While many regulatory themes center around barriers, some interviewees noted opportunities around potential changes to Minnesota law that would ease TENs development. These opportunities mirrored proposed legislative changes from the TENs Work Group report, as discussed in Section 2.5. Changes to utility service requirements and authorization for utilities to recover costs for TEN systems were noted by stakeholders who equally stressed the interest and importance of community owned TEN systems. A utility stakeholder noted that changes to the definitions of "public utility" and "district energy," two possibilities also outlined in the Work Group report, might have critical regulatory implications for TENs beyond the NGIA's narrow scope. Yordy (Geothermal Drillers' Association) noted that Minnesota's environmental safety regulations are already strong, and leveraging the state's existing groundwater regulations, drilling knowledge, and exceptional Well Index will help create robust regulatory frameworks.[85]

Stakeholders also highlighted the future potential to use public surface waters for thermal storage. As TENs expand in Minnesota, permitting could be revisited to allow water bodies to serve as thermal sinks or sources where appropriate, with clear regulatory processes and temperature exchange thresholds.

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[85] Minnesota Department of Health, Minnesota Well Index, https://mnwellindex.web.health.state.mn.us/.

4.5 Political and Community Support

TENs require strong champions and broad, sustained community support. Successful infrastructure development depends on alignment among building owners, stakeholder groups, local planning priorities, and elected officials. As one interviewee noted, the most promising opportunities often arise for larger institutions or companies with clear sustainability commitments and geographically proximate buildings.

In places like St. Paul, Rochester, and Carleton College, TENs have aligned with long-term emissions goals, engaged stakeholder networks, and geographically concentrated building portfolios. Though each jurisdiction has its own political and community dynamics, TENs appear to already have positive recognition across the state as Urlaub (Salas O'Brien) stated: "...when CenterPoint sent out their RFI to every community, 40, 50-some communities responded and said 'Yes!'...So I think there's momentum happening in the state."

Even with strong champions, TEN projects must remain flexible and gradual because political, financial, and organizational conditions inevitably shift. Leadership buy-in takes time as local officials balance innovation with practical governance. As Lauren Jensen (Energy and Sustainability Manager, Destination Medical Center) emphasized, "Incremental planning is important because things will change." Public and private partners will also need to share risk – such as providing bridge funding until incentives are realized – underscoring the importance of robust civic engagement across sectors.

Communities without local champions face a much harder path through planning and construction. In the words of one stakeholder with district energy experience, "If there's not a public or private business leader, or local coalition, or a stakeholder group that wants to see it happen, and we have to tell everyone why this is a good idea for them, that's a tough climb. We can't want it more than they do." In another interview, an initially aligned coalition ultimately dissolved due to loss of political support, limited staff capacity, the absence of a broader guiding sustainability framework, and withdrawal of key federal funding. With diminished public and private capacity and little political will to assume risk, the window for pursuing a TEN closed before a durable coalition could form.

Interviews indicate that while grassroots support from nonprofits and utilities often exists, successful TENs require broader political buy-in and proactive community education beyond established stakeholders. Interviewees also emphasized the importance of local financial commitment, noting the risks of relying solely on grants that may shift with federal priorities. Even in communities with strong political and grassroots backing, managing expectations and avoiding overpromising was seen as critical. While community enthusiasm often centers on residential service, interviewees stressed that long-term viability depends on aligning political and community support with sufficient load diversity.

Ultimately, TENs tend to move forward when strong, sustained leadership aligns with clear goals, stable coalitions, and the capacity to manage the risks and complexities of long-term infrastructure development.

4.6 Workforce Needs

Stakeholders representing local governments, clean energy organizations, equipment manufacturers, designers/builders, and workforce associations all acknowledged different workforce barriers related to TENs, as well as areas where Minnesota is well-positioned to lead on workforce and can leverage existing resources for growth.

Discussion on current barriers to TENs deployment often center on current worker and capacity shortages. Numerous stakeholders indicated that continued investment in TENs may help resolve this. Urlaub (Salas O'Brien) indicated: "The barrier is not that there's not enough people. If you don't have a market, you won't have interested workers. So, we need more projects."

Multiple interviewees emphasized that standardized, consistent, and streamlined training and permitting processes would improve workforce growth. One interviewee stressed that unified geothermal standards (i.e., the American National Standards Institute (ANSI), Canadian Standards Association (CSA), and International Ground Source Heat Pump Association (IGSHPA) C448 Design and Installation Standard for Ground Source Heat Pump Systems for Commercial and Residential Buildings) must be adopted to diminish variability in state and local requirements, which is necessary for industry growth and job creation. IGSHPA representatives emphasized that their focus is on promoting geothermal technology through education standards (based on C448), advocacy, and education – including finishing a new training curriculum with modules for networked systems.

Drillers and drilling equipment are key to the TENs workforce. Stakeholders mentioned a need for increased and improved drilling equipment availability and increased deployment of cutting-edge technologies capable of drilling in Minnesota's varied geology. A representative from a design/builder organization felt that projects were at risk of being delayed because of the limited availability of drillers and equipment.

Geothermal drillers operate under water well drilling licenses in Minnesota. One stakeholder estimated that there are approximately 140 active water well licensees in the state, but their capacity and level of work output vary. Training existing water well drillers on geothermal drilling is one method to quickly increase the drilling workforce. Yordy (Geothermal Drillers' Association) also noted specific opportunities to increase drilling capacity in Minnesota: recruit new drillers from sectors such as logging and snow-plowing to create year-round employment; utilize new technologies that can excel in Minnesota's sand and gravel areas; grow a workforce by focusing on project designs that require shallower boreholes (400-500 feet instead of 850 feet or more); and leverage Minnesota's existing strengths to train workers, including strong groundwater regulations and extensive Well Index.[86] Crucially, maintaining standards for family-sustaining wages, and deploying projects relatively close-to-home, is necessary to encourage workers to join this workforce.

One interviewee felt strongly about prospects for TENs in the state: "From a workforce perspective… Minnesota has great drillers and excellent partnerships here, so I feel very confident in that. On the traditional [common historical type of geothermal of vertical bored systems or even horizontal trenched systems] side, I've been surprised how few people there are in the industry – it's a hard, very physical job. If demand ramps up, scheduling will be tight, but I see no technical reason you couldn't deploy the technology at a fairly high clip here outside of the constraint of how many drill rigs are available."

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[86] Minnesota Department of Health, Minnesota Well Index, https://mnwellindex.web.health.state.mn.us/.

After installation, there are additional workforce considerations related to TENs operations and maintenance. In one location with an existing TEN, a stakeholder noted that they had to find specialized contractors for heat pump maintenance and shifted away from the licensed boiler operators. Stakeholders noted that rural areas face particular constraints, as some lack energy auditors and require scheduling general contractors up to six months in advance. However, another interviewee noted that drillers are accustomed to traveling for municipal projects, so rural areas pose little barrier – though scheduling could be tight if demand increases.

Most interviewees were optimistic about the growth of TENs-related jobs and expressed that the existing workforce was well-suited to expand their skills into this area. Union workers support efforts to expand TENs, and expressed apparent consensus that TENs offer a significant opportunity for current workers in the pipe and water drilling trades to transfer and build skills in a comparable field. Minnesota unions are already incorporating geothermal well and HVAC training into their curricula, via installations of technologies like Darcy Solutions' geothermal heat exchanger at training centers across the state.

Stakeholders noted TENs were an opportunity for job growth in previously marginalized communities. Creating inclusive job opportunities will require intentional planning and programming. A community-based organization mentioned they currently lack funding for training programs, the capacity to run them, and initiatives to address language and access barriers. These efforts are critical for reaching experienced immigrant workers who could help meet growing demands for TENs projects. Another interviewee predicted that as funding, financing, and ownership requirements are streamlined and more projects are put in place, interest in these jobs will grow.

Ultimately, industries grow where projects are underway, and workforce transitions occur where there is available work. State support can advance market readiness and technical capacity for TENs in Minnesota by increasing the number of shovel-ready projects, while complementary policy, financing, and market actions create strong opportunities for continued growth. Equity and wage standards will ensure sustainable growth and promote pathways for a diverse workforce across the state.

4.7 Knowledge Gaps and Preparing for Implementation

Interviewees expressed great potential for TENs in their communities but acknowledged that at this early stage, many questions remain about widespread deployment. Interviewees emphasized the need for concrete, real-world examples of successful implementation, moving from theoretical projects to actual benefits. One stakeholder, speaking to the need for more network construction, stated there are "too many feasibility studies but no projects."

Others highlighted a lack of technical expertise on how TEN systems are designed, built, and financed, stressing that this expertise, along with understanding system integration, will be key as demand grows. Others spoke not just to the need for the public to understand this technology more, but also for materials to be presented in plain language, translated into Spanish and other languages, and for greater awareness of the harms associated with natural gas use.

Some of those interviewed expressed concerns about "over-promising" on TENs with some members of the community being fully behind them and wanting projects in their neighborhoods. These interviewees worried that the reality of smaller projects in locations with better load balance might not align with where champions and advocates hope to see them. This can be a concern when older residential areas are targeted for TENs by community organizations, but another site in the community makes better sense from an efficiency and load standpoint.

Other questions from interviewees focused on learning the steps, process, and timing of construction as they navigate city permitting and working with utilities when digging. Practical concerns mentioned by stakeholders included managing noise, traffic disruption, and structural integrity during drilling; handling water and drill cuttings in confined areas; and providing heat to vital buildings during technology updates.

5 Results

5.1 Identification of Representative Neighborhoods

Utilizing both the mapped suitability layers and insights gleaned from the stakeholder and community interviews, 16 sites were identified that represent a diverse set of neighborhood types found across Minnesota (Figure 5-1 and Table 5-1). While these sites were explicitly chosen based on their potential suitability for a future thermal energy network, they represent many other similar communities across the state. These sites also highlight generalizable trends that can be gleaned from this analysis for widespread suitability (i.e., a high scoring site located in a small town with an ice rink and a school can confer similar suitability to other similar neighborhoods).

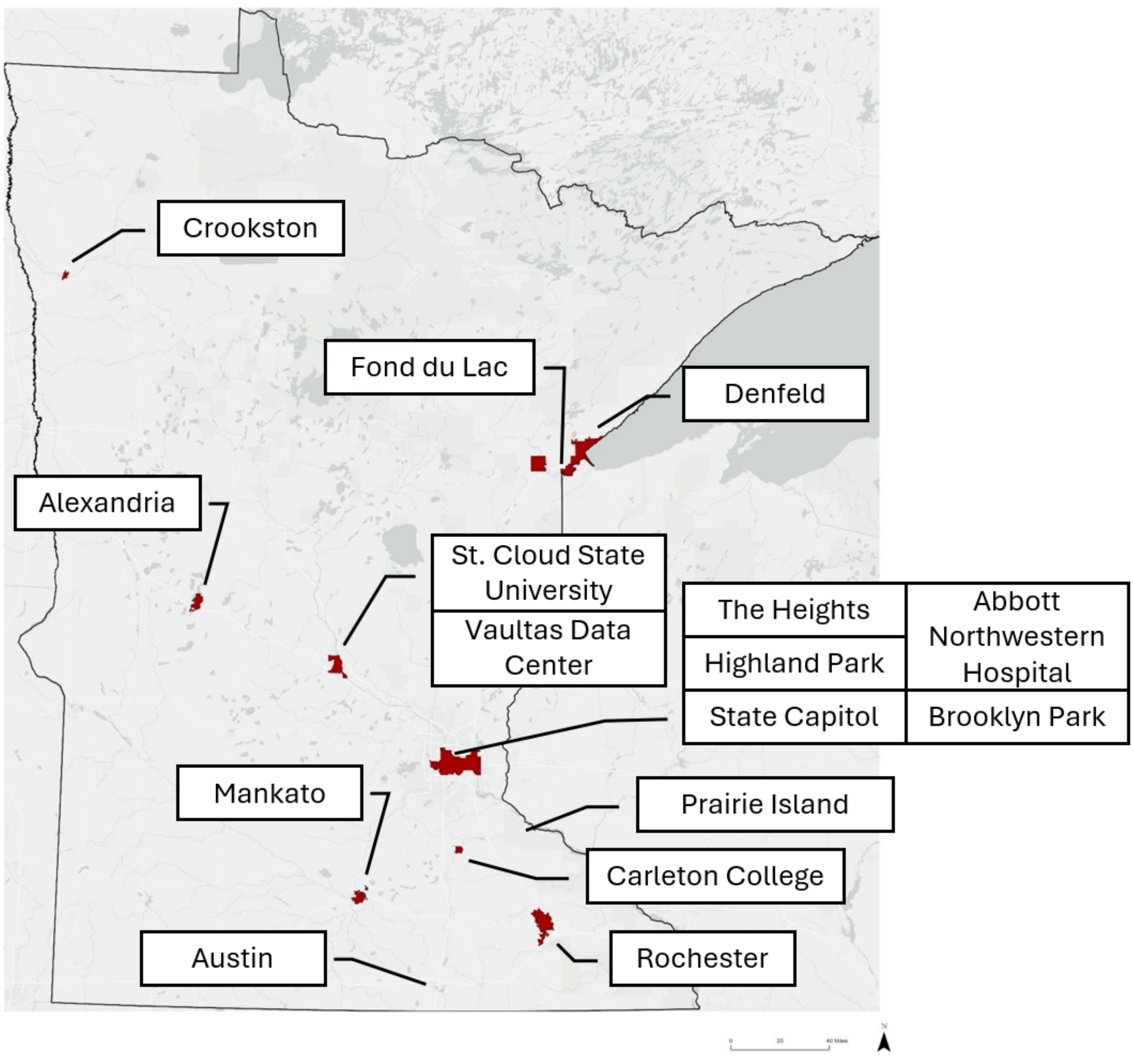


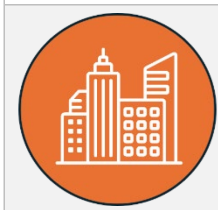
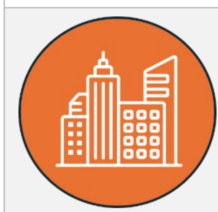
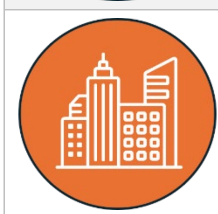
***Figure 5-1**. Sites selected for suitability scoring.*

