Connecticut Community Geothermal Case Study – Design and Feasibility

October 2024

From October 2023 to October 2024, the Bureau of Energy and Technology Policy at Connecticut Department of Energy and Environmental Protection (DEEP) led a team to design and assess the feasibility of a community geothermal heating and cooling system in Wallingford, Connecticut. The team included Northeast Energy Efficiency Partnerships (NEEP), the University of Connecticut (UConn) Pratt & Whitney Institute for Advanced Systems Engineering, the Wallingford Housing Authority (WHA), the Wallingford Electric Division (WED), and the engineering firm LN Consulting.[1] This project, entitled “District Geothermal Heating + Cooling Deployment in a CT Environmental Justice Community,” was funded by the U.S. Department of Energy (DOE) as part of its competitive Community Geothermal Heating and Cooling Design and Deployment Initiative. The Project Advisory Board included staff from the CT Department of Health, the CT Department of Housing, the CT Housing Financing Authority, the CT Office of Workforce Strategy, a national laboratory, an electric utility, a gas utility, and others. DOE funding for Phase 1 supported an investigation into the feasibility of community geothermal at a chosen site (including initial modeling, design, workforce, and community engagement). After completion of the feasibility investigation, project teams could apply for competitive Phase 2 funding that would support construction and commissioning of the proposed geothermal systems.

CT DEEP: Connecticut Department of Energy and Environmental Protection
DOE: U.S. Department of Energy
NEEP: Northeast Energy Efficiency Partnerships
UConn: University of Connecticut
WED: Wallingford Electric Division
WHA: Wallingford Housing Authority
WSHP: Water-Source Heat Pump

The project involved design of a geothermal system for Ulbrich Heights, an existing multifamily affordable housing community of 132 apartments in Wallingford, Connecticut, owned by WHA. The proposed community geothermal design would retrofit the entire community’s heating and air conditioning systems to provide clean and efficient climate control for residents while saving tenants money, improving community air quality, and reducing the facility’s greenhouse gas emissions. The system would consist of a large central geothermal system – geothermal wells, pumphouse, and piping – to deliver a ground-conditioned water/glycol solution to each of 38 buildings, where interior piping and water-source heat pumps (WSHPs) would provide heating and cooling in each apartment. This system would replace natural gas boilers, eliminate onsite emissions for space heating, and provide space cooling that would replace inefficient, tenant-owned window air conditioning units. During the project’s first phase, the team analyzed best practices and conducted on-site testing and analysis to develop a comprehensive design for this system.

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[1] WED is part of the Town of Wallingford Department of Public Utilities.

Other communities across the state, region, and country seeking to implement geothermal systems at similar facilities can learn about the successes and challenges of the first phase of the project through this case study and the project website. The case study describes the team's efforts to build a coalition, design the system, consider deployment options as well as costs and emission reductions, assess workforce development needs, and determine economic and environmental outcomes. Due to challenges described below, the project team ultimately decided not to apply for Phase 2 funding to construct the system.

Coalition Building

Due to the level of coordination, community engagement, and detailed planning required for a community geothermal design and feasibility study, having the right project partners was critical. DEEP assembled the project team through an initial Request for Information in September 2022 and through direct outreach to organizations with competencies necessary for the project. DEEP sought partners with four main categories of expertise: community voice, workforce, technical analysis/ design, and deployment (Figure 1). DEEP then worked with the Connecticut Housing Finance Authority to select a suitable project site. The team selected the Ulbrich Heights community because it is in an area designated in 2022 as a Connecticut Environmental Justice Community and WHA indicated it planned to update the facility's heating system.

Figure 1. *Community geothermal coalition roles*

(as presented in the Department of Energy's "Community Geothermal Heating and Cooling Design and Deployment" announcement)

DEEP maintained close communication and coordination with the WHA staff throughout the planning process. The WHA director in turn helped coordinate and facilitate the team's community engagement activities with residents. Having the municipal electric utility, WED, as a partner made it easier for the team to obtain data about the Ulbrich Heights apartments, such as energy assessment data and electricity usage. UConn and LN Consulting utilized these relationships and data to complete modeling and design for Phase 1. UConn was the technical lead for this project, providing energy and cost modeling, and coordinated extensively with LN Consulting for the system design.

