A National Network of Geothermal Drilling Centers of Excellence:

Supporting an Equitable Transition to Clean Energy

Acknowledgments

The Geothermal Market Capacity Coalition gratefully acknowledges the writing and editorial services of Asha Nigh from Science Editors Network, Stacy Kinnaly from HEET, Laura Calderon from Laura Calderon and Associates, and Lisa Lipe from the International Ground Source Heat Pump Association.

Copyright & Contact

If you have questions or would like to follow up with any member of the Geothermal Market Capacity Coalition, please email info@heet.org.

On the cover from left: The street in front of a home in Framingham, Mass., is marked where a geothermal service line runs from the street to a ground source heat pump in the house; geothermal pipes staged and ready to be installed in the street; a geothermal valve indicating the location of a borehole. [Photos: HEET]

Contents

Executive Summary

Geothermal energy networks and ground source heat pumps (GSHPs) have emerged as integral components in the shift toward sustainable energy in the United States (MIT review, DOE report). Although these technologies are widely used in many parts of the world, critical labor and supply chain shortages are interfering with their deployment in the U.S. The industry needs to quickly adapt in order to meet the unprecedented scale and speed of deployment that is expected for these technologies.

The Geothermal Market Capacity Coalition (GMCC) aligns industry stakeholders to relieve supply chain, knowledge, labor, and capacity shortages that are stifling growth. This will be accomplished through establishing regional Geothermal Drilling Centers of Excellence (Geo-CoEs), beginning in the Northeast, that will relieve the shortage of geothermal drillers and drill rigs needed to produce ground heat exchangers. Addressing this critical bottleneck is the first step towards rapid and sustainable growth in the GSHP sector and in geothermal energy networks.

Value Proposition

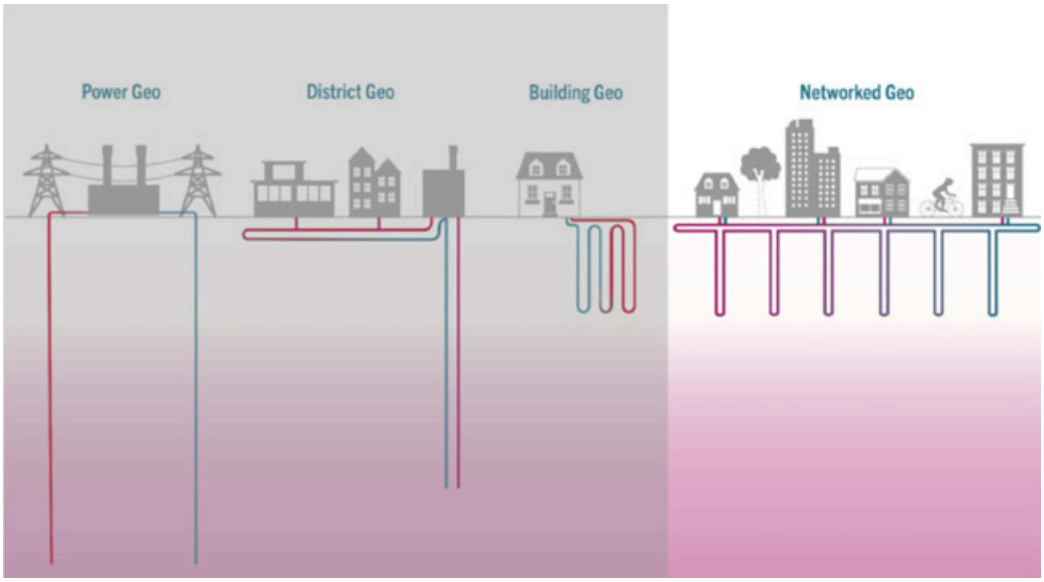
Electrifying building heating and cooling is a critical step towards meeting national greenhouse gas reduction targets. In 2021, over half of the homes and businesses in the United States were heated using fossil fuels. Meanwhile, building cooling demand is rising as the summers warm. This presents a potentially overwhelming load increase for the electricity grid—particularly during the hottest and coldest days of the year—and a very large market opportunity for geothermal technologies.

Powerful tools for transitioning away from fossil fuels, shallow geothermal technologies harness the Earth's constant underground temperature and are the most efficient path toward electrification of both heating and cooling. GSHPs have coefficients of performance (COP) that are more than twice as high as those of air source heat pumps (ASHPs) and excel in extreme weather conditions, meaning they demand less electricity during the hottest and coldest days and thermal components are buried out of harm's way. Geothermal energy networks, which are centrally managed systems of interconnected GSHPs and thermal energy exchangers, can improve average annual system performance up to six times over the most efficient gas furnaces on the market today and further flatten seasonal electricity loads.