Table 5-1. *Sites selected for suitability scoring.*

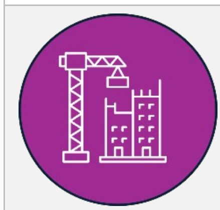
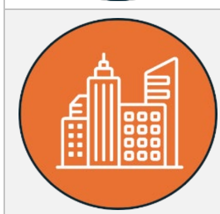
Typology	Site Name	Characteristics
	The Heights *St. Paul*	New mixed-use development with a TEN (currently under construction)
	Rochester City Hall[87]	Existing / Operational TEN with two geothermal wells; expansions currently planned
	Carleton College *Northfield*	Existing / Operational TEN with two geothermal borefields serving the campus
	Downtown Crookston	Downtown mixed-use district north of the Woods, a residential neighborhood selected for the state's Geothermal Planning Grant Program
	Denfeld *Duluth*	Alternative site to the original Lincoln Park DOE site (selected to receive funding to design a geothermal heating district); included to evaluate viability in Duluth

[87] Site boundaries for the existing district energy system and future expansions published by the City of Rochester. https://www.house.mn.gov/comm/docs/BYy8pNjULE231xOiQ8OPLQ.pdf

				
Greenfield / New Development	**College / University Campus**	**High-Density Mixed Use**	**Medium-Density Mixed Use**	**Residential Neighborhood**

	Highland Park *St. Paul*	Representative of a typical medium density residential neighborhood with ice rink and school
	Alexandria City Hall	Representative of a typical medium density mixed-use neighborhood with city hall, library, and data center
	Downtown Mankato	Representative of a typical urban downtown area in a mid-sized city with an abundance of waste heat opportunities
	St. Cloud State University *St. Cloud*	Representative of a college campus in a medium-density neighborhood with opportunistic thermal resources
	State Capitol *St. Paul*	Existing TEN present within the State Capitol and surrounding buildings; demonstrative project for comparing suitability of existing municipally owned projects to others for development potential
	Abbott Northwestern Hospital *Minneapolis*	Representative of a high-density mixed-use area with a hospital

				
Greenfield / New Development	**College / University Campus**	**High-Density Mixed Use**	**Medium-Density Mixed Use**	**Residential Neighborhood**

	Fond du Lac *Cloquet*	Tribal community; refrigerated food storage warehouse and community services as thermal resources
	Prairie Island Indian Community	Tribal community next to nuclear power plant; Prairie Island highlights ongoing environmental justice issues faced by the tribal community
	Northwest Growth Area Plan *Brooklyn Park*	New mixed-use development with bio-tech commercial center and medium-to-high density residential housing
	Vaultas Data Center *St. Cloud*	Representative of a medium density residential area with a data center and nearby apartment complex
	Hormel Foods *Austin*	Medium-density mixed-use district in a smaller population city with a large meat processing facility

5.2 Site-Specific Scoring

The 16 specific project sites analyzed represent a vast number of opportunities across the State of Minnesota. Each site is unique compared to the others, yet similar neighborhoods are structured in comparable ways throughout the state. Each site presents distinct barriers and opportunities to TENs development, though several common themes have emerged.

Across many sites, municipal buildings are emphasized as key anchor tenants. These include buildings such as city halls, public libraries, courthouses, and schools. This is due to their typically large footprint and energy demand compared to surrounding infrastructure in addition to the sociopolitical influence these institutions hold within the community. Incorporating one or multiple large municipal facilities should be viewed as a catalyst for garnering support and engagement from additional potential network tenants.

Another important element of this site-specific analysis is the typical collocation of dense energy demand, municipal buildings, and diverse commerce. The latter fosters not only a more stable load profile but also typically opens opportunities for thermal energy capture. Commercial entities such as data centers, ice rinks, supermarkets, and breweries are often collocated with centers of high energy demand, and each offers significant opportunity to enhance system-level performance through thermal energy capture.

Finally, Minnesota contains an abundance of thermal storage resources in the form of lakes, rivers, and subterranean aquifers. These resources can sequester thermal energy during warm months and supply thermal energy during colder months. Minnesota's abundance of large water bodies can be viewed as an opportunity for improving performance and suitability for TENs development.

Based on the quantitative criteria and weighting described in Section 3.1, each site has been scored between 0 and 100 in Table 5-2. For context, a score of 100 would mean a site meets ideal conditions across geology, HVAC systems, building stock, grid capacity, priority community location, etc. While all these ideal conditions are unlikely to be met by a single location, the resulting scores for each site represent the anticipated level of relative ease or difficulty in developing a TEN for that location and similar locations across Minnesota. So, higher scores indicate sites with fewer barriers to implementation, whereas sites with relatively lower scores may still be viable with appropriate resources.

Table 5-2*. Results from relative quantitative site scoring.*

Site Name	Score
The Heights	72.04
The Heights (extension into broader neighborhood)	42.43
Rochester City Hall (existing TEN)	74.61
Rochester City Hall (expansion into downtown)	59.65
Carleton College (extension into college-owned buildings)	70.87
Carleton College (extension into broader neighborhood)	34.98
Downtown Crookston	40.03
Denfeld	56.97
Highland Park	45.95
Alexandria City Hall	69.38
Downtown Mankato	71.28

Site Name	Score
St. Cloud State University	67.13
State Capitol	59.70
Abbott Northwestern Hospital	60.52
Fond du Lac	47.05
Prairie Island Indian Community	62.17
Brooklyn Park Northwest Growth Area Plan	70.24
St. Cloud Vaultas Data Center	65.14
Hormel Foods	61.60

Each site that was interviewed was also scored by the qualitative criteria outlined in Section 3.2. Scoring, shown in Table 5-3, was done using the “traffic light” method where individual criteria were rated green (✓), yellow (O), or red (X) based on how well the site met the given criteria. For scenarios where not enough information was available to score a criterion, it was noted as a question mark. Many aspects of qualitative scoring are inherently subjective, based solely on available information that may be incomplete, and are almost certain to change over time. Scores presented here should be interpreted with this in mind. Full written context for each score is provided in the Site-Level Scores tab of the Site Suitability Criteria and Scoresheet.

***Table 5-3**. Relative qualitative site scoring results.*

	Carleton College (college-owned buildings)	**Carleton College** (broader expansion)	**The Heights** (planned TEN)	**The Heights** (broader expansion)	**Rochester City Hall** (existing TEN)	**Rochester City Hall** (downtown expansion)	**Downtown Crookston**	**Denfeld**	**State Capitol**	**Fond du Lac**
Neighborhood / User Support	✓	?	✓	?	✓	**O**	**O**	**O**	✓	✓
Project Champion	✓	**O**	✓	**O**	✓	✓	✓	?	✓	✓
Capacity for Financial Risk	✓	?	✓	?	✓	**O**	**O**	?	✓	✓
Project Economics / Anchor Customers	✓	**O**	✓	**O**	✓	✓	?	**O**	✓	**O**
Broader Community Support	✓	?	✓	**O**	✓	✓	✓	**O**	✓	✓
Alignment with Population and Growth Trends	**O**	**O**	✓	?	✓	✓	?	?	X	**O**
Sustainability Goals	✓	?	✓	?	✓	✓	✓	**O**	✓	✓

Navigable System Ownership	✓	?	✓	**O**	✓	**X**	?	?	✓	✓
Planned Infrastructure Alignment	**O**	?	✓	?	**O**	**O**	?	?	**O**	**O**
Workforce Availability	✓	✓	✓	✓	✓	✓	**O**	**O**	✓	✓

5.3 Site-Specific Narrative and Takeaways

For some of the sites, interviews were conducted with local stakeholders to gain context into the qualitative aspects of the site. With this information, qualitative scoring was conducted to the greatest extent possible. For sites with existing district or TEN systems, scoring was done evaluating the existing site's characteristics and a hypothetical scenario where the system expanded into neighboring areas. Sites without insights into qualitative criteria were not scored to avoid inaccuracies and assumptions. Each location's header table provides quantitative and qualitative scores, with qualitative totals summarizing findings detailed in Table 5-3. These values indicate how many qualitative criteria were met (green), partially met (yellow), not met (red), or whether they could not be determined (grey).

Abbott Northwestern Hospital, Minneapolis, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)
60.52	Not qualitatively assessed

Abbott Northwestern is a large hospital surrounded by a high density, predominantly residential area – a typical neighborhood typology found across the State of Minnesota. A large hospital like Abbott Northwestern represents a strong anchor tenant for a thermal energy network due to its large, consolidated thermal demands and prominence within the local area. Additional anchor tenants such as Andersen Middle School and Allina Central Laboratory represent strong opportunities for network interconnection and are indicative of similar anchor tenants found across the state within this neighborhood type. Refrigeration processes at Midtown Global Market represent a primary opportunity for thermal capture, along with secondary sources such as Chicago Lake Coin Laundry. Favorable characteristics of this site suggest further evaluation on a site-specific basis would be advantageous in considering moving forward a project.

Alexandria City Hall, Alexandria, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)
69.38	Not qualitatively assessed

Downtown Alexandria is an example of a medium-density mixed-use neighborhood typology commonly found across Minnesota. Alexandria City Hall is located at the center of downtown Alexandria, and, due to its sociopolitical influence over the surrounding community, is an example of a key building that could serve as a network's anchor customer. Additional key anchor tenants include multiple churches and municipal buildings such as a public library and courthouse, all within proximity to City Hall. These tenants represent great opportunities for positive stakeholder engagement and generation of public interest and support. The Vaultas Alexandria Data Center and Copper Trail Brewery represent primary opportunities for thermal capture due to high-temperature effluent associated with cooling servers and brewing beer. Refrigeration processes at multiple small markets and convenience stores represent additional capture opportunities. This site is adjacent to Lake Winona, a large body of water that could potentially be evaluated as a balancing thermal resource to improve system economic performance throughout the year. This site's relatively high score positions it well for a further site-specific feasibility study and qualitative analysis to confirm its suitability and potentially pursue a project.

Northwest Growth Area Plan, Brooklyn Park, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)
70.24	Not qualitatively assessed

Brooklyn Park's Northwest Growth Area Plan is a new development 10 miles north of Minneapolis – representative of greenfield development projects emerging across the state. The project aims to develop over 700 acres of land into a balanced mix of multi-family residential, office space, research and laboratory facilities, retail, and a new Biotech Innovation District. Developing a TEN from the outset would allow a project developer to integrate TEN-compatible building-level HVAC systems into the buildings' initial designs – eliminating the costs of building retrofits needed to otherwise "plug in" to the network. Borefield drilling and laying distribution piping could be coordinated with road construction and utility installation to help optimize construction costs. The planned mix of residential, commercial, and institutional buildings would create favorable load diversity and balance, improving system performance and economic viability. Given the stage of development for this site and its high score in quantitative analysis, it is particularly opportunistic for Brooklyn Park to consider a TEN in this development.

Carleton College, Northfield, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)			
70.87	8	2	0	0

Carleton College represents a small college or university located within a medium density residential neighborhood, a typology that recurs throughout the state. This site was chosen due to the strong alignment of colleges and universities with capacity to develop TENs and because an existing system is already in place on campus. Colleges and universities are particularly well suited to TENs development as they typically have high energy demand and sole control over infrastructure that must be modified, developed, or replaced across an entire campus.