NEEP's role in the project focused on workforce assessment and community engagement. Because Ulbrich Heights is an affordable housing facility in an environmental justice community, it is especially important to have a partner who can emphasize community involvement and ensure that those directly affected by the project are engaged in a meaningful way.[2] At the same time, systematically addressing workforce development is crucial as the geothermal heating and cooling industry expands.

[2] The census block in Wallingford that contains Ulbrich Heights was designated as a CT Environmental Justice Community in 2022 due to greater than 30 percent of the population living below 200 percent of the federal poverty level. The CT mapping is updated yearly based on new census data, and in 2023 the same census block was no longer designated as an environmental justice community. The 2024 mapping was not yet released at the time of publication.

Design

Ulbrich Heights

Ulbrich Heights was built primarily around 1952 and has 132 apartments distributed across 38 buildings and seven building typologies (see Figure 2 and Table 1). Most of the buildings are duplexes (2 apartments each), and the facility also has a mix of garden-style townhome buildings with 4 to 8 apartments each.

Figure 2. ***Seven building types at Ulbrich Heights***

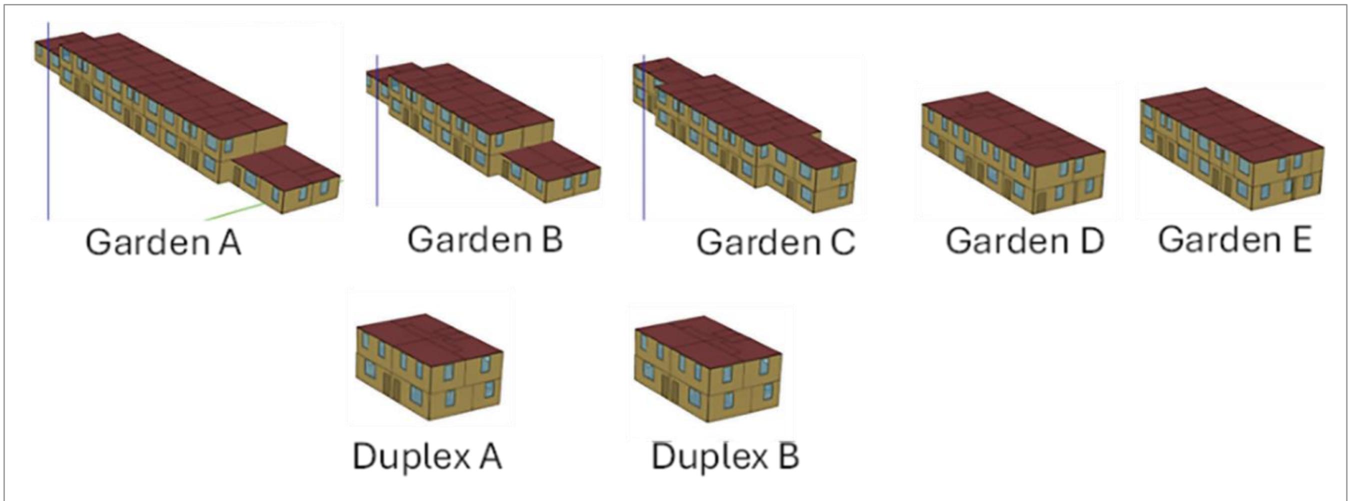


Table 1. ***Breakdown of building type, number of buildings, and number of apartments***

Building Type	Number of Buildings	Number of Apartments Per Building	Total Apartments
Garden A	2	8	16
Garden B	5	6	30
Garden C	3	6	18
Garden D	2	4	8
Garden E	4	4	16
Duplex A	11	2	22
Duplex B	11	2	22
TOTALS	**38**	**-**	**132**

The project team determined that a central geothermal borefield would be preferable for this project, given that centralizing the boreholes could reduce drilling costs and time for the approximately 14-acre site. Ulbrich Heights has 0.54 acres of green lawn available for a central borefield (see Figure 3). Other greenspaces on the property have trees that would need to be removed to accommodate the borefield.