Utility-led installations of geothermal energy networks can quickly move many consumers to clean energy at once, spreading the cost among utility ratepayers and ensuring that low-income consumers are not left behind. Recognizing the potential of shallow geothermal technologies, state and federal programs (including the Inflation Reduction Act) offer generous incentives to install GSHPs, and utilities in states like

Massachusetts and New York are installing demonstration geothermal energy networks (also known as networked geothermal systems—see *geothermal energy networks* in Appendix 2 for additional synonymous terms). Annual growth rates of between 4% and 10% over the next few years are predicted for installed geothermal capacity (GeoVision analysis, Grand View Research).

Transitioning to thermal technologies will combat climate change, enhance public



"Geothermal" is a broad term that encompasses a range of technology applications, including electricity generation (far left). The focus of this paper are the two segments on the right, shallow, low temperature geothermal. (Source: HEET)

health, increase the nation's energy independence, and establish a dependable and secure source of heating and cooling. Significantly, GSHP installers and gas utilities deploying geothermal energy networks in the Northeast have encountered a severe shortage in regional capacity to deploy GSHPs to meet demand (LeGUp research project). The Geo-CoE initiative will relieve the inhibiting supply chain, labor, and skill shortages, and support the industry transformation needed to electrify at the speed and scale required.

Intended Assets of a Geothermal Drilling Center of Excellence

Physical Assets

- Geothermal drilling tools & equipment
- Workspace
- Training classrooms
- Field training and test sites

Knowledge Assets

- Worker skills training & curricula
- Technical & engineering
- Project finance & funding sources
- Business models
- Regulatory & policy

Relationship Assets

- Industry connectivity - increases information transfer
- Subject matter expertise networks - improves quality
- Social capital - increases mutual support between drillers

Source: HEET

Approach

The GMCC proposes to establish a nationwide network of Geo-CoEs that will help the industry meet market demand for GSHPs, thereby furthering the myriad health, social, economic, and energy benefits of geothermal energy networks. At the core of the GMCC's mission is a commitment to facilitating an equitable transition away from fossil fuels. The specific objectives of the Geo-CoEs are to:

1. Provide geothermal drillers and other workers with comprehensive training and development programs, including wraparound supports, transition training, and startup capital as needed, to professionalize the workforce
2. Develop innovative drill rig leasing programs and other financing tools to overcome barriers to growth
3. Catalyze domestic manufacturing capacity and sustainable innovation of geothermal equipment, including drilling technologies
4. Seek additional opportunities to drive sustainable growth and innovation

across the industry, e.g., attract capital investments, build a knowledge base, develop cross-industry alignment, ease additional bottlenecks to GSHP deployment throughout the supply chain, and realize industry-wide market potential.

Our first step is to establish a Geo-CoE in the Northeast. This center will expand the regional geothermal workforce, increase the availability of needed geothermal drill rigs, and standardize the process for assembling geothermal exchangers—all critical limitations to deploying GSHP technologies in the region.

The Geo-CoEs will also actively support the launch of new geothermal projects by enabling financial assistance and sharing open-source databanks and other resources.

Goals and Timeline

The launch of the Northeast Geo-CoE, slated for January 2025, will serve as a model for future centers planned throughout the country. Importantly, the Northeast Geo-CoE will consolidate relationships between large players in the space, including companies installing GSHPs and utilities deploying geothermal energy networks. By engaging with local communities, organizations, legislators and regulators in each Geo-CoE region, the GMCC will ensure that responsible and beneficial employment and community engagement practices are put into place, aligning with the specific needs of each region. Exploratory activities may include workshops to identify gaps, solutions and workforce constraints; educational events with partner community and labor organizations; use of case studies from other states integrating workforce and unions; and local assessment of schools interested in future training opportunities.

Team Composition

The composition of the GMCC team reflects the diverse stakeholder base that will be affected by the GSHP market (see Appendix 1) and is key to the success of the Geo-CoE initiative. The team includes leading GSHP manufacturers, contractors and geothermal drillers; trades groups; and educational, environmental, and advocacy organizations. Our coalition is further strengthened by allies from various communities, local governments, labor and professional sectors, and gas utilities, reflecting a multi-faceted approach that is key to the geothermal sector's development. Finally, in planning for the Northeast Geo-CoE, coalition members are consulting with Massachusetts Clean Energy Center (MassCEC), New York State Energy Research and Development Authority (NYSERDA), New York State Department of Environmental Conservation (DEC), ten state regulators, and Connecticut Department of Energy and Environmental Protection (DEEP). The GMCC will continue to recruit diverse members that engage our entire stakeholder base.

Impacts of the Approach

With higher COPs than air source heat pumps, GSHPs—and centrally managed geothermal energy networks—are key to flattening annual peak energy demands and meeting the country's energy security needs (MIT). In a 2023 report, the Department of Energy (DOE) estimated that 68% GSHP market penetration would result in cumulative emissions reductions of 7,351 million metric tons CO2e and an undiscounted savings of $1 trillion by 2050 (DOE). To capitalize on these benefits, domestic capacity will need to grow by 640% above current production rates.