Expanding the existing system at Carleton College to an adjacent college owned campus using a second thermal loop to serve a mix of medium size and residential-style buildings is currently under consideration. The existing borefield and system greatly reduce the risk and cost of any future development if these systems can leverage one another for heat sharing. Carleton College is also adjacent to the Cannon River, a large body of water that can be leveraged to more effectively balance thermal loads throughout the year and improve economic performance. Carleton College's proposed expansion to additional college-owned buildings scores well on both quantitative and qualitative criteria because the campus already operates a TEN and can rely on a simple, single-owner building portfolio.

Potential expansion into broader neighborhood at Carleton College

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)			
34.98	1	3	0	0

Carleton College is adjacent to a breadth of residential neighborhoods that present an opportunity for further expansion. Given the nature of these residential buildings, however, this prospect is hindered by the complexity of engaging numerous unique building owners and overcoming behind-the-meter challenges such as incompatible HVAC systems expanding beyond university buildings would create additional challenges with ownership structure and new regulatory requirements, which were not explored in detail in an interview with the college. With these considerations in mind, potential expansion into the broader neighborhood at Carleton College scored low in quantitative analysis and presented a lot of unknowns that made its qualitative scoring difficult. Further evaluation at a local level would be useful for this site.

Denfeld, Duluth, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)			
56.97	0	5	0	5

Denfeld is a predominantly residential neighborhood in Duluth representing a highly populated and industrially oriented community. The site area was selected due to the presence of residential buildings, municipal facilities, and industrial activity all within a 1-2-mile radius. Both Denfeld High School and Laura MacArthur Elementary School represent key anchor tenants due to their significance and central location within the community and the high density of their thermal loads. A large paper mill in the southern portion of the site area could be leveraged as a large source of thermal capture for a TEN, helping balance thermal load during colder months and improve economic performance. The St. Louis River is adjacent to the site area and could be utilized as a strong thermal balancing resource, particularly during warmer months. Denfeld is in an area with lower bedrock suitability and a higher proportion of older buildings, which are potential barriers to TENs development.

Duluth had hoped for a federal grant for an ambitious TEN project in a different location. The community had even hired staff to work specifically on the TEN and invested time and effort in building support for the project. The project would have been timed with another federal grant involving street repairs and improvements, making alignment of these projects mutually beneficial for the city. This was viewed as an opportunity to address equity considerations by providing sustainable energy for some of the city's most in-need residents. Ultimately, the grant was not funded and there is now less enthusiasm for pursuing another project. The city cannot fund such an extensive project without federal grant money. The city's priorities have shifted, and the opportunity to coordinate with street work will have passed by the time any new project begins. However, the city indicated it might consider a smaller-scale project if funding becomes available. These difficulties weighed heavily into qualitative scoring, ultimately leaving it with few green lights, especially around criteria involving political support, capacity for risk, and a project champion.

Downtown Crookston, Crookston, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)			
44.53	3	3	0	4

Downtown Crookston represents a relatively medium-density mixed-use neighborhood in Minnesota. The site area was chosen due to the dense presence of municipal buildings, community centers, places of worship, and commercial retail infrastructure. Crookston City Hall and adjacent municipal offices were identified as strong anchor tenants due to the recurring significance and influence of municipal activity over the surrounding community. Several places of worship and a Lutheran school also represent key tenants within the site area. Although there are no significant opportunities for thermal capture within the site area, the diversity of smaller commercial operations would contribute to balancing and strengthening the operational performance of a TEN.

Furthermore, the presence of the Red Lake River on two sides of the site area presents a strong opportunity for thermal balance.

Crookston has city staff and community support for a TEN and for sustainability goals more broadly. They have been awarded a Geothermal Planning Grant for a site feasibility study and are focusing on an older residential area that would support the city's equity goals (south of the area considered in this report). If project economics work out for that site or another area dependent on the feasibility study's findings, the city would likely explore possible paths to implement TENs. The city mentioned possible workforce constraints, but other stakeholders thought that project developers and builders are accustomed to working in other areas of the state, creating the ability to train local workers for ongoing maintenance and operations. Despite meeting some favorable criteria in qualitative analysis, the ownership complexity and load uniformity of the residential neighborhood currently considered by Crookston may present feasibility barriers and ultimately contributed to its relatively low scoring.

Downtown Mankato, Mankato, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)
71.28	Not qualitatively assessed

Mankato represents a typical medium-density mixed-use community found across Minnesota. The site area includes municipal buildings, small businesses, and several larger commercial entities. This site is adjacent to the Minnesota River, an excellent thermal storage resource particularly during warmer months that can drastically improve system performance. Downtown Mankato also includes an abundance of waste heat opportunities. A data center, ice arena, supermarket, soybean processing plant, and wastewater treatment plant are all located in a proximal area, offering a strong opportunity for incorporating thermal resources into a TEN. With multiple opportunities for thermal capture, high density of municipal, commercial, and residential buildings, and proximity to a large body of water, downtown Mankato and other neighborhoods of similar typology are very well suited to TENs development. These favorable characteristics of this site lent it to score relatively high in the quantitative analysis and make it a good candidate for further local evaluation and consideration for a TEN.

Fond du Lac Band of Lake Superior Chippewa, Fond du Lac, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)			
51.55	7	3	0	0

The Fond du Lac Band of Lake Superior Chippewa is located on Tribal Lands and represents a lower density but commonly recurring neighborhood typology across the state. Fond du Lac is designated as an environmental justice community and represents a priority opportunity for development of next-generation energy technologies. The site is a small campus-like area with an educational center, school, refrigerated food storage building, and a small number of residential buildings. However, without a significant thermal resource beyond heat from refrigerated storage and with low building density, likely requiring significant HVAC upgrades, the site is relatively unfavorable for TENs development compared to other high-density sites evaluated. This site may be better served through individual ground-source systems within each building if site-specific analysis deems a networked system too high a cost for achievable energy savings.

Because governance within the Fond du Lac Band of Lake Superior Chippewa is centralized within the nation, the political and community approvals often required in other jurisdictions are significantly simplified. For instance, Native Nation rights of way are controlled by the land use committee and housed in the same building as the energy services and energy projects manager. In addition, sustainability outcomes are a core priority when projects are financially sound, making TENs development on Native Nations potentially more straightforward than in other parts of Minnesota. The favorable qualitative characteristics of this site suggests a TEN might be worth further evaluation on a technical and financial basis to determine if the benefits would be worth the investment.

Highland Park, St. Paul, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)
45.95	Not qualitatively assessed

Highland Park, located in southwestern St. Paul, represents a medium-density residential neighborhood. This site was selected due to the collocation of a dense residential neighborhood and a large ice rink – a significant opportunity for thermal energy recovery. The Charles M. Schulz-Highland Arena represents the primary anchor tenant for a network at this site, alongside Highland Park Middle and High School and Messiah Episcopal Church. Thermal resources such as the rejected heat from the ice rink can provide balance and improved performance to the network. However, there is still a lack of load diversity at this site, due to the imbalance of residential and non-residential buildings, and this is less favorable for system performance. For sites with imbalanced load, a greater number of boreholes may also be needed to meet overall thermal demand, further increasing project cost. The Highland National golf course presents a great opportunity for developing a large borefield. However, private land ownership can present access challenges. The relatively low scoring of this site does not preclude it from being further evaluated for feasibility but suggests resources might be best used to evaluate and consider other sites within the state.

Hormel Foods, Austin, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)
66.10	Not qualitatively assessed

Hormel Foods is a large meat processing facility located just north of Austin's downtown. This site represents a medium-density, mixed-use community adjacent to a large industrial facility. Both the Hormel Foods and Apple Valley Foods facilities represent opportunities for significant thermal energy capture due to intense use of refrigeration, sterilization, and cooking equipment onsite. Austin's urban center is adjacent to these facilities and includes many additional key anchor tenants and thermal capture opportunities such as a Mayo Clinic hospital, municipal buildings, Austin High School, Riverside Ice Arena, and many potential commercial tenants such as supermarkets, restaurants, and a small brewery. The Cedar River, which runs through the middle of the site area, represents another excellent opportunity for thermal exchange. This site demonstrates an ideal profile of mixed building use and load types, combining a large thermal source with diverse customers including residential and commercial buildings. The favorable characteristics of this site position it well for qualitative analysis and further technical feasibility assessment.

Prairie Island Indian Community, Red Wing, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)
66.67	Not qualitatively assessed

The Prairie Island Indian Community represents a site on Tribal Lands with substantial thermal resources. The Treasure Island Resort and Casino and Prairie Island Nuclear Generating Plant, both located onsite, offer strong opportunities for heat capture. The sparse settlement of residential buildings at this site leads to lower load density, which is generally unfavorable for TEN performance and development. However, underserved communities such as Prairie Island should be emphasized as priority sites for TENs development as these communities are generally less able to support new infrastructure and their residents are in greater need of cheaper and more reliable energy. This site would benefit from future qualitative analysis to evaluate the political and social viability of leverage casino and nuclear plant heat capture and reuse opportunities.

Rochester City Hall, Rochester, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)			
74.61	9	1	0	0

Downtown Rochester represents a high-density mixed-use area, a favorable site for a TEN primarily due to the density and diversity of thermal load. Rochester's existing thermal energy network has been developed by taking advantage of scheduled replacements of the city's underground steam lines. The site's current planned scope is to include the Mayo Civic Center, Rochester Art Center, Rochester Civic Theatre, and the Rochester Public Library, and it has the potential to grow further into a broader portfolio of wider reaching commercial and residential buildings. Further, the presence of two geothermal wells onsite greatly reduces the risk and cost associated with any future drilling. While a dense area is favorable for load and system performance, stakeholder coordination with many unique buildings and landowners could be a barrier to development. So far, however, parties interested in TENs in Rochester have held ongoing knowledge-sharing meetings that have helped bridge knowledge gaps across organizations and may be important civic infrastructure to overcome this barrier. This site scores favorably in quantitative and qualitative analysis when considering only the proposed government owned buildings.

Potential expansion into downtown at Rochester City Hall

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)			
59.65	6	3	1	0

For expansion of the existing TEN, the primary challenge is establishing a sustainable ownership and operating model, as shifting from a city-owned system to one involving private entities introduces complexity and uncertainty. Who would own and operate is currently unclear. Financial viability and rate structures – particularly fair cost allocation and avoiding cross-subsidies from non-users – remain unresolved, underscoring the need for clear policies and governance frameworks to balance public and private participation. The ownership structures and regulatory requirements needed for expansion were not explored in detail in an interview with the City of Rochester, Destination Medical Center, and one other Rochester-based stakeholder. The added complexity introduced when evaluating downtown expansion is the primary contributing factor to it scoring lower than the current system.

State Capitol, St. Paul, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)			
59.70	8	1	1	0

The St. Paul Capitol Complex is served by an existing district system owned and operated by District Energy St. Paul (DESP), which also serves neighboring multi-family residential developments and much of downtown St. Paul. DESP is heated and cooled by a central plant including gas boilers and is exploring wastewater heat recovery from the Metropolitan Water Resource Recovery Facility to fully decarbonize heating, including for the Capitol Complex.

The load density of large municipal facilities surrounding the State Capitol - including the State Office Building, Department of Transportation, Veterans Service Building, Judicial Center, and several other large municipal offices – demonstrates dependable anchors and long-term revenue for a TEN. The Capitol Mall's large open spaces with single entity ownership present a favorable opportunity for geothermal capacity from large borefield potential. While the site benefits from sociopolitical favorability, the lack of thermal resources such as data centers or industrial heat sources beyond the aforementioned option for the entirety of DESP, to interconnect with a TEN lowers overall favorability for broader expansion.

A qualitative review of DESP’s past expansion to the Capitol Complex shows high scores for neighborhood and user support, ease of ownership and governance, and financial stability because the state is a single owner and the system built on an existing, revenue-generating customer base. The Capitol’s enduring governmental role suggests continued investment and visibility, and its central location in the Twin Cities with strong unionized labor means workforce constraints are not expected to be a barrier, even if local population growth is modest.

St. Cloud State University, St. Cloud, MN

Quantitative Score	Qualitative “Traffic Light” Totals (see Table 5-3)
67.13	Not qualitatively assessed

St. Cloud State University represents a medium-density residential community collocated with a college or university. Universities and college campuses offer unique opportunities for a TEN due to the advantages of having a single commercial owner and streamlined decision-making and approval processes. Procuring permitting and easements for borehole development under parking lots or greenspace at St. Cloud State is likely simpler due to the university's sole land ownership. The presence of diverse building stock and a centralized heating and cooling system also help provide adequate load balance and compatibility with network development. In addition to buildings with high thermal demand such as dormitories, lab spaces, and dining halls, the campus features a large hockey arena representing a strong opportunity for thermal capture. The high quantitative scoring and simplicity in ownership at this site makes it a clear candidate for further qualitative evaluation and consideration as a TEN project site.

