

# A COMMUNITY GUIDE To Mine Water GEOTHERMAL HEATING AND COOLING

*Informing Communities about  
Geothermal Potential*

2015

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# A Community Guide To Mine Water Geothermal Heating and Cooling

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## Preface

This guide is intended to give communities tools to analyze the potential for using mine water for heating and cooling buildings in sufficient detail to make an informed decision on whether to invest further time and money to pursue a detailed design. It is written for a broad audience including community members, politicians, small businesses, contractors, and groups interested in renewable energy resources.

This guidebook covers the basics of heating and cooling buildings with geothermal energy from mine water. It then covers strategies and tools for community-assessment and participatory planning, thinking through ownership structures, and innovative funding mechanisms. The fundamental message of this guidebook is that these large unused underground thermal reservoirs are available to be utilized now and in the future.

The instructions and tests featured in this guidebook were developed and tested in collaboration with the community of Calumet, MI. Examples from Calumet and other communities illustrating how to apply ideas, concepts, and steps described generally in the guidebook are featured in call out boxes.



# Introduction

"The first step toward getting somewhere is to decide that you are not going to stay where you are."

-John Pierpont Morgan

Millions of people live near a closed underground mine (2015 Micheal Korb, personal communication, unreferenced). Former mining communities often face a multitude of economic, social, and environmental challenges [1,2]. Reusing the flooded mine shafts for heating and cooling buildings can be a tremendous economic, social, and environmental opportunity [3].

Mine water geothermal systems can be both a financially and environmentally efficient means of heating and cooling buildings. Benefits can include reduced costs and vulnerability to market fluctuations in energy prices as well as significantly reduced CO<sub>2</sub> emissions.

In addition to being a highly efficient source of heating and cooling, the installation of mine water geothermal systems has the potential to create jobs, educate people and reduce energy costs on a local scale, while helping to reduce emissions on a global scale [4,5].

This guidebook discusses many opportunities for large scale geothermal systems. The sheer size of the thermal reservoir in a flooded underground mine opens the possibility of large installations whether it be district heating, industrial parks, or large manufacturing facilities.

However numerous homeowners can also sink individual shafts into a common reservoir. Flooded underground mines are vastly largely unrecognized thermal reservoirs that can be used for geothermal heating and cooling of buildings [6].

Kevin Rafferty of the HeatSpring Learning Institute said, "The fact that you are considering a geothermal heat pump system, places you among the best informed and most innovative homeowners in the country" [7].

There are seven main sections to this guidebook:

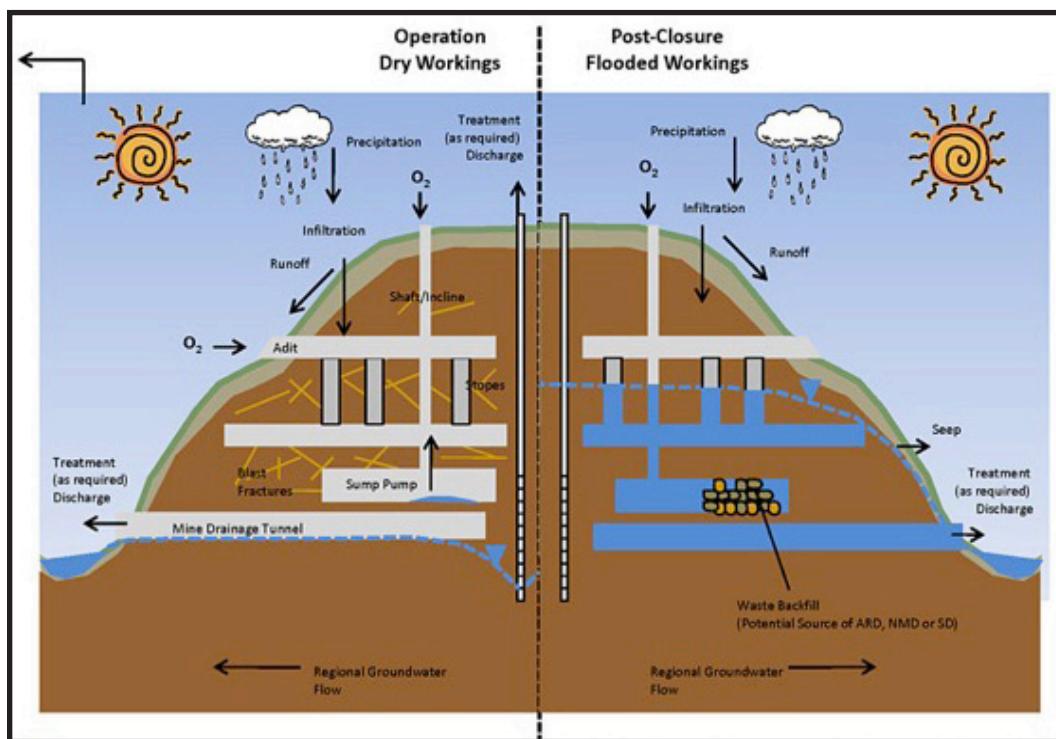
- 1: Details on geothermal heat pumps and the unique opportunities it can offer when paired with mine water
- 2: How to spread the word about geothermal, build support and leadership, and assemble a planning team
- 3: What data needs to be gathered and methods to do so
- 4: Analyzing data and what it means
- 5: Determining the best system configuration for the community
- 6: Exploring available funding assistance and potential legal concerns
- 7: Finding experienced, qualified geothermal professionals and HVAC experts

This guidebook would not be possible without the inspiration and lessons learned from Calumet, MI. Calumet is located in Houghton County, Michigan, in the middle of the Upper Peninsula's Copper Country district along the shores of Lake Superior. It was once at the center of the copper mining industry during the mid - 1800's until the mines officially shut down in 1968.