The Geo-CoE initiative advances these goals by:

- Increasing the market share of GSHPs and promoting shallow, networked geothermal technologies where appropriate
- Achieving a 3- to 5-fold increase in production capacity of GSHPs in the Northeast by 2028, supporting U.S. and state emissions reduction goals and aligning manufacturing supply chains
- Creating a minimum of 100 construction, technology, or clean energy jobs throughout the GSHP and networked geothermal workspace over the next 36 months
- Improving the local availability of fair wage jobs, and promoting diversity, equity and inclusion by increasing the participation of women and underrepresented minorities in the manufacturing workforce and in small business ownership
- Improving resilience of critical infrastructure and reducing demand on the electricity grid, particularly during peak heating and cooling days
- Reducing emissions and helping reach state and national decarbonization goals

The Geo-CoEs will enhance economic competitiveness by creating jobs, stimulating local industries, and fostering cooperation and innovation. The approach has the potential to serve as a model to address scaling and quality control with this cutting edge technology that requires mobile, site-specific manufacturing.

Stakeholders impacted by a regional Geothermal Drilling Center of Excellence

Outcomes

In response to increasing demand for GSHPs and geothermal energy networks, the GMCC is establishing Geo-CoEs across the United States aimed at accelerating the

sector's growth, enhancing market capacity, and promoting a culture of innovation and

Natural gas utilities	Electric utilities	Municipally-owned utilities	Gas utility workers
Startups & early-stage companies	Feasibility study engineering firms	Design engineering firms	Construction firms
Geothermal HVAC & heat pump installers	Investors	Academia/ researchers	Regulators
State governments	Local governments & communities	Environmental justice communities	Nonprofits & climate organizations

collaborative knowledge sharing. Collectively, the Geo-CoEs will bolster, refine, and expedite national scaling of the GSHP sector through three pillars:

- Equitably recruiting and training the qualified workforce required to meet projected demand
- Easing supply chain shortages needed to support rapid growth
- Nurturing innovation and knowledge-sharing to meet new realities in the market

Through this national network of Geo-CoEs, the GMCC aims to become a catalyst in the emerging shallow geothermal technologies marketplace, enabling growth, innovation, and sustainability through collaborative partnerships.

PHASE 1 OF GEO-COE ROLLOUT: Northeast Geothermal Drilling Center of Excellence

Establishing Mobile Thermal Exchanger Manufacturing Platforms for Ground Source Heat Pumps

Overview

All heat pump systems (air source, ground source, or water source) consist of two components: a heat pump and a thermal exchanger that supplies the heat pump. The thermal exchanger for air source heat pumps, called a condenser, can be manufactured in a traditional factory and shipped to consumers, whereas the thermal exchanger for ground source heat pumps (which consists of boreholes, grout, pipes, and couplers) must be assembled in-ground near the site of installation. It is impossible to build a factory to produce thermal exchangers because they must be assembled at the construction site by drillers. The most critical bottleneck to growth of the GSHP market in the Northeast is a shortage of qualified geothermal drillers and specialized drill rigs. To professionalize and scale the manufacturing of thermal exchangers, the Geo-CoE will create mobile platforms consisting of thermal exchange manufacturing equipment and trained personnel (Mobile Thermal Exchanger Manufacturing Platforms, or M-TEMPs) that can be deployed to build thermal exchangers where needed.

The GMCC proposes to create a Geo-CoE over the next 36 months, at a cost of $30 million, that will operate in Massachusetts, New York, and Connecticut with the capacity to serve the region. Since the production of heat exchangers is currently dominated by small businesses using varied equipment and expertise, scaling will require optimization and standardization of equipment and a new model of workforce training that can both support the growth of existing players and rapidly scale the number of standardized M-TEMPs.

The goals of this first Geo-CoE are to:

1. Increase production capacity of GSHPs 3- to 5-fold in the Northeast by 2028, supporting U.S. and state emissions reduction goals
2. Improve the local availability of fair wage jobs and promote diversity, equity and inclusion by increasing the participation of women and underrepresented minorities in the GSHP manufacturing workforce and small business ownership
3. Create a minimum of 100 construction, technology, or clean energy jobs throughout the GSHP and networked geothermal workspace
4. Increase the number of GSHP and networked geothermal installations by improving access to capital for deployment to communities and utilities

Market Overview

GSHP installations occur at a rate of around 70,000 per year (around 2% of total heat pump sales), and the industry has grown at roughly 3% per year. The Geothermal Technology Office's GeoVision analysis concluded that the U.S. market would expand consistently through 2050 at a conservative estimated compound annual growth rate of 4.3-5.4%.

Net zero emissions goals in the Northeast support even stronger growth predictions (15%) for the region. Massachusetts and New York, for example, have set ambitious targets to electrify 1 million homes by 2030. Both states have mandated that all utilities submit plans for piloting geothermal networks, and Massachusetts gas utilities Eversource and National Grid are deploying the first utility-scale geothermal networks in the country, transitioning whole neighborhoods at once. Other states, such as Connecticut, also have net zero goals, and Philadelphia is evaluating transitioning its municipal utility to a thermal utility. Currently, nine Northeast gas utilities are installing or proposing to install networked GSHPs as an alternative business model. These factors substantiate the Northeast as the site for the inaugural Geo-CoE.

