U.S. DOE Community Geothermal Heating and Cooling Design and Deployment Status

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ABSTRACT

Community Geothermal Coalitions across the United States are nearing completion of their first phase of work focused on expanding community-scale geothermal systems. The work began on October 1, 2023, and is funded through U.S. Department of Energy (DOE), Geothermal Technologies Office (GTO) Community Geothermal Heating and Cooling Design and Deployment Initiative Cooperative Agreements.

A main goal of the initiative is to support the formation of U.S.-based community coalitions that will develop, design, and install community geothermal heating and cooling systems that supply at least 25% of the heating and cooling load in communities. The coalitions describe how switching to a geothermal district heating and cooling system would result in greenhouse gas emission reductions for the community where the system is installed.

In total, the selected coalitions comprise more than 60 partners across the U.S. and include one or more partners that: represent the community, are expert geothermal designers, focus on geothermal workforce development and training needs and include a deployment focused coalition partner such as a gas utility.

The eleven coalitions are designing their heating and cooling systems in close partnership with, and many led by, the communities in which the geothermal projects would be deployed. The

coalitions are based in urban, suburban, rural, and remote communities each developing innovative community scale systems.

Anticipated community benefits include addressing: environmental justice conditions, such as cumulative environmental pollution and other hazards; underserved and disadvantaged communities; and community members who have historically experienced vulnerability due to climate change impacts.

Preliminary case studies developed in the first phase will help illustrate how Community Geothermal Coalitions can be replicated throughout the U.S. followed by the development of more complete case studies by coalitions whose projects move to the deployment phase.

1. Introduction

On July 12, 2022, the U.S. Department of Energy (DOE) announced the Community Geothermal Heating and Cooling Design and Deployment Funding Opportunity Announcement (FOA), for projects that will help communities design and deploy geothermal district heating and cooling systems, create related workforce training, and identify and address environmental justice concerns. Widespread adoption of geothermal heating and cooling systems will help decarbonize the building and electricity sectors, reduce energy costs for families, and boost resilience.

The eleven Community Geothermal (ComGeo) Coalitions funded in Phase 1 are helping to expand community-scale geothermal by supporting new systems and developing preliminary case studies to be replicated throughout the country.

1.1 U.S. DOE Community Geothermal Heating and Cooling Initiative Background

On April 25, 2023, the U.S. DOE Geothermal Technologies Office (GTO) announced the selection of 11 projects in the first phase (Phase 1) of the ComGeo Heating and Cooling Design and Deployment Initiative. In the second phase, following a down select, GTO will support multiple projects to deploy their systems. Under this initiative, GTO is funding U.S.-based urban/suburban, rural, or remote/islanded ComGeo Coalitions to develop, design, and install ComGeo heating and cooling systems.

1.1.1 Community Geothermal Heating and Cooling Design and Deployment Project Locations

The Phase 1 projects are in Nome, AK; Seward, AK; Carbondale, CO; Shawnee, OK; Hinesburg, VT; Wallingford, CT; Chicago, IL; Framingham, MA; Ann Arbor, MI; Duluth, MN; and New York City; NY

1.1.2 Community Geothermal Coalition Role Definitions

Each ComGeo Coalition features representatives in four key roles (Figure 1) including:

- Community Voice: Understand & communicate community needs
- Analysis & Design: Design geothermal district heating/cooling system
- Deployment: Obtain permits & build
- Workforce: Develop & implement training/apprenticeships

Entities in the "Community Voice" role understand and can communicate the energy, environmental, economic, social, and/or other relevant needs that the proposed system would address, as well as local development and regulatory requirements. ComGeo Workforce entities know the community labor market and can help the coalition with apprenticeship opportunities, job placement, and developing training or lesson plans for the applicable trades. Analysis and design entities have the experience designing geothermal systems as well as analyzing the economic and technical aspects of such systems. Deployment entities, although not developing the community systems in Phase 1, have experience building new or retrofitting existing energy systems and can assist or learn from other ComGeo Coalition partners.

To assist coalition formation, GTO provided a Teaming Partner List where interested parties could provide contact information and areas of expertise and search for other entities interested in partnering on an application.

Figure 1: Graphic describing the four types of partners each ComGeo Coalition is required to include in their project team.