St. Cloud Vaultas Data Center, St. Cloud, MN

Quantitative Score	Qualitative “Traffic Light” Totals (see Table 5-3)
65.14	Not qualitatively assessed

This site represents a data center located in a low-density mixed-use neighborhood, a recurring typology throughout the state and a particularly relevant opportunity as demand for computing and data processing power continues to grow. This data center is adjacent to the Heritage Park Apartment Complex Site, representing a strong opportunity to pair a heating-dominant load with a significant thermal resource. The site also includes several commercial facilities that would provide strong load diversity to a potential TEN. There is adequate open space for borefield development in parking lots surrounding the data center and nearby commercial buildings. With a diverse and dense thermal load located near a substantial thermal resource, this site represents a favorable typology for TENs development across Minnesota.

The Heights, St. Paul, MN

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)			
72.04	10	0	0	0

The Heights is a new mixed-use development owned by the St. Paul Port Authority that, upon completion, will be served by a TEN. The site represents an existing TEN adjacent to a medium-density residential neighborhood. With planned lower- and higher-density residential areas, commercial buildings, and light industrial uses, the load characteristics and HVAC compatibility of this site are highly favorable. These characteristics alongside very favorable social, political, technical, and economic contexts score this site extremely high in quantitative and qualitative analyses.

Potential expansion into broader neighborhood at The Heights

Quantitative Score	Qualitative "Traffic Light" Totals (see Table 5-3)			
34.98	1	4	0	5

While the TEN is still under construction, this site presents a potential opportunity to expand the planned system to serve adjacent residential areas. However, the complexity of coordinating with numerous unique building owners and potential incompatibility of existing household HVAC systems represent potential barriers to system expansion. Further, the nearby residential area lacks thermal resources to help provide system balance. These considerations make the potential neighborhood expansion score considerably lower than the primary project on the quantitative basis and introduces more qualitative unknowns.

5.4 Emerging Themes from Site-Specific Analysis

Load Diversity and High-Density Areas

TENs are optimally suited for locations with higher building density and use types to maintain system efficiency and load balance. Increased diversity of buildings, such as a mix of residential, commercial, industrial, and institutional (i.e., school or hospital) customers, allow the network to more effectively share heating and cooling energy throughout the day and year. Sites such as downtown Mankato, Rochester, and Alexandria demonstrate favorable conditions for an existing or new thermal energy network due to their balance of residential, commercial, and industrial customers, presence of strong anchor tenants, and building density that creates opportunity for delivering more thermal energy along the network. For sites not specifically studied as part of this work, siting a TEN should look towards neighborhoods with higher concentrations of buildings that vary in how they consume heating and cooling energy over time.

Bedrock Suitability

Geologic and hydrologic conditions strongly influence how efficiently a TEN can exchange heat with the ground. In geothermal networks, long-term performance depends on both local bedrock properties and a balanced mix of network-wide, aggregated annual heating and cooling loads; persistent load imbalances can gradually warm or cool the subsurface, degrading geo-exchange potential over time. Although favorable bedrock improves performance, the analysis shows that even sites with modest geologic suitability can succeed if connected buildings collectively maintain relatively balanced heating and cooling demand throughout the year. Prospective TENs should therefore pair basic characterization of local geology and hydrogeology with careful load analysis to ensure that diversified, seasonally complementary building end uses share the network.

Accessibility and Availability of Thermal Resources

TENs can improve upon their technical performance and economic viability when drawing from heat recovered from locally available thermal resources, whether they are human-created heat sources like data centers or food processing facilities, or natural bodies of water, such as lakes or aquifers. Sites such as Austin and St. Cloud scored higher in the overall site scoring due in part to the presence of waste heat resources that could be recovered for inclusion into a TEN.

For prospective sites beyond the 16 studied in this work, identifying facilities or natural resources in the community that could be leveraged for heat recovery is a key early step in site selection. These facilities should avoid infrastructure barriers such as highways or natural features like rivers that can restrict expansion potential and the ability to interconnect thermal resources. For example, thermal resources near the Downtown Crookston site are located across the Red Lake River, while at Denfeld, a paper-processing mill lies across a major highway, both creating significant obstacles to integration. However, sites like Downtown Mankato with a data center, ice arena, supermarket, soybean processing plant, and wastewater treatment plant located in a proximal area, offer easy access to thermal resources.

Ownership of Open Space and System Infrastructure

Ownership structures can present significant hurdles to both new construction and TEN expansion projects. The need to engage many unique owners can complicate and prolong the procurement of required permitting and easements. In contrast, sites with a single owner make for a substantially less complex coordination process for access to open space. At Carleton College, the two existing borefields were developed more seamlessly because the college serves as a single commercial owner, streamlining decision-making and approvals. A potential expansion of the system to the nearby Weitz Center for Creativity is likely to be straightforward as the property is also owned by Carleton College.

The type of ownership can also influence the ease of stakeholder coordination. For example, a single municipal owner of a parking lot is easier to coordinate than multiple commercial owners. The Denfeld site illustrates this challenge; although there is ample open space for borefield development in the site's large parking lots, the parcels are owned by multiple commercial entities, increasing the complexity of stakeholder coordination. For the City of Rochester, while there is interest from multiple ownership groups, challenges exist to expanding service outside of city owned buildings due to complexities with the responsibility of managing the thermal energy resource.

New Development

New mixed-use developments that incorporate light industrial, commercial, and varying residential densities provide more balanced thermal loads, leading to more efficient systems. Brooklyn Park's Northwest Area

Growth Plan, for example, includes a well-balanced mix of residential and commercial units alongside biotechnology and manufacturing facilities. New development also allows for buildings and TENs to be constructed concurrently with new building-level HVAC systems and neighborhood scale infrastructure, enabling direct integration of compatible, high-efficiency HVAC systems from the outset and coupling civil works costs for economic efficiency.

Addressing Equity and Environmental Justice

Where there is alignment between technical feasibility, secure financing and political support, tribal reservations and other traditionally disadvantaged communities should be prioritized for exploration of pilot projects. These communities often face higher energy burdens and may qualify for financial incentives, making TENs both more feasible and impactful.

6 Conclusion and Recommended Actions for TENs

Minnesota's climate targets and recent legislation create both the urgency and the enabling framework to advance thermal energy networks to a core strategy for community-scale building decarbonization. Through thoughtful siting of thermal energy networks, the state can deploy these systems in ways that cut emissions, lower energy burdens, build long-term community resilience, and create a pathway to responsibly electrify the state's building stock. With clear regulatory pathways, targeted public and private financing, and sustained stakeholder engagement, Minnesota is well positioned to translate the findings of this report into on-the-ground projects that showcase how TENs can help achieve a net-zero future.

To advance TEN projects across Minnesota, the following actions are recommended for specific entities:

<u>For municipal and state level officials:</u>

Conduct Detailed Feasibility Studies

One of the first steps in working towards implementing or expanding TENs is to perform a detailed engineering and economic analysis at a specific site. These studies help either confirm or deny overall network feasibility and refine technical assumptions and cost estimates. More comprehensive engagement with the communities located within and around study areas should be included, and decision-makers in transportation, municipal utilities, and urban planning should be encouraged to share timelines and priorities. Publicly facilitated feasibility studies should be viewed as a valuable resource for enabling private development of TENs. A key first step municipal and state official can take is to evaluate the suitability of their own communities using the Worksheet for Additional Sites present in the Site Suitability Scorecard and associated ArcGIS Online platform.

Unlock Funding, Financing Opportunities, and Incentives

Both municipal and state level officials should work to explore state and federal funding opportunities, including environmental justice grants and infrastructure programs, to offset upfront costs, perform feasibility studies (including drilling test boreholes), support customer-side building retrofits, initiate and enable multilingual community outreach, and accelerate deployment. Additionally, creating financial incentives – such as grants, tax credits, and low-interest financing opportunities – will encourage adoption and align the creation of new TENs with statewide decarbonization and equity goals. If state and municipalities already have funds at their disposal, they should work with community outreach groups to advocate for applications and raise awareness of these funds.

Establish Policy and Regulatory Frameworks

Establishing clear policy and regulatory frameworks is essential to accelerate TENs deployment across Minnesota. Municipal and state agencies should collaborate to streamline permitting, licensing, and evaluation processes, reducing administrative delays and uncertainty for developers. Clarifying infrastructure and thermal resource ownership rights, thermal market contracts, and shared infrastructure responsibilities will help prevent legal disputes and simplify project coordination. The state should work to demystify regulatory requirements across different ownership structures providing a clear pathway for both private and public ownership models. Policymakers should look to create legal opportunities for widespread TENs deployment, such as reforming utility service requirements and authorizing utility spending on TENs to provide certainty to these regulated entities and the workforce that supports them. Policymakers should also consider requiring utilities to routinely evaluate TENs as alternatives to gas heating and system expansion, with attention to avoided investments and maintenance, as well as carbon benefits.

Develop Representative Projects

Minnesota and its municipalities should develop TENs projects representing different neighborhood typologies – such as high-density mixed-use areas, tribal communities, and new mixed-use developments – to demonstrate the feasibility of TENs. These projects, which can demonstrate the viability of varying ownership models and community types, can serve as proofs-of-concept – providing critical data on technical performance, economic viability illustrated in replicable financial pro formas, and stakeholder engagement strategies. Lessons learned from these projects should inform statewide scaling efforts, ensuring that future TENs are optimized for diverse conditions and community needs.

Create a Statewide TEN Development Roadmap

Based on pilot outcomes and feasibility studies, the State of Minnesota and its municipalities should work to develop a phased roadmap for scaling TENs across the state, prioritizing regions with high suitability scores and strong stakeholder alignment. Similarly, establishing guidelines and well log databases with published, public geothermal bore drilling information can help de-risk the process of drilling new wells and reduce a barrier to broader geothermal energy expansion in the state. By establishing clear milestones and governance structures, Minnesota can position itself as a national leader in next-generation energy systems.

<u>For commercial developers, owners, and operators of TENs:</u>

Engage Key Stakeholders Early

Proactive stakeholder engagement is critical to the success of TENs development. Outreach should begin with municipal leaders, tribal authorities, and major anchor tenants such as hospitals, universities, and large commercial entities. These stakeholders play a pivotal role in shaping community support, securing land access, and streamlining permitting processes. Establishing partnerships at the outset will help identify shared priorities, align project goals with local needs, and build momentum for implementation. Early informational material and Q&A can help to prepare key stakeholders to participate in future projects.

Conduct Detailed Feasibility Studies

Feasibility studies can be initiated through both private and public avenues. Government-led research, such as technical reviews or funded feasibility studies, can be utilized by developers in a similar fashion to this report. If feasibility studies have not been conducted publicly, then a potential developer would need to initiate a focused study privately.

Secure Funding and Incentives

Commercial stakeholders should actively pursue state and federal funding opportunities to reduce upfront capital costs and accelerate project deployment. Programs such as environmental justice grants, clean energy infrastructure funds, federal tax incentives, and low-interest financing, including through bonds, can significantly improve project economics and reduce risk. Leveraging these incentives early in the development process will help attract private investment and ensure long-term financial viability. Coordinating with state agencies and utility partners can further unlock cost-sharing opportunities and position projects for success.

Align Project with State Goals

Private developers should work to align their projects at the outset of the site selection and design process with the stated goals and priorities of state and municipal leaders. Road mapping, feasibility studies, and pilot systems should be carefully studied by TEN developers to inform community groups and local stakeholders about their work and set projects up for the highest likelihoods of success.

For communities and advocates:

Evaluate TENs for Your Community

TENs are a fit for many communities, but their suitability depends on qualitative characteristics just as much as technical feasibility. Community leaders and advocates can utilize the key themes from this report, along with the Worksheet for Additional Sites present in the Site Suitability Scorecard and the quantitative maps provided in the ArcGIS Online platform, to understand which areas of technical, economic, political, and social considerations fare well for new TENs. Understanding the local relevance to some of the key barriers and opportunities in this report can also inform a roadmap towards understanding local suitability for TENs.