Assuming GSHP market penetration remains under 5% of heat pump totals, GSHP installations in the Northeast need to increase annually by three-to-five times to meet these electrification goals. Market penetration by GSHPs is limited by production constraints rather than poor demand. Northeastern states provide financial incentives to consumers installing GSHPs; they are also promoting utility-scale installations (geothermal networks) as a way to meet their decarbonization goals. Long wait times and non-standard production of thermal exchangers means that GSHP deployment rates lag behind demand. The entry of large-scale players is leading to market transformation, fostering standardization and increasing the competitive position of GSHPs in the market.

The Northeast Geo-CoE is well-positioned to capitalize on this market growth potential. Our network of heat pump manufacturers, geothermal drillers, cross-sector advocates, and purchasers is aligned behind the Geo-CoE concept to standardize and scale thermal exchanger production.

Approach

The Geo-CoE for the Northeast will be launched in a distributed approach in January, 2025, with three pilots:

Pilot 1: Optimize and standardize thermal exchange workforce training

HEET has partnered with Brock Yordy, a driller and coach experienced in delivering training at scale in union and military settings, to pilot a M-TEMP workforce training initiative in Massachusetts beginning this summer (2024). Over the next 36 months, we will recruit at least 30 students (over 40% from underrepresented groups) into the pre-apprenticeship program. The International Ground Source Heat Pump Association (IGSHPA), the National Ground Water Association (NGWA), union trainers, and local community colleges are designing online and classroom curricula which will be supplemented by hands-on programming. The pilot will place at least 10 graduates in Northeast GSHP-installer apprenticeships and follow them through certification, supporting their training as needed and collecting data on their progress. The goal is to develop recruitment and training materials, training standards, and wraparound supports that can be scaled to train a local workforce where M-TEMPs are needed for networked geothermal projects. This pilot will serve as a template for future Geo-CoE training programs.

Pilot 2: Develop optimal specifications for M-TEMPs

The Geo-CoE will purchase drill rigs and other manufacturing equipment, making them available for training and for lease or purchase to certified geothermal drillers. We will track output, performance, usage, and quality for each rig. The goal of this pilot is

A shortage of qualified geothermal drillers and specialized drill rigs is the most critical bottleneck to growth of the GSHP market in the Northeast. Geo-CoE will create mobile platforms consisting of thermal exchange manufacturing equipment and trained personnel—like those pictured above—that can be deployed to build thermal exchangers where needed. [Photos courtesy of Eversource.]

to develop data-driven standards for thermal exchange manufacturing equipment, and develop standard operating procedures (SOP) for equipment maintenance, innovation, and quality improvement.

Pilot 3: Deployment of a single M-TEMP in Westchester, NY

Sustainable Westchester aims to launch the Geo-CoE's first M-TEMP—including a drill rig for thermal exchange assembly, workforce training programming led by community colleges and unions, and a drill rig leasing program (note: Current Drill Rig Manufacturer RFP). Working with partners such as the Coalition for Green Capital (CGC) or state green banks, the GMCC will test financing tools that could make drill rigs immediately available to regional drillers for rent, lease, or purchase. The goals of this pilot are to understand the deployment challenges to scaling M-TEMPs and to develop innovative models for increasing the regional capacity to support large-scale networked geothermal projects.

Operationalize a Geothermal Drilling Center of Excellence for the Northeast

The GMCC will appoint a director of the first Geo-CoE who will lead the industry transformation needed to meet projected regional GSHP demand. Building on the three pilots above, the Geo-CoE will support deployment of additional M-TEMPs by:

- Establishing scalable training programs and standard procedures for geothermal exchanger production
- Increasing access to M-TEMP equipment through supply chain innovation and improved financial tools
- Developing M-TEMP certification and support mechanisms. The Geo-CoE will aim to deploy 60 additional M-TEMPs within the first 3 years of operation, which will support a 3- to 5-fold increase in GSHP deployment in the region.

Develop financial tools to support market expansion

The GMCC will partner with financial organizations such as the CGC to finance projects in the area, including equipment leasing programs for M-TEMPs, loans for drill rig manufacturing companies, and support for utility-led networked geothermal projects planned for deployment in the Northeast. The Geo-CoE is considering implementing a $250 million loan program that will facilitate and expedite networked geothermal projects across the Northeast. These tools would address the immediate financial needs of projects that are either stalled or in various stages of development.

Training and workforce development

The Northeast Geo-CoE will align with labor to promote retraining of workers displaced from the fossil fuel industry and evolve equitable workforce programs that support

utilities installing networked geothermal systems across the U.S. The center will also work with other stakeholders, including universities, technical and community colleges, veterans, construction workers, and gas utilities, to participate in programs that grow the industry workforce. Outreach and educational activities will allow the Northeast Geo-CoE to work with stakeholders across the country, leveraging our market insights to facilitate industry growth and support additional Geo-CoEs in other regions.