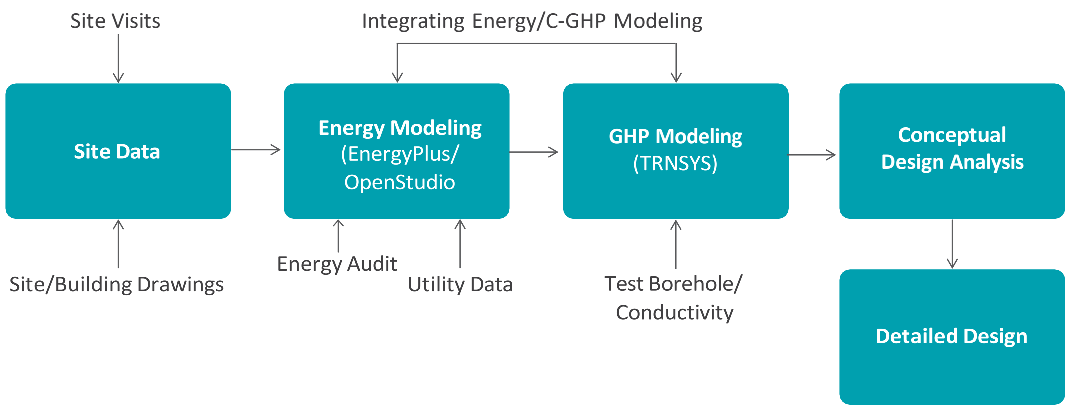
Figure 3. ***Aerial view of Ulbrich Heights with borefield location circled.***

Modeling and Design Process

The University of Connecticut's Institute for Advanced Systems Engineering was the projects technical lead and developed building energy models. The UConn team simulated network piping and supported the WSHP system design, while LN Consulting prepared the conceptual design for the overall geothermal and WSHP systems. The team started the process with data collection on the Ulbrich Heights site. Data collected from site visits and existing sources such as energy audits and utility data from WED informed the UConn team's models. UConn used EnergyPlus and OpenStudio for the energy load modeling, conducted initial geothermal sizing simulations in TRNSYS, then developed an initial field layout in GLD (see Figure 4).[3] Data from a test borehole and conductivity test were critical to the second round of modeling. UConn and LN Consulting worked together to complete the conceptual design analysis, with LN Consulting using GLD for the modeling and final design of the borefield and UConn employing TRNSYS to account for heat gain and loss in the horizontal piping.

[3] EnergyPlus and OpenStudio are software tools for whole-building energy modeling. TRNSYS is Transient System Simulation Tool, a graphical software. GLD is Ground Loop Design, geothermal system design software.

Figure 4. ***Schematic of the community geothermal heat pump system modeling and design process.***



Modeling and Design Considerations

Several factors informed modeling and design of the geothermal system.

Heating and Cooling Loads: Building heating and cooling loads were obtained using the EnergyPlus software and normalized with actual building energy use. The building loads, along with ground thermal properties obtained from the test borehole, were used in modeling and sizing the ground heat exchanger loop.[4] Once the team determined the number of ground heat exchangers needed, it developed a layout for the borefield based on the site constraints and a layout of the full geothermal system.

Soil Thermal Data: A contractor drilled a test borehole in February 2024 to determine subsurface geology, including the depth of the bedrock, as well as thermal conductivity, thermal diffusivity, and undisturbed ground temperature. All thermal properties were found to be favorable.

Applicable Codes: The project would be required to comply with the 2021 International Energy Conservation Code mandates. The 2022 Connecticut State Building Code has no specific technical provisions for geothermal systems.

Additional Technologies: With electrification of heating and cooling via the proposed geothermal and WSHP systems, fossil fuels would be used only for domestic water heating.[5] To explore full electrification, UConn also considered incorporating heat pump water heaters (HPWHs) and solar photovoltaic (PV) in the overall modeling

[4] A *ground heat exchanger* in this case consists of a vertical borehole, a u-shaped pipe in the borehole, and grout that establishes comprehensive contact between the pipe and the ground.