Appendices

A Data Collection

Geospatial data was used to assess the conditions across Minnesota that are conducive for thermal energy networks (TENs). Considerations ranged from infrastructure interference to geology to demographics. Assessing each criterion for sites across Minnesota required several public data sources provided by multiple agencies and organizations. The Minnesota Geospatial Commons was valuable in obtaining layers from different government agencies relevant to environmental conditions for project siting such as geology, hydrology, and infrastructure.[88] The Commons included the following relevant data sources:

- **Roads**: used to identify dividing infrastructure (e.g., railways, highways) that may impact expansion of a TEN. The Minnesota Department of Transportation (MNDOT) provides data on highways, major roads, and local roads, including length of road segments. Street types, such as interstates, were also used to assess the level of obstruction pedestrians may face during the installation of a TEN.[89]
- **Bedrock**: sourced from the Minnesota Geological Survey, this data was used to identify the predominant bedrock geology.
- **Aquifer Properties**: sourced from the MNDNR, this database provided information on transmissivity, hydraulic conductivity, and storativity of aquifers statewide.[90] The data were used to identify the presence of aquifers across Minnesota. Hydraulic conductivity values were used to understand the potential for thermal exchange between network piping and geothermal wells.
- **Conservation Areas**: used to determine if proposed sites are proximate to protected lands that would need to be considered in the construction of a TEN. Using Marxan, the most widely used decision support software for the design of conservation reserve systems, the Minnesota Department of Natural Resources (MNDNR) mapped priority areas for protecting biological diversity.[91]
- **Wetlands**: used to determine the proximity of potentially sensitive wetlands. The data is from the National Wetlands Inventory compiled by the MNDNR.[92]

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[88] Minnesota Geospatial Commons. https://gisdata.mn.gov/

[89] MnDOT. “MnDOT Route Centerlines.” https://gisdata.mn.gov/dataset/trans-roads-centerlines

[90] MNDNR. “Aquifer Properties - Public Version.” https://gisdata.mn.gov/dataset/env-aquifer-properties

[91] MNDNR. “MNDNR SNA Conservation Opportunity Areas and Marxan Conservation Prioritization.” https://gisdata.mn.gov/dataset/env-sna-conserv-opportunity-area

[92] MNDNR. “National Wetland Inventory for Minnesota.” https://gisdata.mn.gov/dataset/water-nat-wetlands-inv-2009-2014

- **Surface Water Bodies**: used to identify potential thermal resources such as rivers and lakes. This data set is from the Minnesota Pollution Control Agency.[93]
- **Remediation Sites**: used to identify contaminated brownfield or superfund sites that should be avoided due to contaminant migration concerns or increased cost of drilling and subsequent waste disposal. This data set is from the Minnesota Pollution Control Agency (MPCA).[94]
- **Environmental Justice**: this data set combines estimates from the American Community Survey and calculations performed by the MPCA.[95] In addition to census tribal areas, this dataset identifies environmental justice areas defined as communities where ≥40% of the population identifies as a person of color, ≥35% are economically disadvantaged, and ≥40% of the population has limited English proficiency.
- **Census Data**: compiled by the U.S. Census Bureau, this data provides estimates for population by census block and was used to calculate population density.[96]
- **Anchor Sites**: defined as buildings central to communities such as schools, churches, or government buildings that represent long term anchors for a TEN. These buildings may also represent heat resources either due to their process waste heat or due to the energy profile of the building. A comprehensive list of sites evaluated include:
    - Schools – data obtained from the Minnesota Department of Education.[97]
    - Hospitals – data obtained from the Minnesota Department of Health.[98]
    - Wastewater Facilities – data obtained from the Minnesota Pollution Control Agency.[99]
    - Additional anchor sites including supermarkets, places of worship, community centers, housing communities, and government buildings were identified after initial site selection using Google Earth and Open Street Maps.

In addition to data from the Minnesota Geospatial Commons, data layers from other sources were used in this evaluation. These layers include:

- **Building Footprint Data**: used to determine the number of buildings within a given site, the land use classification of buildings, as well as the density of buildings as calculated by dividing site building square

[93] MPCA. “Surface Water API”. https://gisdata.mn.gov/dataset/surface-water-api-pca

[94] MPCA. “MPCA Remediation Sites.” https://gisdata.mn.gov/dataset/env-remediation-sites

[95] MPCA. “Environmental Justice.” https://gisdata.mn.gov/dataset/env-ej-mpca-census

[96] United States Census Bureau. “Census Data.” https://data.census.gov/

[97] Minnesota Department of Education. “School Program Locations, Minnesota, SY2025-26.” https://gisdata.mn.gov/dataset/struc-school-program-locs

[98] Minnesota Department of Health. “Hospitals Serving Minnesota, 2020.” https://gisdata.mn.gov/dataset/health-facility-hospitals

[99] MPCA. “Wastewater Facilities in Minnesota.” https://gisdata.mn.gov/dataset/util-wastewater-facilities

footage by total site square footage. This data is derived from the USA Structures dataset which provides footprints for all buildings greater than 450 square feet in the US based on FEMA data.[100]

- **Indoor Ice Rinks**: data obtained from the Minnesota Arena Guide.[101] Ice rinks produce heat as a byproduct, representing an opportunity for use as an anchor site for a TEN.
- **Utility Systems**: used to identify points of interference with existing utility systems (sewer interceptors and main roadways). This data was sourced from the Minnesota Geospatial Commons.
- **Depth to Bedrock**: data was obtained from the Minnesota Geological Survey to understand the potential impacts on the costs of drilling at a given site.[102]
- **Waste Heat Facilities**: Waste Heat Facility data was obtained from the Minnesota Department of Commerce report. Potential heat sources were characterized by estimating thermal energy (MMBTU) using reported NO_x emissions and applying EPA-established emissions factors to convert pollutant output into corresponding heat generation estimates.

[100] FEMA. “USA Structures Dataset.” https://gis-fema.hub.arcgis.com/pages/usa-structures

[101] Arena Guide. “Minnesota.” https://arena-guide.com/locations/minnesota/

[102] University of Minnesota Duluth. “Depth to Bedrock - State.” https://mnatlas.org/resources/depth-to-bedrock-state/

B Geospatial Analysis

A comprehensive geospatial analysis was completed to evaluate statewide suitability for TEN siting across Minnesota using a multi-criterion, spatially explicit approach in ArcGIS Pro. This analysis integrated geological, hydrogeological, environmental, and demographic datasets to generate a composite TEN Suitability layer at the census block level.

B.1 Layer Development and Classification

All spatial datasets were processed and standardized within ArcGIS Pro. Individual raster layers were developed to represent both suitability and constraint factors, each reflecting key physical or regulatory parameters influencing the technical feasibility of TENs.

B.1.1 Suitability Layers

Suitability layers were derived primarily from geologic and hydrogeologic datasets and represent subsurface and surface conditions conducive to efficient thermal exchange and stable system performance. These include:

- **Hydraulic Conductivity** (Figure B-1): Hydraulic conductivity reflects the ease with which groundwater moves through rock or sediment. The amount of water flowing through the ground has a large effect on thermal exchange in hybrid and open well configurations. Generally, higher flow rates can lead to improved system economics.
- **Bedrock Thermal Conductivity** (Figure B-2)**:** This layer quantifies the ability of subsurface rock formations to transfer heat, a critical determinant of the efficiency of energy exchange. High conductivity zones increase heat transfer between the subsurface and geothermal wells, enhancing system performance. A map of normalized thermal conductivity with a continuous color scale is shown in Figure B-7.
- **Surface Water Bodies** (Figure B-3): Lakes and rivers can act as thermal resources for TENs. Proximity to sites represents an opportunity for a relatively stable thermal resource, with TENs potentially removing heat from surface water adding an ecological benefit.