Other Geo-CoE activities

The Geo-CoE will also collect data on regional GSHP deployment; maintain quality control; promote increased manufacturing and innovation in geothermal drill rigs; maintain communication with heat pump manufacturers and other upstream component manufacturers to encourage sustainable growth of the supply chain; and facilitate connections with large-scale customers such as utilities, contractors, and developers to anticipate demand and smooth market growth. These activities will bolster the supply chain, manufacturing, licensing, and permitting landscape and allow regional market assessment and planning for scale.

Finally, the Northeast Geo-CoE will build a network of regional stakeholders committed to expanding and professionalizing GSHP production in the region. In its initial 3 years, the Northeast Geo-CoE will generate 5 to 10 jobs at the Center itself in training, finance, and outreach functions. The infrastructure built through this effort will allow M-TEMP scaling nationally with minimal additional investment.

The Northeast Geo-CoE will shift production of thermal exchangers from niche operations to scalable, mobile assembly-line processes, fostering standardization and aligning production capacity with market demand. The resulting increase in GSHP production capacity will reduce U.S. dependence on foreign fossil fuels and decrease carbon emissions, improving energy independence and enhancing national security.

Establish additional Geo-CoEs

Based on the model established by the Northeast Geo-CoE, the GMCC aims to establish additional regional Geothermal Drilling Centers of Excellence, tailored to the market demand and resources in each location. This scaling will be required to capitalize on the full economic, environmental, and social health and welfare potential offered by the emerging shallow geothermal technologies marketplace.

Project Location

Work will begin in Boston, MA, Westchester, NY, and Springfield, IL, until a permanent site is identified in the Northeast region. Evaluation criteria for the Geo-CoE permanent

site include:

- Justice40 community in a semi-rural or rural setting to allow for expansion
- Geological characteristics favorable for active drilling
- Access to potential manufacturing workforce
- Proximity to unions and community colleges
- Willing local community

Potential sites include:

- Troy, NY, adjacent to Hudson Valley Community College
- Westchester, NY, near various SUNY Educational Opportunity Programs and Westchester Community College
- Framingham, MA, near the first Eversource networked geothermal project and Framingham State University
- Worcester, MA, near Quinsigamond Community College and Worcester State University

Production Capacity

This project aims to support production of GSHPs by increasing capacity to produce thermal (ground heat) exchangers in the Northeast in order to meet projected growth in demand by 2030. Based on conservative estimates, the Northeast Geo-CoE will produce roughly 90,000 thermal exchangers over the first 3-5 years, representing nearly 45 million linear feet of boreholes that supply geothermal energy to an estimated 70 million square feet of "office equivalent" space (assuming an average borehole depth of 500 feet, suitable for the typical geological conditions of the Northeast). The Northeast Geo-CoE's goal is to increase regional capacity to produce thermal exchangers by 6% above baseline per year in the first 36 months. Coupled with increased heat pump production by our allies, this translates to a 3- to 5-fold increase in the production of ground heat exchangers.

Domestic Supply Chain Impacts

Lack of capacity to produce thermal exchangers is not only slowing deployment of GSHPs, it is also sharply impacting the installation of utility-scale geothermal network projects in the Northeast (LeGUp research project), preventing states from reaching their climate and energy security goals. The first-in-the-nation utility-led networked geothermal installation in Framingham included the on-site manufacture of 92 thermal exchangers servicing 37 buildings, including a fire station, a school, businesses, single-family homes, and low-income housing. Drilling expertise for the installation, however,

came from western American states.

By scaling thermal exchanger production and aligning with heat pump manufacturers, the Northeast Geo-CoE's initiatives (and subsequently those of other regional Geo-CoEs) will increase domestic capacity to satisfy current and projected demand for GSHPs and speed deployment of utility-scale geothermal networks, catalyzing both utility and consumer transitions away from fossil fuels. Furthermore, Northeast Geo-CoE research on the number and rates of GSHP deployment and geothermal network installation, to be led by HEET, will inform supply chain planning and help mitigate the risk of supply chain disruptions in GSHP production. The Geo-CoE (and others in the future) will in this way support secure, resilient domestic clean energy supply chains for GSHPs.