1.1.3 Objectives

GTO set five primary goals for the ComGeo initiative as follows:

- Deploy new or retrofitted geothermal, or geothermal-hybrid, district heating and cooling systems in U.S. districts, neighborhoods, and communities;

- Identify solutions for environmental justice conditions, such as cumulative environmental pollution and other hazards; underserved and disadvantaged communities; and community members who have historically experienced vulnerability due to climate change impacts;
- Assist U.S. communities to develop career and technical education and workforce transition initiatives to design, install, inspect, operate, and maintain new energy systems such as geothermal heating and cooling;
- Develop U.S. case studies about projects, including technical and economic data, to illustrate how projects can be replicated by communities throughout the United States; and
- Publish data and information about U.S. community-scale geothermal heating and cooling system deployment to demonstrate the success of such systems in a range of environments and geographies.

1.2 U.S. DOE Community Geothermal Heating and Cooling Initiative Project Requirements

The 11 ComGeo Coalitions are working in American communities with partners from local and state governments, nonprofits, educational institutions, national labs, tribal government entities, utilities, industry, and unions. While there are more than a few terms and conditions that must be adhered to as part of the ComGeo Coalition Cooperative Agreements with DOE, several important requirements are highlighted below.

1.2.1 Coalition and Resources

Since achieving broad community support for a proposed ComGeo heating and cooling system is key, the entity representing the community where the geothermal system is planned to be located is a critical part of the overall project. Thus, each ComGeo Coalition (the project team) is required to include qualified leaders with appropriate expertise and sufficient time committed to each required role in community representation, workforce planning, geothermal analysis and design, and project deployment.

1.2.2 Project Planning, Community Research, and Data Availability

For the ComGeo systems to produce the desired community benefits, plans for system adoption including workforce training require community research and data gathering. To measure the community benefits and impacts, community baseline conditions are assessed including greenhouse gas emissions reduction or prevention, fuel use, electricity use, and/or environmental contamination that can be reduced or avoided. To prepare for geothermal system deployment, regulations, codes, and standards must be included in a permit plan.

2. ComGeo Project Status as of March 30, 2024

Since the ComGeo projects began on October 1, 2023, all eleven teams shared information with each other pertaining to how their community members are being included and how their workforce training and design plans are proceeding. In the final quarter of Phase 1, teams will meet with DOE to review the data they plan to make public and will discuss sharing important lessons learned in preliminary case studies. A generalized status of the ComGeo team activities during the first two quarters is provided below.

2.1 Community Geothermal Engagement and Workforce Training

The Ann Arbor, MI. ComGeo team engaged more than 50 stakeholders using resident-centered success metrics. The City of Chicago "Blacks in Green" ComGeo team is facilitating community conversations to make decarbonization, electrification, and beneficial electrification meaningful and accessible to Chicago communities in their "Sustainable Square Mile" area. The Duluth, MN. ComGeo team is providing outreach to their top 50 natural gas consumers. The Framingham, MA. ComGeo team is conducting a pilot recruitment and training program for geothermal drillers with planned 4–6-week summer internships. In addition, the team is partnering with the GHP trade associations on curriculum development. Union forums were conducted with electrical, utility, operating engineers, plumbing and pipefitting trades. The New York City ComGeo team scheduled site visit with their community stakeholder organizations and are researching NYC workforce entities including technical and vocational schools and local trade unions. The Wallingford, CT. ComGeo team met with their town government, school board, and residents and surveyed four stakeholder groups about employees, barriers, capacities, and other workforce needs. The Carbondale, CO ComGeo team shared preliminary design and modeling at a community open house. The Hinesburg, VT. ComGeo team obtained community input on priorities, concerns, and perspectives on the feasibility of geothermal projects and met with the non-profit "Habitat for Humanity" regarding housing for under-resourced populations. The Seward, AK. ComGeo team receives strong support from the City Manager. The Seward team is also supporting demonstration-related training where residential CO2 heat pump equipment for hands-on training is being provided. The Shawnee, OK ComGeo team gained approval from their tribal (Potawatomi Nation) partner. The Nome, AK ComGeo team conducted community planning meetings to help inform their design options.