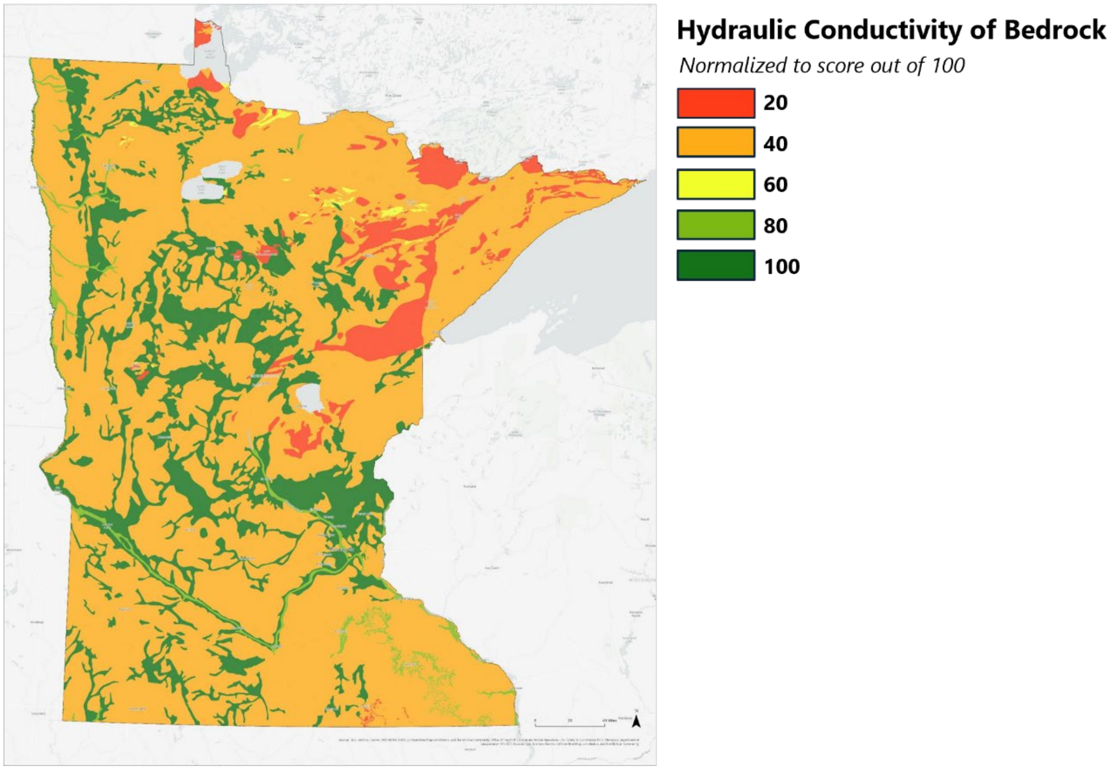

***Figure B-1**. Relative hydraulic conductivity of bedrock.*

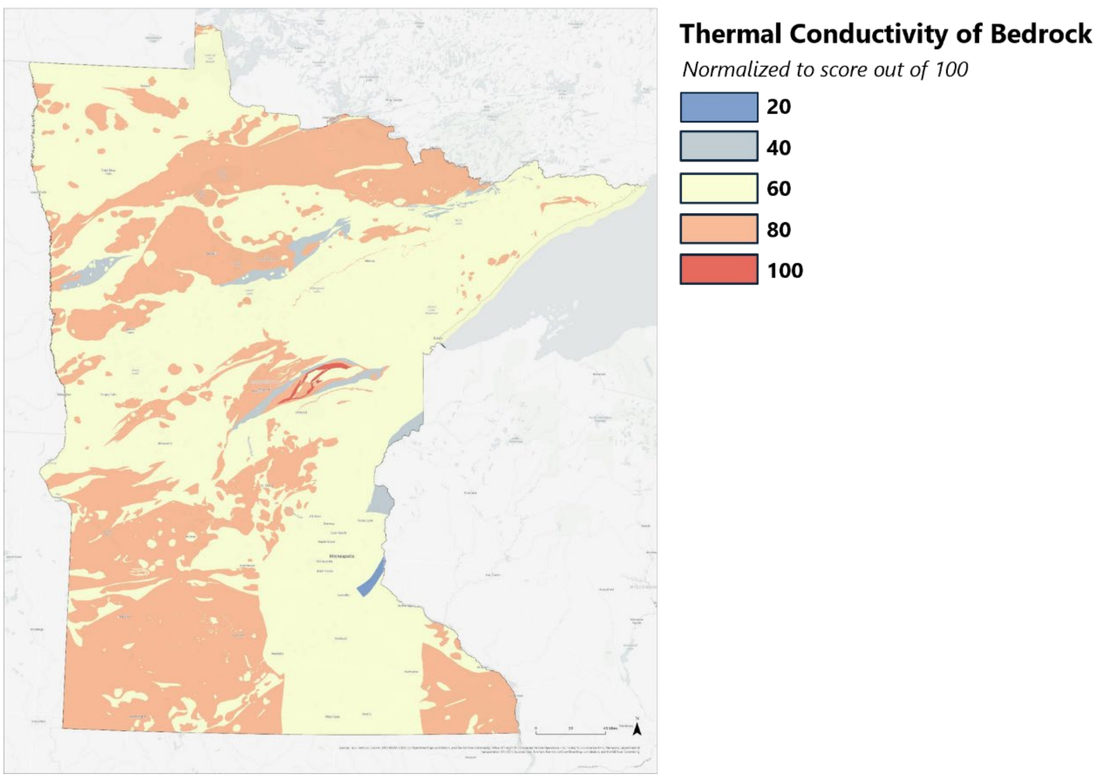

***Figure B-2**. Relative thermal conductivity of bedrock.*

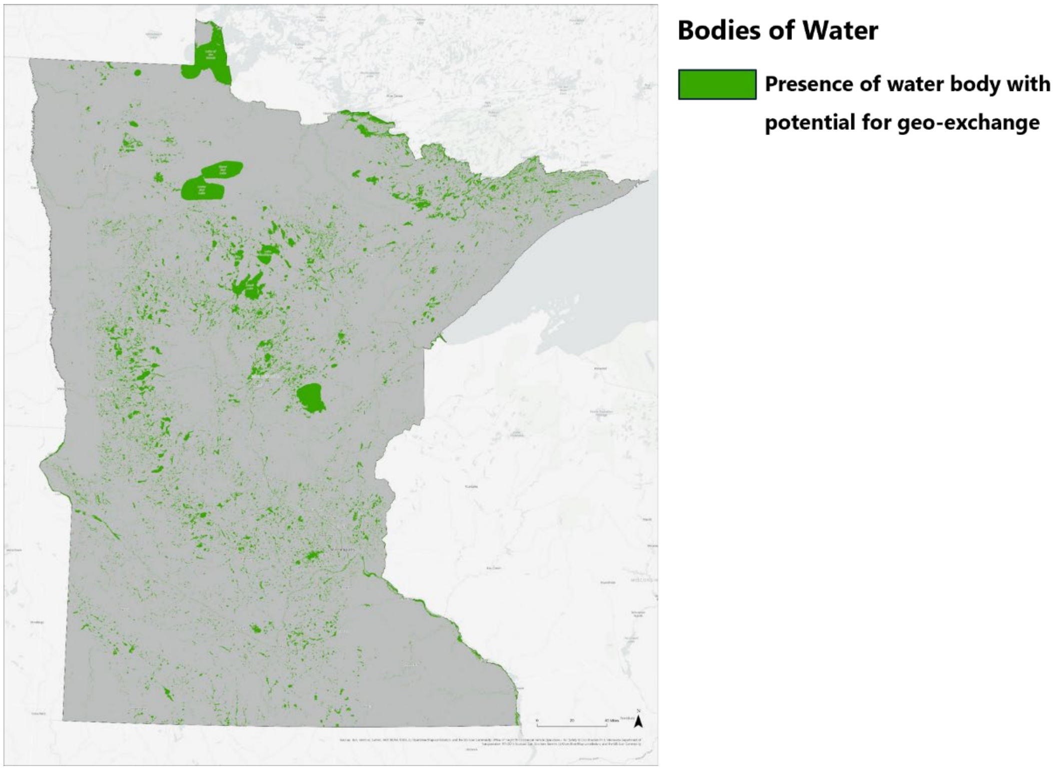

Figure B-3. *Existing surface water bodies in Minnesota.*

Layers were normalized and re-ranked on a scale from 0 (least suitable) to 100 (most suitable) using the Raster Calculator and Normalize tools to ensure comparability across datasets. A Weighted Overlay Analysis was then performed, applying weighting factors to integrate these layers into a single TEN Suitability Layer (Figure B-4) based on geological and hydrogeological conditions.

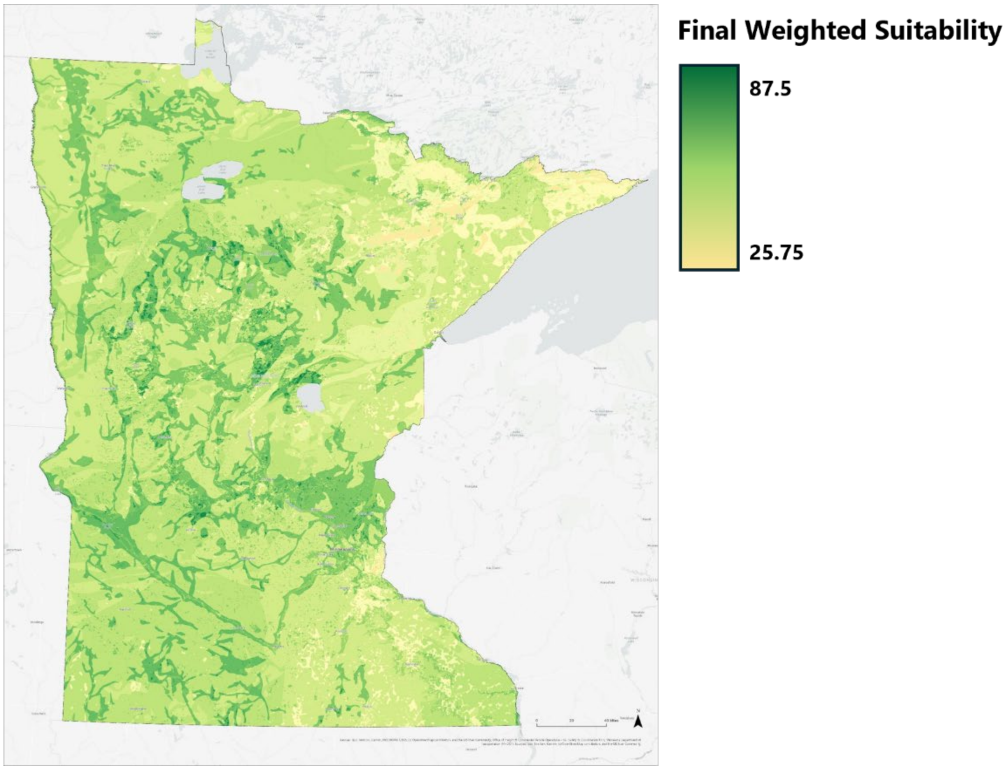

Figure B-4. *Overall weighted bedrock suitability for Minnesota.*

B.1.2 Constraint Layers

Constraint layers delineate areas generally deemed unsuitable for drilling or network construction due to regulatory, environmental, or health protection considerations. These include:

- **Water Bodies and Rivers (with 50 ft Buffer)**: Buffer zones were created using the Buffer tool to reflect statutory setbacks that restrict drilling near surface water features. These areas were excluded from potential siting areas to ensure compliance with environmental protection regulations.
- **Contaminated Sites (with 50 ft Buffer)**: Known superfund or brownfield sites pose risks for subsurface disturbance. Applying a 50 ft buffer mitigates risk by excluding zones where soil or groundwater contamination is likely. This layer does not include plumes extending offsite that may influence drilling feasibility and cost.

All constraint layers were merged using the Union and Dissolve tools to create a comprehensive Drilling Constraints Layer (Figure B-5), which was subsequently used as a mask to eliminate unsuitable areas from the TEN Suitability Layer via the Extract by Mask function.

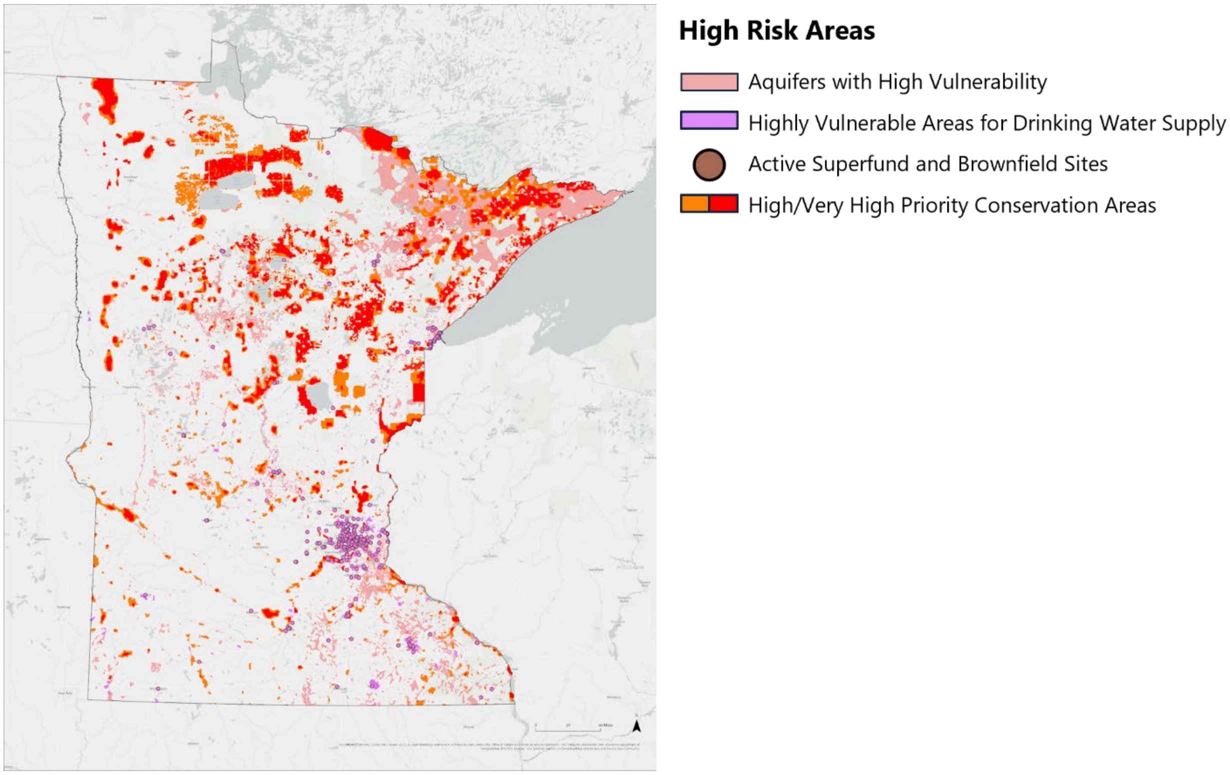

Figure B-5*. Drilling constraints layer of Minnesota.*

B.1.3 Population Density Filtering

To incorporate demand-side feasibility, a vector layer of census block data from the U.S. Census Bureau was mapped. Blocks were filtered based on population density thresholds of 1,000 to 5,000 (medium density) and >5,000 people per square mile (high density), representing areas with sufficient thermal demand potential to justify network investment. These thresholds are informed by precedent from existing district-scale TENs.

B.1.4 Hotspot Visualization

The refined suitability dataset was visualized as a heat map using the Kernel Density tool, highlighting “hotspots” of high thermal energy network siting suitability that also meet demographic demand criteria (Figure B-6). Kernel Density estimation creates a smooth, continuous surface of suitability intensity, enabling the identification of clusters of optimal sites for further feasibility assessment.

The ArcGIS Online webtool provides an interactive, statewide map with suitability hotspots as the default layer.