[5] At present, 72 percent of the apartments have water heaters that use natural gas. The others were built with electric-resistance water heaters or have been converted to electric resistance.

and design. Two alternative electrification scenarios also were considered: air-source heat pumps (ASHPs) instead of geothermal; and distributed geothermal, with separate wells for each building. A similar project conducted by the Meriden (Connecticut) Housing Authority utilized solar PV to accommodate the increased load of electrification and reduce tenant's electric bills. For Ulbrich Heights to employ solar PV, WHA would need to assess the buildings' capacity to support solar arrays and identify a suitable billing arrangement. WED, the local electric utility, does not offer financial incentives for solar installations at this time. Many of the apartments already have received free weatherization services provided by WED.

Design Scenario

The factors outlined above shaped the final design proposed. The design calls for installation of ninety 500-feet-deep boreholes spaced 20 feet apart in the housing community's large central greenspace (see figure 3), using 1-¼"piping. This configuration is based on UConn's energy modeling and geothermal field simulations. Using the greenspace would be advantageous because it can accommodate all the boreholes in a single location and sufficient space would remain for installation of a central pumphouse. This pumphouse would contain the main circulator pumps and the manifold for the geothermal borehole field loops. Locating the pump house centrally would offer the advantage of reducing pipe length. This configuration would allow the piping to split after leaving the pumphouse, with each of two main branches carrying the ground-conditioned water/glycol solution to approximately 50 percent of the community.

The design calls for ninety 500-feet-deep boreholes spaced 20 feet apart, connected to a centrally located pumphouse.

The buildings currently are heated by natural gas-fired boilers, with circulator pumps and hot water "convectors" in each apartment (see Figure 5). The buildings have limited available space to run ductwork without significant architectural rework. To overcome this barrier, the project team selected console-style WSHPs to provide electrified space heating and cooling (see Figure 6). The console units are similar in size to the existing convectors. With this design, piping for ground-conditioned water/glycol solution and piping for condensate would run from the basement in each building, within the walls, and connect to wall-mounted heat pumps in several rooms in each apartment.[6]

Figure 5 (left). ***A convector in a Ulbrich Heights apartment.***

Figure 6 (right). ***An example of a console-style water-source heat pump*** (from WaterFurnace).

[6] Condensate piping would serve as a drain for water that condenses as the heat pumps cool humid air during the cooling season.

Deployment

Ownership – As the Phase 1 work proceeded, ownership of the envisioned system emerged as a variable more complex than the team had anticipated. WHA owns the Ulbrich Heights facility; but the team learned it is not well positioned to own, operate, and maintain the geothermal infrastructure or to maintain the water-source heat pump system. The organization's financial resources are too lean to enable it to contribute materially to the capital investment needed for the new system, to pay the central geothermal system's relatively modest operating and maintenance costs (e.g., cost of electricity for the pumphouse), or to assume responsibility for maintaining the water-source heat pumps in the facility's 38 buildings (note that tenants would be expected to pay for the electricity the heat pumps consume). The team learned that WHA also lacks legal authority to assess tenants for "common charges," which in this case means the agency could not require tenants to pay the cost of operating and maintaining the central geothermal system or the cost of maintaining the heat pumps.

Ownership of the envisioned system emerged as a variable more complex than the team had anticipated.

The team explored two other ownership scenarios as well. WED, as the municipal electric utility, would at least theoretically be able to assess common charges on tenants. But the company indicated it did not have sufficient experience or expertise to undertake an ownership role for the proposed facility. DEEP began a tentative conversation with Eversource, the parent company of Yankee Gas, which supplies natural gas to Ulbrich Heights. Eversource is well qualified to undertake this large geothermal project, given the company's experience developing and implementing a networked geothermal project in Framingham, MA, and Yankee Gas' experience in managing a capital-intensive gas business that involves building, operating, and maintaining underground infrastructure. Crucially, though, no regulatory construct currently exists in Connecticut for a regulated gas company to develop a rate structure and recover costs associated with geothermal projects.[7,8]

A further complication in the ownership equation: Federal rules for geothermal tax credits under the Inflation Reduction Act (IRA) require that the party owning the geothermal system also must own the heat pumps. This seemingly would preclude an arrangement in which WHA owned the heat pumps but a utility or other third party formally owned the central geothermal system. Since the Ulbrich Heights project would be unlikely to proceed without tax credits for both of these major components, it would be essential for the team to identify a way to satisfy the federal rules or work around them.