2.2 Community Geothermal Design

Several of the ComGeo Coalitions are designing innovative community-scale geothermal heating and cooling systems (GDHC). These preliminary designs contemplate GDHC systems that flow ambient temperature water through a single distribution pipe, loop, or network to Geothermal Heat Pumps (GHPs). This type of design is also referred to as a Thermal Energy Network (TEN) or one that includes several generations of district heating and cooling technology capable of operating as a modular, installed network.

GDHC systems and TENs are more common outside of the United States, although U.S. interest in such systems is growing. GDHC systems leverage commercially available geothermal direct use and GHPs. Conventional direct use systems take advantage of naturally hot water from deep underground, which is pumped to the surface and through a heat exchanger for heating, while GHPs use the naturally occurring difference between the above-ground air temperature and the shallow subsurface soil temperature to create a heat sink in warmer temperatures and a heat source in cooler temperatures.

Unless innovative engineering techniques are used, direct use systems are limited to regions where naturally occurring, hydrothermal resources can be located and brought to the surface for heating. Innovation is needed to add cooling to a direct use system. In contrast, where there is electricity, GHP technology can be used anywhere in the United States for both heating and cooling. In a GHP-based system, an above-ground electric-powered heat pump moves water or another fluid

through a series of buried pipes or ground loops that are generally located tens to hundreds of feet below the surface, where heat is exchanged with the earth.

When either direct use or GHP systems are used to heat or cool water using common piping (or a district loop), GDHC systems can be efficiently designed to heat and cool multiple buildings. The degree of innovation and planning used in the system design can result in more efficient energy distribution taking advantage of heat sources and sinks to the greatest extent possible. Borehole design and spacing to correctly size a system requires innovation.

Early district energy systems, referred to as "1G" or first-generation systems, shown in Figure 2, mostly required fossil fuels to heat water to high temperatures conducive to making steam. As district energy systems evolved, the required water supply temperature significantly dropped. As such, in "4G" or fourth-generation district energy systems, renewable energy such as GHPs can circulate low-temperature—even ambient temperature—water to heat and cool buildings.

Innovative GDHC systems can be roughly classified as either fourth or fifth generation. Fourth-generation systems contain two separate pipe loops, one that acts as a source of hot or cold water, and a second that acts as a sink. In these systems, hot or cold water is delivered directly to buildings, where it is used for heating or cooling. In a fifth-generation system, pipe loop(s) containing ambient temperature (50–60°F) water can act as a source or sink for multiple buildings. An important innovation is the way heat is used throughout the system. For example, discarded heat from one building can be transported and used in another. Buildings connected to this type of system often contain their own heat pump. GDHC systems may also include non-geothermal components. Supplemental boilers and chillers can provide additional heating and cooling on very hot or cold days. Electricity is needed to operate the heat pump(s), and solar panels or another renewable could provide all or some energy.

	1G	2G	3G	4G	5G
Piping Configuration	Pipe acts only as source Only provides heating	Pipe acts only as source Only provides heating	Pipe acts only as source Only provides heating	Two different pipe loops (one loop as source, other loop as sink) Provides heating and cooling	Single "ambient temperature" pipe loop can simultaneously act as source or sink for various buildings, thus enabling "prosumers" Provides heating and cooling Can take discarded heat from one building and transport it for use in another building
Temperature of Supply Pipe	~400 °F	~250 °F	~190 °F	~140 °F for heating ~45 °F for cooling	~60 °F
Fluid in Supply Pipe	Steam	Pressurized Hot Water	Water	Water	Water

Source: Dana Levy, NYSERDA

Figure 2: District Energy Technology Advancements

GHP systems can use several different ground heat exchanger configurations (e.g., closed-loop horizontal and vertical, standing-column wells, open- and closed-loop pond). The analytical model used in the GeoVision (The Distributed Geothermal Market Demand Model, known as dGeo) considered only the most common and widely applicable of these configurations: closed-loop

horizontal (field loops) and vertical (borehole) systems. Data and information from innovative ComGeo systems will be an important addition to future analysis to estimate the potential for geothermal district heating and cooling systems. Although GHP and GDHC technologies are commercially available, innovation is necessary to develop new systems in regions and communities that have been underserved in this technology space and to transition existing district-scale systems from fossil fuels to geothermal. Successful innovation can be measured by the degree to which a new or an existing system can transition to geothermal heating or heating and cooling.