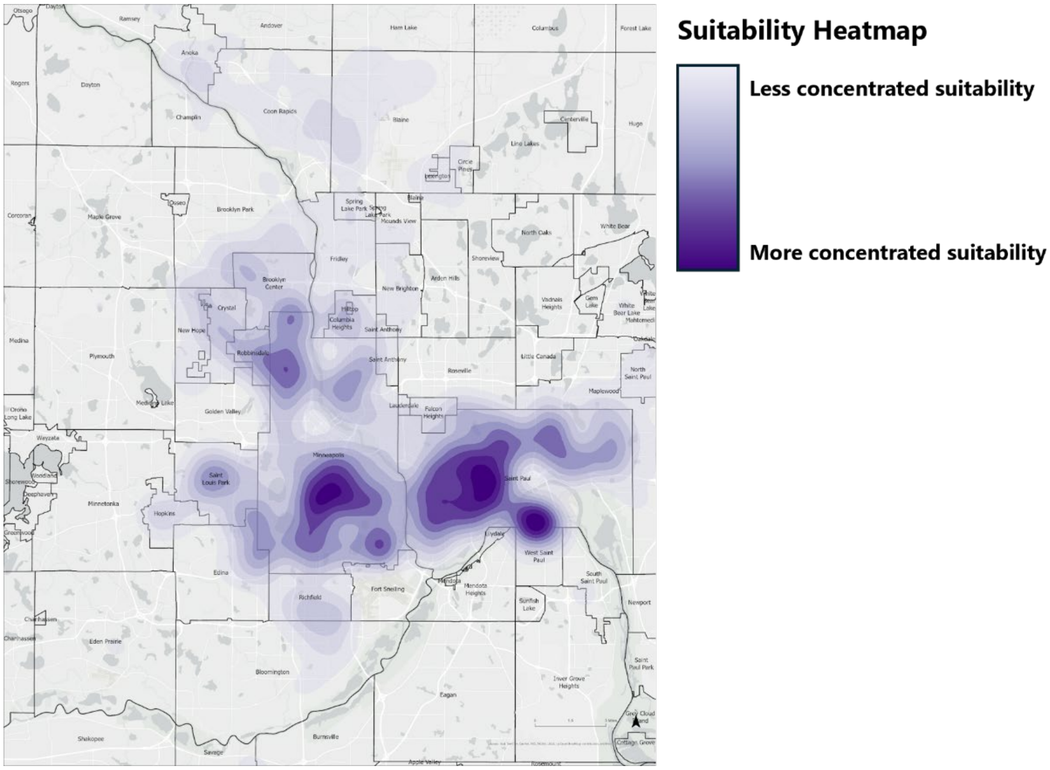

Figure B-6*. Hotspots for drilling suitability in Hennepin County, Minnesota.*

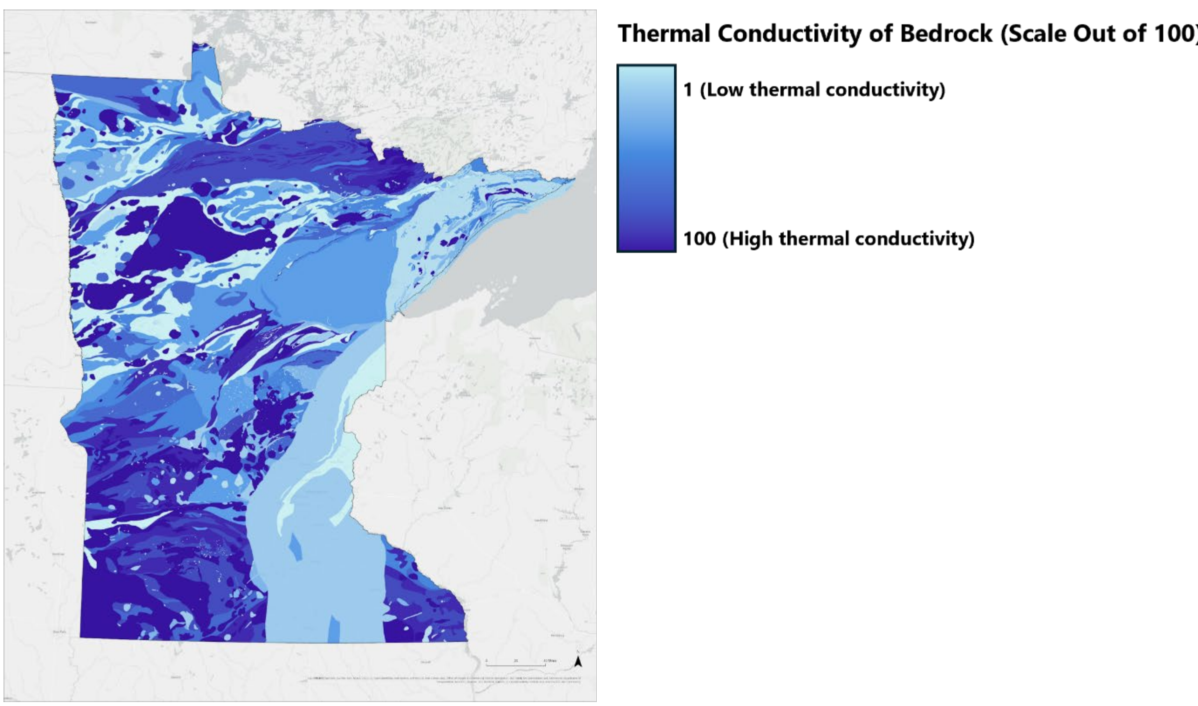

Figure B-7. *Bedrock thermal conductivity on a scale of 1-100.*

C Site Identification

To accurately evaluate the suitability of TEN development across Minnesota, a second level of geospatial analysis was completed to down-select specific sites and typical neighborhoods found across the State of Minnesota. Geospatial results were used in tandem with insights pulled from stakeholder engagement meetings to identify neighborhoods well-suited for TEN development and then characterize recurring elements found throughout them.

C.1 Site Opportunities and Neighborhood Typologies

While a key objective for this project is to identify the state-wide suitability for TENs, the detailed nature of the suitability scoring process requires specific sites to be reviewed in terms of their physical, infrastructural, and political viability. Thus, it was determined that the sites chosen for scoring should either be very specific site opportunities for TENs (e.g., expansion or greenfield construction projects) or sites representing neighborhood typologies that are commonly found across the State of Minnesota. These typologies assume that if a site scores well, any other similar neighborhoods found in the State could also be considered suitable for TENs. Specific site opportunities were determined based on both direct feedback from the community and stakeholder engagement meetings as well as identification of existing TENs that could be further expanded based on the surrounding building stock not yet included in an existing TEN.

D Quantitative Scoring Approach

D.1 Criteria and Indicators

Each criterion and indicator represent a key consideration in evaluating the suitability for a site to implement a TEN. A weighted scoring system was developed to quantify the relative strength of each site studied. The scores and weights of each of these indicators were then combined to produce a comprehensive net rating of each identified project site.

D.1.1 Borehole Accessibility and Construction

The viability of physically drilling and installing a borefield and TEN is a critical factor to consider in the early stages of evaluating project viability. First and foremost, sufficient land area, ideally open space, must exist in order to install a borefield. However, geothermal wells may be installed in dense urban areas under buildings prior to construction or even retroactively in building basements post-construction. In general, the surrounding area should ideally be free from an overburdened utility corridor, providing access for both vertical and horizontally installed pipes. The area surrounding the borefield should ideally have a high building density for efficiency and effectiveness of thermal exchange. Social and legal considerations should also be made around technical feasibility such as potential disruption to the community and barriers to securing permitting or customer offtake.

Indicators:

- Availability of area for borefields
- Concentration of utilities (buried and overhead)
- Traffic density
- Complexity of stakeholder coordination for open space access

D.1.2 Geologic Conditions and Thermal Conductivity

Geologic and hydrologic conditions determine where geothermal energy can be most efficiently injected or extracted to and from the ground. Areas with high heat flow and permeable rock formations are ideal for ground loop and hybrid well construction. Hydrogeologically, the presence of groundwater is essential for transferring heat from the surrounding rock to the working fluid within the closed loops. The interaction between geologic and hydrogeologic factors can create regions where thermal resources are ideally suited for TENs development. Understanding both geology and hydrogeology ensures safe, efficient, and long-term TEN balance. Bedrock Suitability is an indicator that considers aforementioned factors and ranks viability for drilling and thermal exchange on a percentile scale.

Indicators:

- Relative bedrock suitability

D.1.3 Load Characteristics

Load balance plays a crucial role in the viability of TEN development as it heavily impacts system efficiency and stability over time. A well-balanced load profile, with diverse building use types, ensures that heating and cooling demands are distributed throughout the day and across seasons, reducing peak loads and preventing system oversizing. Increased diversity of buildings, such as a mix of residential, commercial, industrial, and institutional (i.e. school or hospital) offtakers, increases the efficiency of a TEN by allowing for load cancellation and the use of waste heat. For example, waste heat from the processes of a brewery can be used to heat nearby residential buildings through a TEN. Load diversity also acts to stabilize the long-term performance of the system by minimizing changes to the temperature of the ground surrounding the TEN. Over time, imbalanced heating and cooling loads can change the temperature of the ground causing the efficiency of thermal exchange between the TEN and the ground to decrease to a point where the system is no longer viable. Without sufficient load diversity, the network may face inefficiencies, higher costs, and reduced long-term sustainability. Load density, or the concentration of heating and cooling prosumers, is also important for the performance of a TEN. Sources of heating and cooling must be in proximity to consumers of heating and cooling to minimize thermal losses.

Indicators:

- Load balance
- Load density

D.1.4 Environmental Constraints

Environmental constraints such as proximity to wetlands or areas with contamination can significantly affect the feasibility of TEN development. Wetlands often have strict regulatory protections, limiting drilling activities and increasing permitting complexity. Contaminated sites pose additional risks, as drilling could mobilize pollutants or require costly remediation measures during installation. These factors can lead to higher project costs, longer construction timelines, and reduced site availability, ultimately impacting the economic and technical viability of a TEN. Sites containing sensitive habitats or materials should ideally be avoided, and an environmental assessment is essential to ensure compliance and minimize ecological impact.

Indicators:

- Proximity to wetlands/permitted jurisdictions
- Proximity to subsurface environmental contamination

D.1.5 Behind-the-Meter Costs and Complexity

Beyond the technical considerations of developing the system, a key challenge to implementing TENs is the site-specific building and community conditions that may require retrofits for network compatibility. Existing buildings may have non-ducted, aging, or incompatible HVAC systems, or may have poor building envelope performance – requiring costly retrofit upgrades to transform them into effective participants in a larger shared energy network. Conversely, regions with strained electrical capacity represent opportunity sites as TENs lower peak electrical demand and represent the most energy efficient method of heating and cooling.

Indicators:

- Building stock quality
- Existing HVAC system
- Capacity for electrical demand

D.1.6 Opportunistic Thermal Resources

Opportunistic thermal resources such as data centers, ice rinks, breweries, manufacturing facilities, wastewater treatment plants, and large supermarkets can greatly enhance the viability of TENs. These facilities often produce significant amounts of waste heat or have cooling demands that can be integrated into the network, improving overall energy efficiency. By leveraging these resources, the system can reduce reliance on primary geothermal heat extraction, lower operational costs, and increase resilience through diversified energy inputs. Additionally, incorporating waste heat recovery supports sustainability goals and can make projects more attractive to stakeholders. Without these synergies, the network may require larger borefields and higher capital investment.

Indicators:

- Opportunistic thermal resources

D.1.7 Disadvantaged Communities

Siting TENs within disadvantaged communities represents an opportunity to develop cutting edge infrastructure within a community that has historically been underserved and/or experienced underinvestment. These areas often qualify for enhanced incentives, grants, and policy support aimed at promoting energy equity and reducing environmental burdens. Integrating TENs in these communities can also deliver long-term social benefits, such as lower energy costs and improved resilience, which strengthen stakeholder support. Ultimately, thoughtful planning and engagement are essential to balance technical, economic, and social considerations necessary for successful implementation.

Indicators:

- Development within a priority community

D.1.8 Viability for Future System Expansion

The ability to expand a TEN in the future is a key factor in its initial viability. Designing for scalability ensures that the system can accommodate growing demand for new buildings without requiring major redesigns or costly retrofits. If expansion potential is limited by land availability, borefield constraints, or infrastructure capacity, the long-term economic and operational benefits of the network may be reduced. Conversely, planning for modular growth can improve investor confidence, enhance resilience, and maximize the return on initial capital investment. Future-proofing the system through flexible design is essential for sustainable development.

Indicators:

- Physical expansion

D.2 Scoring Rubric

Each suitability indicator was given a discrete quantitative score based on how it measured through geospatial or other desktop review. Some indicators that map directly to quantitative ranges were broken into percentile scores between 1 and 100. Indicators that are binary in nature were broken into a score of either 0 or 100. Indicator scores were evaluated based on Table D-1.

***Table D-1**. Indicator scoring rubric used to inform site suitability results.*

Availability of Area for Borefields		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
100	Complete or easy accessibility	Site has flat terrain, plenty of existing open space, minimal permitting hurdles, and/or low environmental impact. Costs are low and predictable.
75	Good accessibility	Site has manageable terrain, some open space, minimal permitting hurdles, and environmental impacts are controllable. Costs are moderate.
50	Some accessibility	Site has manageable terrain, some open space, permitting may be complex, and environmental concerns require mitigation. Costs are high but feasible.
25	Little accessibility	Site has challenging terrain, limited open space, permitting is uncertain or difficult, and environmental concerns are likely. Costs are high and unpredictable.
0	No or unknown accessibility	Site has challenging terrain, limited open space, permitting is uncertain or difficult, and environmental impacts are prohibitive. Costs are prohibitive or unknown.

Concentration of Utilities (Buried and Overhead)		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
100	No major utilities	Necessary rights-of-way are clear of potential utility obstructions
50	1-2 major utilities	Rights-of-way are likely to include one or two existing utilities such as major roads and/or sewer lines
0	3 or more major utilities	Rights-of-way are likely to include three or more utilities such as major roads and/or sewer lines

Traffic Density		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
100	Non-pedestrian area	No noticeable pedestrian or vehicular presence.
75	Low density	Sparse pedestrian and vehicular activity. Area is primarily residential or industrial with limited destinations or transit access.
50	Moderate density	Noticeable pedestrian and vehicular presence during peak hours, but low during off-peak. Area may include residential zones with some commercial or transit access.
25	High density	Steady pedestrian and vehicular activity during most hours. Area includes mixed-use developments, schools, or popular retail corridors.
0	Extreme density	High pedestrian and vehicular activity. Area likely to be urban or downtown.

Complexity of Stakeholder Coordination for Open Space Access		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
100	Easy	A single municipal or commercial owner.
50	Semi-Easy	Moderate number of commercial or residential owners.
0	Semi-Difficult	High number of unique commercial or residential owners.