Logistics – Deployment of the proposed community geothermal system was estimated to take approximately 30 months, but this period could vary significantly depending on equipment and labor availability as well as

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[7] Massachusetts, New York, and several other states have adopted statutes enabling regulated gas utilities to develop, own, and operate thermal energy networks. Connecticut has not.

[8] Any of these parties – WHA, WED, and Yankee Gas – could have employed a third-party firm to develop the Ulbrich Heights project under a formal Design/Build/Own/Operate/Maintain or Design/Build/Own/Operate/ Transfer arrangement. However, such arrangements did not appear to offer immediate, clear means to resolve WHA's inability to assess "common charges" or Yankee Gas's lack of explicit statutory authority.

the scheduling preferences of WHA and the tenants. Ultimately, the timeline would be determined during the contractor procurement process. The selected architect would work with contractors to obtain all necessary permits required for construction and ensure the project is completed in a timely manner. Implementation of the geothermal borefield and pumphouse would take approximately one year.

This timeframe could be reduced five to six months if contractors utilized additional personnel and drilling rigs and if work were conducted during the summer to allow for the pumphouse and boreholes to be developed simultaneously. Once the borehole field and the pump house were completed, work on the buried heat pump loop piping and building interior retrofits could begin. The horizontal buried heat pump loop piping would be installed from the pumphouse outwards to the furthest buildings. The buildings closest to the pumphouse would be converted from natural gas-fired boilers to heat pumps first, and the heat pump loop piping would be installed concurrently. This would allow buildings to be brought online as they were completed, limiting the time that individual buildings were without heating or cooling.

Deployment was estimated to take 25-30 months, with drilling being the limiting factor in construction

Drilling, which would take the longest, is the limiting factor in how quickly construction of the rest of the system could proceed. Apartment renovations and installation of the horizontal heat pump loop piping would occur afterwards. Construction (piping, condensate, and power) for an individual apartment is estimated to take about two weeks. With ideal coordination between the trades, this process could be expedited.

The most significant disruption for tenants would be the required removal of existing hydronic heating systems and installation of the heat pumps and associated piping. Other disruptions would include noise and excavation work associated with drilling the geothermal field and installing underground piping. Construction could be phased to limit when these disruptions occur. The general contractor would develop a master plan to guide work in the interior of each building and align the various trade work and schedules.

Maintenance – The proposed systems would require ongoing maintenance. Each WSHP would need regular filter changes, at least every 6 months, to keep fans and coils clean and running efficiently; and condensate drain lines should be checked regularly.[9] Yearly testing of the geothermal water/glycol solution would be required, as would annual inspection of the circulator pumps. Buried piping typically is warrantied for up to 50 years; after the piping is installed, leak tested, and commissioned, no maintenance should be required. The heat pumps and circulator pumps would be expected to last 20 years or more.

[9] A ducted system would require less maintenance, because there would be fewer heat pump filters to change.

Projected Outcomes

The team estimated the cost of constructing, operating, and maintaining a system based on the community geothermal design as well designs involving the variants and alternatives. It also calculated expected changes in environmental emissions.[10]

Estimated capital cost for the community geothermal design is roughly $8.7 million, with annual operating and maintenance costs around $158,000.

Capital and Operating/Maintenance Costs – The estimated capital cost for the community geothermal design is roughly $8.7 million, with annual operating and maintenance costs around $158,000.[11] WED would be expected to provide a one-time incentive of $105,000; and Yankee Gas, the facility's gas utility, would be expected to provide a state-mandated incentive of $740,000. A federal Investment Tax Credit, bolstered by the IRA, would cover up to 40 percent of the remaining capital costs (assuming an ownership configuration that makes credits available for both the geothermal system and the heat pumps).[12] With these federal, state, and local incentives, the net capital cost would be $4.7 million.