2.3 Community Geothermal Deployment

Planning for potential system deployment, various ComGeo ownership options are under review by each ComGeo Coalition. The Ann Arbor, MI. team is in conversations with utilities and regulators about municipal ownership. Chicago team ownership options include the City of Chicago as a municipal entity owner or ownership through a private entity. The Duluth, MN. team is assessing business models for construction, ownership, maintenance, and operations. The Framingham, MA. team will decide whether to adopt the ownership model currently in place at an adjacent ComGeo system. The New York City Housing Authority would own their system as would the Wallingford, CT. Housing Authority own theirs. The Carbondale, CO. team is developing a plan that includes project finance, construction, retrofitting, ownership, and operation. The Hinesburg, VT. team is considering a joint development / utility ownership model where all-electric systems are made available to as many utility rate payers as possible and where it is easy for the customer to participate. The City of Seward, AK. would own their system. In Nome, AK. a consortium of five indigenous-led organizations would own their system, and in Shawnee, OK. the Citizen Potawatomi Nation would own theirs.

3. Community Geothermal Data Submissions to the U.S. DOE Geothermal Data Repository

The U.S. DOE Geothermal Data Repository (GDR) is the repository and catalog for data generated by projects funded by GTO (Weers et al., 2022). The GDR provides public access to geothermal datasets, which are increasing in variety, size, and complexity. GTO funds recipients are required to upload their project data to the DOE GDR as the project data is generated in its final form. ComGeo data sets uploaded as of the date of this writing include:

- GDR Submission 1594: “Ann Arbor Electricity and Gas Usage Data” describes hourly electric and gas data for a single-family home type: Worst, Mid, Best. Both the existing system type and replacement geothermal system is simulated.
- GDR Submission 1997: “Connecticut Workforce Needs Assessment Report and Data” provides a geothermal industry workforce needs assessment report for Connecticut.
- GDR Submission 1598: “Final Thermal Conductivity Test Report and Data Logs - Carbondale, CO.” includes the final thermal conductivity test report, a drilling log, and a heat rejection log from Carbondale, CO.
- GDR Submission 1590: “Thermal Conductivity Test and Data Analysis Report” from Wallingford CT. includes a report on a formation thermal conductivity test that was performed on the geothermal test bore at Ulbrich Heights in Wallingford, CT.

Additional details about data uploaded to the GDR is available at GDR: All Submissions (openei.org).

GTO looks forward to sharing additional data helpful to low-temperature geothermal development, including thermal conductivity and drilling datasets, across the country. To facilitate the submission of larger datasets, future ComGeo Coalition project data submissions may utilize a recently developed GDR tool known as an automated data pipeline. The first automated data pipeline implemented within the GDR is for drilling data. This pipeline currently supports and is capable of processing data from Pason (Pason Systems Corp., 2023) and RigCloud (Nabors Industries Ltd., 2021) drilling data platforms in Excel and CSV formats and may in the future be amended to standardize drilling data from other sources and in other formats as well. The pipeline recognizes the platform-specific field names and units and converts them to the standard field names and units in CSV format. The standard additionally includes the RIMBase drilling data platform (Infostat, 2023) field names (Taverna et al., 2023).

4. Community Geothermal Preliminary Case Studies

Case studies of different type of communities (Remote/Islanded, Urban/Suburban, Rural) are an important component of the overall ComGeo initiative. In Phase 1, preliminary case studies are anticipated from ComGeo Coalitions and final case studies at the end of the deployment phase are anticipated from those down selected to continue to Phase 2. During the last quarter of Phase 1 work, ComGeo Coalitions will decide which community, design, workforce or deployment related lessons or best practices to include in their preliminary case studies.

5. Conclusion

While GTO can fund only a subset of the 11 ComGeo Coalition projects to proceed to the deployment stage, the work accomplished by all the teams in Phase 1 is already making an impact on the future of geothermal heating and cooling. The 11 Phase 1 projects are enabling community-scale deployment of GDHC systems in a diverse set of communities by coalitions comprised of technical experts, community leaders, workforce innovators, and deployment professionals. The objective to support the formation of U.S. community coalitions that will develop and design ComGeo heating and cooling systems is more than halfway accomplished. In 2025, ComGeo Coalitions that deploy their systems are poised to supply at least 25% of their overall community heating or heating and cooling demand. Many of the communities are hoping to supply most of their heating or heating and cooling from deployed ComGeo systems.

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