Relative Bedrock Suitability		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
0 - 100	Percentile ranking	Factored based on bedrock typology, thermal conductivity, and groundwater flow rate
Load Balance		

Quantitative Score	Qualitative Score	Scoring Metric
100	80% or less heating dominant	Building stock can maintain a relatively balanced heating and cooling load year over year
50	80% to 90% heating dominant	Building stock exhibits typical heating dominance found in climate zones like Minnesota
0	>90% heating dominant	Building stock is overly heating dominant and unbalanced

Load Density		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
100	Highly diverse and dense	Site has a high percentage area of site occupied by energy-consuming buildings
50	Moderately diverse and dense	Site has a moderate percentage area of site occupied by energy-consuming buildings
0	Less diverse and dense	Site has a low percentage area of site occupied by energy-consuming buildings

Proximity to Wetlands / Permitted Jurisdictions		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
100	No concerns within proximity	Site is located at a safe distance from any kind of environmental concern
0	Concern within proximity	Site infringes upon a wetland or other critical wildlife habitat

Proximity to Subsurface Environmental Contamination		
Quantitative Score	**Qualitative Score**	**Scoring Metric**

100	No concerns within proximity	Site is located at a safe distance from any kind of significant contamination
0	Concern within proximity	Site infringes upon a significant contamination area

Building Stock Quality		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
100	Newer building stock	Site primarily contains buildings constructed or renovated within the last 10 years
66	Mixed age building stock (majority new build)	Site contains a mix of building ages with most being constructed or renovated within the last 25 years
33	Mixed age building stock (majority old build)	Site contains a mix of building ages with most being constructed or renovated within the last 45 years
0	Older building stock	Site primarily contains buildings that were constructed at least 50 years ago

Existing HVAC System		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
100	Good	HVAC systems include existing ductwork and either air or ground source heat pumps
50	Average	HVAC systems include either existing ductwork or air/ground source heat pumps
0	Poor	HVAC systems include neither existing ductwork nor air/ground source heat pumps

Capacity for Electrical Demand		
Quantitative Score	**Qualitative Score**	**Scoring Metric**

100	Limited constraints	The surrounding electrical grid has ample capacity to support a thermal energy network, infrastructure is modern, and interconnection is anticipated to be straightforward
50	Moderately constrained	The surrounding electrical grid has capacity to support a thermal energy network, but some upgrades may be required, and interconnection may involve moderate delays
0	Highly constrained	The surrounding electrical grid does not have capacity to support a thermal energy network, and significant upgrades and delays would be required to achieve interconnection

Opportunistic Thermal Resources		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
100	Strong availability	One or more large, naturally occurring thermal reservoirs nearby, accessible, and suitable for network integration OR Several significant waste heat opportunities exist within the study area and are accessible and suitable for network integration
50	Some availability	A reservoir exists but is limited in size, proximity, and suitability for integration OR At least one significant waste heat opportunity exists within the study area and is accessible and suitable for network integration
0	Little to no availability	No suitable reservoirs or waste heat opportunities are present within the study area

Development Within a Priority Community		
Quantitative Score	**Qualitative Score**	**Scoring Metric**

100	Site is within a priority community	Community surrounding the site is a designated Environmental Justice Area. ≥40% identify as people of color, ≥35% are economically disadvantaged, and/or ≥40% of the population has limited English proficiency.
0	Site is not within a priority community	Community surrounding the site is not a designated Environmental Justice Area.

Physical Expansion		
Quantitative Score	**Qualitative Score**	**Scoring Metric**
100	Highly likely	Network expansion is highly favorable and is supported by local zoning and permitting, surrounding infrastructure, and support from additional stakeholders
50	Somewhat likely	Network expansion is possible but faces moderate constraints such as rezoning, infrastructural upgrades, and/or additional stakeholder engagement
0	Unlikely	Major infrastructural, regulatory, and/or social barriers exist to expanding an initial development

E Stakeholder Engagement

To understand factors influencing TENs implementation in Minnesota, the Project Team held 28 interviews with 35 individuals from diverse stakeholder groups and organizations. These stakeholder groups and organizations represented local governments, campuses, union workers and other individuals involved in professions involved with TENs, geothermal technology, contractors, utilities, and community organizations. Interviewees had ranging experience with TENs, and were either involved with existing TEN projects, considering TEN projects, or represented a stakeholder group in the community known for their involvement in studying the barriers and opportunities around TENs development. A full list of the individuals and organizations who were interviewed is provided in Table E-1.

Individuals and organizations were identified through literature review, from information about where TENs lie across the state, industry involvement, and at the request of the Department of Commerce. The findings from these interviews informed the qualitative factors assessed in the scoring of TENs.

***Table E-1**. List of individuals and organizations interviewed for stakeholder feedback.*

Organization and Interviewee	Group
Midwest Building Decarbonization Coalition, Jacob Serfling	Advocate
Resilience and sustainability nonprofit	Advocate
City of St. Paul, Russ Stark	City
City of Minneapolis, Luke Hollenkamp and Megan Hoye	City
City of Rochester, Scot Ramsey	City
City of Crookston, Taylor Wyum	City
Unidos St. Paul, Chelsea DeArmond, Madi Johnson, and Jean Comstock	Community Organization
Rochester Destination Medical Center, Lauren Jensen	Community Organization
COPAL, Monse Perez Barrios	Community Organization
Salas O'Brien, Brian Urlaub	Design/build
International District Energy Association / FVB Energy, Mark Spurr	Design/build
Ever-Green Energy, Michael Ahern and Ken Smith	Design/build
Cordia, Wayne Barnett and Stuart Deets	Design/build
LHB, Rick Carter and Mike Fischer	Design/build
Commercial real estate developer	Design/build
Darcy Solutions, Robert Ed	Equipment

Organization and Interviewee	Group
Minnesota Climate Innovation Finance Authority	Finance
Fond Du Lac Band of Lake Superior Chippewa, Bruno Zagar	Native Nation
Carleton College, Facilities Department	Owner
Mayo Clinic, Brett Gorden	Owner
Minnesota Department of Commerce, Michael Zajicek and Ari Zwick	Policy
Xcel Energy, David Podorson	Utility
CenterPoint Energy	Utility
Traut Companies, David Traut	Workforce
Minnesota Pipe Trades Association, Andrew Campeau	Workforce
Cooperative Energy Futures, Paolo Speirn	Workforce
Geothermal Drillers Association, Brock Yordy	Workforce
International Ground Source Heat Pump Association, Jeff Hammond	Workforce

F Interview Guides

F.1 Existing TENs Projects

Overview:

Before we jump into questions, could you just cover your background as it relates to thermal energy network projects in general?

History – General

1. Walk us through the history of your project: its impetus and formation (goals and drivers).
2. How was the project evaluated for technical and economic feasibility?
    - Was feasibility assessed internally?
3. What were the main opportunities this project opened for you and what were the main challenges?

Economics, Ownership, and Operations

4. Have there been economic challenges for this project?
5. Who owns the TEN / what ownership model best describes your thermal energy network (municipal, cooperative, third-party, etc.) and who makes decisions?
    - What influenced this decision?
    - OR what are the benefits?

- **Optional follow-ups:**
    - Were there any regulatory, permitting, zoning, or other constraints that affected your choice of ownership model?
    - Was the choice of ownership model influenced by outside factors such as community needs, organizational goals, municipal climate plan, etc.?
    - How did you determine your rate structure (if there is one)?

Community and Stakeholder Relations

6. How much community/stakeholder involvement was there leading up to the project? How did it go? Are there particular topics that resonated better with the community? e.g., safety, emissions, utility costs?
7. What strategies have you employed for continued community engagement and education about the TEN?

- **Optional follow-ups:**

    - How has the local community responded to your TEN? Any concerns about ownership structure?
    - How have individuals, community groups, HOAs, neighborhood associations reacted?
    - [for private ownership] how do you navigate relationships with local government? Private utilities?
    - How has the ownership group or ground source heat pump (GSHP) manufacturers involved supported marketing of the project in pre/construction/operational phases?

Technical and Workforce Considerations

8. How was managing the workforce and supply chain for this project? Did you run into any issues?
    - **Optional follow-ups:**
        - Was it hard to attract or hire technical expertise?
        - Was it hard to attract or hire administrative expertise?
        - Did you work with labor unions or institute project labor / peace agreements?
        - What role did existing infrastructure (e.g., rights of way, thermal resources) play in your development process?
        - Were there any technical aspects that led to the selection of the design and GSHP / heat transfer technologies for this project?
        - Should the network continue to scale with additional buildings or with extensions to the loop, do you anticipate the ability for interoperability with other GSHP manufacturers?

Looking Forward

9. What do you wish you had known when you started (FOR FINISHED/In Progress PROJECTS)
    - If you had to do it again, what would you have done differently?
10. What would make you consider this a success? Would you have the same success factors on a future project?
11. What advice would you give to others considering developing a TEN in Minnesota?
12. Are there any key people we should talk with or key data sources you think are important for this study in MN?
13. What information from this study would be useful to you to help you with your thinking about pursuing another TENs project?

F.2 Project Stakeholders

[interviews catered to Sustainability Managers, Property Owners, Community-Based Organizations]

General

1. How familiar are you with Thermal Energy Networks?
2. What kinds of engagement and discussion have happened about TENs in your community?
3. Is this something your community would be interested in pursuing?
4. What are the benefits or barriers of a TEN that you're thinking about?

   - **Optional follow-ups:**
     - What are the main opportunities you see in making this a reality?
     - What are the initial challenges and barriers you foresee needing to be overcome?
     - How would they align with your overall sustainability goals?
     - What other energy priorities or challenges do your community currently face?
     - Do you see thermal energy networks as complementing or competing with other energy initiatives underway in your area?
     - Are there specific sectors (e.g., affordable housing, schools, healthcare facilities) that should be prioritized for connection to a TEN?

Community and Stakeholder Relations

5. What have you heard from community members and stakeholders? Which members/stakeholders are most present/vocal?
6. Who would need to be at the table to make this project viable in your community?
7. What community engagement and education strategies have you used or been involved with regarding clean energy projects if you have not done anything with TENs?
8. What equity considerations should be prioritized in the planning and implementation of a TEN? How are you reducing barriers to participation?

   - **Optional follow-ups:**
     - What concerns have you heard (if any) from residents or businesses about clean energy projects?
     - How would you describe trust levels between the community and energy developers/utilities?
     - Do you think there's some existing understanding in the community about how thermal energy works or its potential benefits?

Economics and Ownership Considerations

There are several different ownerships (municipal, cooperative, utility, third-party, etc.) models for TENs.

9. What ownership model(s) would you like to see if there were a thermal energy network (in your city, project site, community)?
10. Do you or your organization have prior experience working with utilities or third-party energy service providers? If so, how has that shaped your views?

- **Optional follow-ups:**
  - Are there any regulatory, permitting, zoning, or other constraints that you know of that affect your preferences for ownership models?
  - How important is local control or community ownership to your stakeholders?
  - What kind of transparency or accountability would you expect from an entity operating a TEN?
  - What policy or funding support do you think would be necessary to make a TEN successful here?

Technical and Workforce Considerations

11. How could a thermal energy network support local workforce development or training initiatives?
12. Are there local workforce pipelines (e.g., unions, training centers, community colleges) that could be leveraged?
13. How important is it that a TEN provides jobs or business opportunities for local or disadvantaged communities?

Looking Ahead

14. Are there any key people we should talk with or key data sources you think are important for this study in MN?
15. What information would be useful to you to help you in your thinking about pursuing a TENS or in implementing one?

F.3 Local Governments Contemplating Projects

Overview:

Before we jump into questions, do you mind providing your background as it relates to thermal energy networks? Have you any experience with geothermal heat pumps in individual buildings? Any experience with district energy systems?

History – General

1. Walk us through what you are hoping to do and where (goals, drivers).

2. What are the main opportunities you see in making this a reality?

3. What are the initial challenges and barriers you foresee needing to be overcome?

Economics, Ownership, and Operations

4. What are or what do you think will be the economic challenges for this project?
5. What is the planned ownership (municipal, cooperative, third-party, etc.) and decision-making model? How did you or do you plan to evaluate or make that decision?

    - What is influencing this decision?
    - OR what are the benefits?

  - **Optional follow-ups:**
    - Who has decision-making authority and how will you handle decision-making processes for system upgrades or expansions?
    - Are there any regulatory, permitting, zoning, or other constraints that are affecting your choice of ownership model or TENs design?
    - Is the choice of ownership influenced by outside factors such as community needs, organizational goals, municipal climate plan, etc.?
    - How will you determine your rate structure (if there is one)?

Community and Stakeholder Relations

6. How much community/stakeholder involvement do you have planned leading up to the project?
7. What strategies have you employed for continued community engagement and education about the TEN?

  - **Optional follow-ups:**
    - How has the local community responded to your TEN at this point? Any concerns about ownership structure?
    - [If looking at private ownership] how do you navigate relationships with local government? Private utilities?
    - How has the ownership group or GSHP manufacturers involved supported marketing of the project in pre/construction/operational phases?

Technical and Workforce Considerations

8. Do you anticipate any workforce and supply chain issues with this project? Have you run into any issues at this point?

  - **Optional follow-ups:**

- Has it been or do you anticipate it being hard to attract or hire technical expertise?
- Has it been or do you anticipate it being hard to attract or hire administrative expertise?
- Did you plan to work with labor unions or institute project labor / peace agreements?
- What role does existing infrastructure (e.g., rights of way, thermal resources) play in your development process?

Looking Forward

9. What would make you consider this a success?
10. What advice would you give to others considering developing a TEN?
11. Are there any key people we should talk with or key data sources you think are important for this study in MN?
12. Do you know if the city is planning any zoning changes?
13. Are you currently receiving federal funds for weatherization assistance? If so, how is it being used? Have you thought about how it might support your geothermal project goals?
14. What information would be useful to you to help you in your thinking about pursuing a TENS or in implementing one?