Community Benefits Plan

This project is designed to benefit communities across the Northeast at several levels:

1. Engaging labor unions, technical high schools, and local community colleges in traditionally underserved communities to recruit and train personnel
2. Preparing regional graduates for jobs in their communities through classroom, soft skills, hands-on training, job counseling, and wraparound services
3. Working with potential stakeholder communities (veterans' groups, people with disabilities, fossil fuel workers displaced by net zero goals) to develop workforce continuity and inclusion programming

To support diversity, equity, inclusion, and accessibility, the Northeast Geo-CoE is planning comprehensive programs to expand job outreach in disadvantaged communities and inclusivity through collaboration with fossil fuel workers impacted by decarbonization, employers, and marginalized groups traditionally burdened by historical energy inequities. Plans for the Northeast Geo-CoE include recruiting a diverse and local workforce from towns near existing or planned projects, particularly in underserved areas. Worker development programs include education, apprenticeship, advocacy, research, financial assistance, and wraparound services. Finally, the Northeast Geo-CoE will work with labor organizations and other advocacy groups to help enrich the development of a thermal exchange workforce. The ability to rent or lease drill equipment through the Geo-CoE decentralizes the industry in a way that will allow people to not only be workers but to be independent contractors and business owners. There is the potential for a geothermal driller cooperative if the model works well.

Outreach to community colleges is a central part of our program and will include organizations such as the Massachusetts Association of Community Colleges, institutions located in Justice40 areas, and technical schools that currently offer HVAC certificates.

Community outreach and recruitment efforts, particularly in underserved communities, will ensure that the voices of residents are a key part of local energy decisions, providing equitable access to geothermal jobs and entrepreneurship opportunities, and generally connecting communities to this nearly zero cost, clean, reliable, and safe energy resource.

Project Impacts

Ultra-efficient ground source heat pumps—and centrally managed geothermal energy networks—are key to flattening annual peak energy demands, slashing climate-warming emissions, cutting the cost of electricity and grid buildout, and creating secure, resilient energy infrastructure.

To help realize these benefits, the Geothermal Dilling Centers of Excellence will:

- Facilitate the deployment of six networked geothermal systems in New York, Massachusetts and Connecticut
- Increase GSHP production capacity in the Northeast 3- to 5-fold by 2028, supporting U.S. and state emissions reduction goals
- Create 100+ construction, technology, or clean energy jobs in the shallow geothermal industry
- Improve local fair wage jobs and increase the participation of women and underrepresented minorities in the manufacturing workforce and in small business ownership
- Foster cooperation and innovation and promote economic growth—with the potential to serve as a model for scaling and quality control as demand for geothermal energy networks grows

Through Geo-CoEs, the GMCC aspires to not only lead in advanced geothermal technology expertise but also catalyze significant, equitable and sustainable advancements in the sector.

Appendix 1: Coalition Membership

The coalition consists of a broad range of industry stakeholders, including leading manufacturers, contractors, trade groups, and advocacy organizations with either

national or regional focus in the Northeast. Our range of collaborators reflects the critical need for increased production of thermal exchangers to achieve market growth.

ASIP Local 150: The Local 150 Apprenticeship and Skill Improvement Program combines on-the-job paid training with classroom instruction and hands-on practical training at the Local 150 training site in Wilmington, Illinois.

Building Decarbonization Coalition: An advocacy group aligning stakeholders on a path to transform U.S. buildings through clean energy, using policy, research, market development, and public engagement. It will collaborate to find spaces for labor unions within the green ecosystem.

Climate Control Group: A diverse collection of subsidiaries providing HVAC products and solutions for a variety of applications and markets. CCG designs and manufactures market-leading products for multiple applications, where the comfort and efficiency of climate-controlled spaces are required.

Dandelion Energy: An independent company offering geothermal heating and cooling systems to homeowners, starting in the Northeastern US. Dandelion shares a personal commitment to mitigate climate change by making renewable technologies more accessible.

DEEP: A privately held corporation with a mission to develop Saskatchewan's geothermal resources for power generation. DEEP is developing a unique geothermal power facility in southern Saskatchewan, the first of its kind in Canada.

Empire State Water Well Driller's Association: A professional association of contractors, pump installers, suppliers, manufacturers, engineers, and hydrologists.

Enertech Global: With over 75 years of geothermal experience, Enertech produces innovative geothermal product lines, accessories, and complimentary products.

Eversource Energy: A natural gas utility in the Northeast that is piloting the nation's first utility-led geothermal network project in Framingham, MA. This project experienced delays caused by the significant shortage of geothermal drillers.

Framingham State University: Provides access to their students as prospective geothermal workers and is building awareness of thermal drilling job opportunities.

Geothermal Drillers Association: A member-based organization advocating for excellence in geothermal drilling practices, including a commitment to enhancing safety standards and fostering educational advancement and professional development within the geothermal sector. The association promotes safe equipment usage, workforce training, professional licensure, collaborative teaming arrangements, stringent quality control measures, and establishing industry-wide standards.

Geothermal Exchange Organization: A nonprofit trade association that promotes the manufacture, design and installation of GeoExchange® systems. Their mission is to support members' business objectives while promoting maximum, sustainable growth of the GSHP industry through advocacy, partnerships, public outreach, and promotion of quality standards.

Global Drilling Suppliers, Inc.: Supplies, designs and builds drilling tools for construction. Serves the construction, mineral exploration, environmental and water well drilling industries.

GTD: A global manufacturer of state-of-the-art geothermal drill rigs and equipment. Its exclusive focus on GSHP drilling equipment simplifies operations and increases productivity and safety, while lowering drill rig costs.