Two factors – exacerbated by exceptionally high material and labor costs – pushed projected capital costs higher than anticipated:

- The thermal load of the target facility's 132 residential apartments is quite uniform (i.e., not diverse), hence the central geothermal system required to serve the simultaneous load of all apartments would be substantial. Moreover, no waste heat would be available to offset this load.
- Wallingford Housing Authority, which owns the site, indicated at the time of the team's application for Phase 1 funding that it expected to replace the existing gas boilers; however, during the Phase 1 work the organization learned that state funds would not be allocated for boiler replacements, which, accordingly, could not proceed. As a consequence, the avoided cost of ultimately replacing the gas boilers could not be factored into the near-term capital cost of the geothermal scenario. Moreover, because WHA does not own the existing window air conditioning units (the tenants do), the avoided cost of replacing these units could not be counted as a factor in the geothermal cost analysis.

Tenant Costs – The team's modeling indicates that, with implementation of the community geothermal system, tenants' overall utility costs would decrease. This is the case even though the modeling reflects provision of a service that for Ulbrich Heights would represent an important new benefit: universal access to cooling.

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[10] Details on projected capital, operating/maintenance, lifecycle costs, and emissions are available in the team's report "Technical, Economic, and Environmental Assessment for Ulbrich Heights Community Geothermal Heat Pump Project." The report is available on the project web page.

[11] *Estimate capital costs*: $8.1 million for equipment and labor; $552,000 for various fees. *Estimated operating costs*: $39,000 for electricity and maintenance of geothermal system (excluding insurance); $129,000 for tenants' electricity cost for WSHPs; and $5,500 for filter media for WSHPs (two changes per year; excludes cost of labor for filter changes and other WSHP maintenance).

[12] Through IRA's "direct pay" provision, tax credits would be available to WHA or another non-profit entity that has no tax liability.

Tenants currently rely on an assortment of inefficient window air conditioning in scattered rooms; the new system would provide efficient, comprehensive cooling throughout the warm months.

Modeling suggesting that tenants would save 12-31% on energy bills, depending on allocation of shared operation and maintenance costs.

UConn estimated a current average annual tenant baseline energy cost (electricity and gas) of $1,744. With the geothermal system and heat pumps, tenant annual energy cost would decrease $548 (31 percent). If tenants also were assigned the cost of operating and maintaining the central geothermal infrastructure, their average savings would be reduced to $253 annually (14 percent). If tenants also paid the cost of filters for semi-annual heat pump maintenance (but not labor costs for this maintenance), they would save $212 annually (12 percent).[13]

Lifecycle Costs – Accounting for net capital cost as well as the full cost of operations and maintenance, the community geothermal design is projected to cost $8.6 million over 30 years.[14] Fully electrifying by adding HPWHs to the design would bring the 30-year cost down to $6.6 million; and incorporating both HPWHs and solar PV would bring it down to $6.7 million. Both HPWHs and PV would involve higher capital costs, however. Alternatively, deploying a conventional, distributed geothermal system at Ulbrich Heights – with one or more wells for each building rather than a central borefield and pumphouse – is projected to cost $7.8 million over 30 years, while deploying ASHPs instead of geothermal is projected to cost far more: $21.5 million. Either distributed geothermal or ASHPs would involve a net capital cost slightly lower than that of community geothermal.

Emissions – The community geothermal design would reduce carbon emissions 41 percent, NOx emissions 29 percent, and particulate (PM2.5) emissions 34 percent. Reductions in all three of these categories would be significantly greater with the addition of HPWHs and/or solar PV. Emission reductions with distributed geothermal would be comparable to those obtained with the community geothermal design, while reductions with ASHPs would be less substantial.

Workforce

To assess the workforce needs of Connecticut's geothermal heating and cooling industry, NEEP and DEEP contacted ground source heat pump installers, drillers, trade associations, nonprofits, unions, relevant state agencies, utilities, training centers, technical high schools, and other industry professionals. Through surveys and interviews, NEEP identified workforce needs in three main areas: licensing (specifically for heating, piping, and cooling work), drilling capacity, and attracting and training new entrants. NEEP first developed a Workforce Needs Assessment and then organized four workshops with diverse stakeholders to discuss the findings and

[13] Although assessing tenants for "common charges" would not be possible if WHA owned the system, this might be possible under other ownership scenarios.

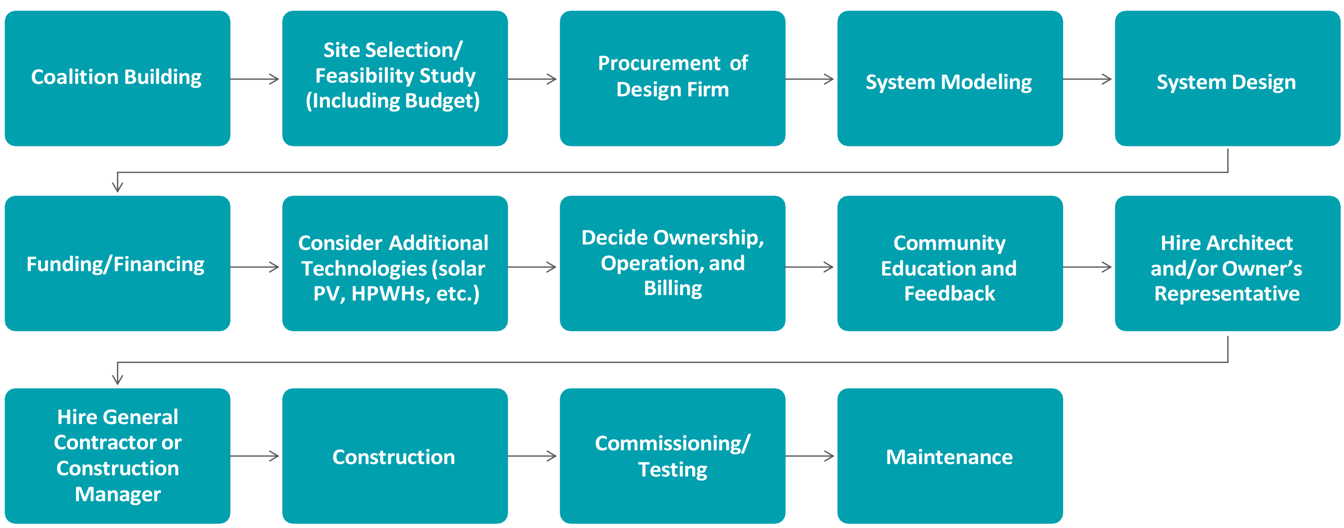
[14] This estimate assumes WHA would hire a third-party firm or firms for maintenance of both the geothermal system and the WSHPs.

explore potential solutions. These discussions were instrumental in shaping NEEP's recommendations to the state in the CT Geothermal Workforce Development Plan.

Process for Creating a Community Geothermal System

Figure 7 shows a series of steps necessary to plan and execute a community geothermal system. The order and exact steps may vary based on the local context, driving factors for developing a community geothermal system, and involved stakeholders. For example, coalition building may happen continuously as the project team engages more building owners and stakeholders who are interested in joining the project. Also, community education and feedback should ideally happen throughout the project, especially if the goal is to engage multiple building owners or homeowners to join the network.

Figure 7. ***Flow chart of the process for creating a community geothermal system.***



Conclusion

While community geothermal systems are complex and require extensive coordination, they provide an important opportunity both to upgrade heating and cooling systems for cost savings, efficiency, and comfort and to reduce greenhouse gas emissions and other forms of pollution. This case study offers insight into the design process and may assist others in designing and assessing the feasibility of community geothermal projects. The economics of the Ulbrich Heights design show that implementation could reduce utility costs for residents, even when factoring in operational and maintenance costs. Given growing awareness of geothermal as an important decarbonization solution and the availability of federal incentives under the Inflation Reduction Act, the project team is hopeful that the state, region, and nation will see many new community geothermal projects in the years ahead. Unfortunately, the combination of high capital costs and lack of a clear solution to the ownership challenge have forced the project team to conclude that the Phase 1 design is not viable for the Ulbrich Heights affordable-housing community at this time. However, the project team intends to continue investigating ways to support deployment of community geothermal in Connecticut and particularly in affordable multifamily housing.

For further information: https://portal.ct.gov/deep/energy/ulbrich-heights-community-geothermal-project
To contact the DEEP team: deep.geothermal@ct.gov