HEET: A nonprofit thermal energy institute that innovated the gas-to-geothermal network transition and is conducting a research study of the first utility-scale geothermal network installations. HEET will collect data from the Geo-CoE to help inform market analysis, and will use their stakeholder engagement approach to support the Geo-CoE's efforts to recruit and train diverse geothermal drillers and GSHP installers, interface with utility-led projects, and help partners develop curricula that address market demand. HEET is piloting a geothermal driller training program that will be a model for the Geo-CoE's Driller Training program.

Hudson Valley Community College: Will support the Geo-CoE's efforts with state-of-the-art facilities, including the college's Gene F. Haas Center for Advanced Manufacturing Skills, and existing train-the-trainer modules on energy efficiency and photovoltaic solar instruction.

International Ground Source Heat Pump Association: A 501(c)(6) nonprofit that promotes GSHP technology on local, state, national, and international levels. With access to the most current advancements in the geothermal heat pump industry via its diverse membership base and its industry alliances, IGSHPA is a bridge between the latest technology and those who will benefit from these developments.

Local 478: Supplies heavy equipment operators, mechanics and support personnel in Connecticut. Local 478's training center combines classroom instruction and hands-on practical training through courses on subjects ranging from plan reading and jobsite layout to the use of global positioning satellites for members in Connecticut and surrounding states.

Massachusetts Association of Community Colleges: Is developing a new sustainability curriculum and is committed to supporting workforce development training.

National Grid: A national natural gas utility piloting networked geothermal projects

in Lowell and Dorchester, MA, with several much larger installations planned in New York State. National Grid serves more than 20 million people throughout New York and Massachusetts.

National Ground Water Association: A community of groundwater professionals working to advance groundwater knowledge and member success. It developed the online curricula for and administers drilling certifications and will modify its curricula for geothermal drillers.

New England Gas Workers Alliance: A worker advocacy group focused on improved gas safety and a responsible transition to renewable energy across Massachusetts.

New Yorkers for Clean Power: A statewide collaborative campaign to rapidly shift to an equitable clean energy economy. NYCP is focused on advancing solar, wind, energy, efficiency, heat pumps, and electric vehicles, as well as creating jobs in these industries for all communities in New York.

New York Geothermal Energy Organization: A nonprofit trade association representing the geothermal heat pump industry in NY State dedicated to promoting geothermal heating and cooling. Their members include geothermal system designers, installers, drillers, general contractors, engineers, manufacturers, distributors, renewable energy consultants, and industry stakeholders who install and advocate for the use of GSHPs to heat and cool buildings throughout New York State.

Ogden Wells: A drilling company providing groundwater development services to residential, commercial, and municipal clients since 1980. It will offer apprenticeships.

Skillings & Sons: A family well-drilling business operating in New Hampshire and Massachusetts with 75 employees and 350+ years of combined experience. It is hosting a driller training pilot and is committed to employing driller apprentices.

Sustainable Westchester: A nonprofit consortium of Westchester County local governments that facilitates effective collaboration on sustainability initiatives. Their goal is to bring socially responsible, environmentally sound, and economically viable solutions that create healthy, resilient, sustainable communities.

Venture Drilling Supply: Provides sales and after-sales support in the U.S. market. To ensure customers succeed with their new equipment, VDS' trained technicians provide pre-delivery inspection, field commissioning, and timely support with parts and service.

WaterFurnace: Has manufactured geothermal and water source heat pump technology since 1983.

Organizations with which the Coalition consults:

Connecticut Department of Energy and Environmental Protection (DEEP): Charged

with conserving, improving and protecting Connecticut's natural resources and environment as well as making cheaper, cleaner and more reliable energy available for the people and businesses of the state.

Massachusetts Clean Energy Center (MassCEC): Funds climate solution innovation to meet Massachusetts emission reduction goals while growing the state's clean energy economy.

New York State Department of Environmental Conservation (DEC): Uses policies and regulations to limit environmental impacts.

New York State Energy Research and Development Authority (NYSERDA): Aims to reduce greenhouse gas emissions, accelerate economic growth, and improve the quality of life for all New Yorkers.

More than 10 state regulators.

Westchester Platform	SUNY (Educational Opportunity Programs at Purchase, Morrisville, Ulster), Sustainable Westchester, Westchester Community College, Westchester County (WC) Government, WC's local International Union of Operating Engineers (IUOE)
Workforce development (beyond IGSHPA, NGWA & HEET)	**Training:** CSA Group, Social Enterprise & Training Center; **Drillers:** RH White, Skillings & Sons; **Labor:** IUOE e.g., Local 150 (IL) and 478 (CT) AFL-CIO, Laborers' International Union of North America; **Justice40 workforce agencies:** DOD Skillbridge Program, Climate Jobs MA, Green Jobs Academy, Power Corps Boston; **Community orgs:** Boston Green New Deal, Eastie Farm, Mothers Out Front, NCLC, PLAN
Higher education	**MA:** Boston University, Framingham State, Roxbury Community College, Quinsigamond Community College, Salem State, University of Massachusetts Lowell, Worcester State; **NY:** Alfred State; Dutchess, Erie, Hudson Valley, Monroe, and Nassau community colleges, PNW & TST BOCES, Rensselaer Polytechnic Institute; **Other locations:** Foundation for California Community Colleges, Fleming College (Canada)
Equipment & supply chain partners	Alucast, Corechem, Derex, Drillmax, Eijkelkamp, Energy Design Corp, GTD, Gefco, Laibe Corporation-VersaDrill, Matrix Drilling Products, Mobiledrill, Rig Source, Simco, Venture Drilling Supply; **Grout & drilling fluids manufacturers:** Geopro, Baroid, IDP, Cetco, Wyo-Ben, Kilfrost
Pump manufacturers	Bosch, Climate Control Group, ClimateMaster, Enertech, WaterFurnace
Heat pump & exchanger installers/purchasers	**Large scale:** Eversource Gas, National Grid Gas, New York State Electric & Gas (and national utility geo coalition members); Residential: Allied Drilling, Aztech Geothermal, Buffalo Geothermal Heating, Brightcore, CHA Consulting, Celsius, Dandelion, Endurant Energy, Geosource, M/E Engineering, Midwest Geothermal, Ogden Drilling, Owahgena Consulting, Phoenix Energy Supply, RH White, Rototech, Salas O'Brien, Skillings & Sons, Smith Well Drilling, Thermex Geothermal Solutions, Trane; **Labor:** New England Gas Workers Alliance, operating engineers, pipefitters, and steelworkers
Research partners	Lawrence Berkeley National Laboratory, MIT, National Renewable Energy Laboratory, University of California Berkeley, University of Massachusetts Lowell
Advocacy groups	Building Decarbonization Coalition, Beyond Gas, Empire State Water Well Drillers Association, Geothermal Rising, Gas Transition Allies, NGWA

HEET and partners also consult with Massachusetts Clean Energy Center (MassCEC), New York State Energy Research and Development Authority (NYSERDA), New York State Department of Environmental Conservation (DEC), 10+ state regulators, and Connecticut Department of Energy and Environmental Protection (DEEP).

Appendix 2: Definitions

ambient temperature loop systems – a distribution piping network that conveys fluid at low to moderate temperatures sharing heat between buildings, to/from geothermal ground loops, and to/from other sources and sinks.

borehole – a hole, typically drilled, bored, cored, driven, hydraulically advanced, or otherwise constructed into the earth. NOTE: A borehole is not a well (see *water well*).

closed-loop system – a continuous, sealed, underground, or submerged heat exchanger through which a heat-transfer fluid passes to and returns from a heat pump.

deep geothermal – see *high-temperature geothermal*

direct use geothermal – use of boreholes deep enough to utilize heat from the earth directly in an application without the need for additional mechanical systems such as heat pumps, typically at temperature above 150 deg F (for example, the supply source for a district heating system).

district geothermal systems – a system that provides heating and/or cooling to multiple buildings as infrastructure and utilizes as sources and/or sinks ground heat exchangers, groundwater, surface water, and/or wastewater.

ground heat exchanger (GHEX) – a variety of heat exchangers, located outdoors or below a building, that use the ground, groundwater, or surface water as a heat source and sink.

geothermal – earth heat or heat from the earth.

geothermal heat pump – see *ground source heat pump system*

geothermal energy system – see *ground source heat pump system*

ground loop or geothermal ground loop – see *ground heat exchanger*

ground source heat pump system (GSHP) – a variety of systems that use the ground, groundwater, or surface water as a heat source and sink. Other terms include geothermal heat pump (GHP), ground coupled heat pump (GCHP), geothermal energy system (includes heat pump, heat source/sink, and system components), geoexchange system, and networked geothermal, among others.

high-temperature geothermal – applications utilizing boreholes deep enough to realize earth temperatures above 300 deg F, for uses such as power generation.

loop – the basic component of a ground heat exchanger where energy transfer occurs between the ground and a mechanical system via a heat transfer fluid.

low-temperature geothermal – ground source heat pump heating and cooling systems using the constant ground temperature as a heat source and sink at depths typically five

to 800 feet, depending upon the type of heat source/sink (see *geothermal heat pump, ground source heat pump, ground heat exchanger, ground loop*).

networked geothermal – see *ground source heat pump system*

open-loop (surface water or groundwater) system – a system designed to use groundwater or surface water for the purpose of extracting or rejecting heat by use of a water-source heat pump.

thermal energy network (TEN) – see *district geothermal systems*

water well – an excavation that is drilled, cored, bored, washed, driven, dug, jetted, or otherwise constructed for the purposes of extracting groundwater, monitoring groundwater, using the geothermal properties of the earth, or injecting water into an aquifer or subsurface reservoir.