There are twenty-seven mine shafts and associated stopes in the town that have since filled with water that may be a potential source for a low-grade geothermal energy project. Documentation of the mine shafts contain information about the inclination, diameter, depth, and rock type of the mines which have been stored away in the town's archives.

## WHAT IS MINE WATER GEOTHERMAL?

An underground mine consists of one or more mineshafts used to access the mineral resource. Underground mining creates voids in the bedrock. Water from the ground or surface percolates into these hollows. When mines are being worked, this water is pumped or drained out to allow miners access to the ore seams. In most cases, when mine works are closed, pumping stops and the mined areas fill with water (Figure 1).



**FIGURE 1. Water Management in active and closed mines [1].**

Each flooded mine can contain millions to billions of gallons of water. The surrounding bedrock conducts the earth's heat into the water and insulates it from wide seasonal variations which keeps the mine water warmer than the ambient air temperature in winter and cooler in the summer, making it an excellent thermal resource [8]. The heat in the water can be utilized through a geothermal heat pump to provide a highly efficient way of heating and cooling buildings.



# Geothermal Heat Pump System

A geothermal heat pump uses the heat from the earth to heat or cool a building. The water in underground mine shafts has been insulated and warmed by the earth's heat to a constant temperature of 45° F to 75° F depending on the location. These are ideal temperatures for a geothermal heat pump system to utilize.

Geothermal heat pumps are more efficient than air source heat pumps because they exchange heat with the ground or water which contains vastly more heat for the same volume than air. As a result less energy is needed to concentrate the heat. Additionally ground temperatures are far more stable year round than air temperatures.

Geothermal energy at these temperatures is considered low (50°F to 65°F) grade geothermal [12].

The low grade designation distinguishes it from high (300°F to 700°F) to medium (80°F to 250° F) grade geothermal energy which are much hotter and found only at limited places on Earth such as in Yellowstone National Park. High and medium grade geothermal energy can be used to heat water into steam to generate electricity or heat buildings without the assistance of a heat pump.

While not as versatile, low grade geothermal energy is available everywhere in the world; however, it is much easier and more cost effective to access it in places with flooded underground mines.

Geothermal heat pumps can exchange heat with the ground and water sources in a variety of configurations as shown in Figure 3. Typically, these systems require a large amount of drilling or excavation to access the geothermal heat source.

Mine water geothermal is an innovative approach that uses the enormous thermal reservoir of a flooded underground mine as a heat source/sink [3]. This allows for greater heating and cooling capacities than other types of geothermal systems with little to no drilling required.

Geothermal heat pump systems are categorized into open and closed loop systems[16, 17]. Closed loop systems circulate an antifreeze solution inside sealed, closed loop pipes submerged in mine water. Heat from the mine water is then transferred through the wall of the pipe into the antifreeze solution and brought to the heat exchanger (Figure 3, row one).



## Economic Benefits - Ball State University & Marywood University



The dramatic difference is evident in the comparison between the geothermal system at Ball State University and Marywood University.

At Ball State University 3600 400 to 500 ft deep wells were drilled to create the geothermal exchange interface for their closed loop heat pump system [13]. This closed loop system also required 10 miles of pipe. In contrast at Marywood University a similar sized geothermal heat pump system utilizing a flooded underground mine required two boreholes and 2000 ft of pipe [14, 15].

The dramatic reduction in drilling costs is possible due to the much larger thermal capacity of a flooded mine. By comparison, a geothermal heat pump system that exchanges heat with the ground in a vertical setup requires a 100 to 300 ft well to be drilled for every ton of heating/cooling; for a large system, that translates to many wells. In some situations, it may be possible to use existing mine shafts as access points. In other cases, it may be more convenient and cost effective to drill a new access point.

In this system configuration, the mine water never leaves the mine. It can be used even when the water quality is poor as in areas with acid mine drainage. However, since the heat from the water must go through more heat transfer steps, a closed loop system requires more piping and may be less efficient than an open loop system.

In an open loop system, water is pumped into a pipe that brings the water out of the mine and runs it through a heat exchanger (Figure 3, row two). Afterwards the water is returned through the same mine shaft or through another shaft dedicated to return water.

If the water is returned to the same shaft, it must be returned at a different depth than from where the water is withdrawn. If the withdraw point and the return point are too close together, the water being withdrawn will not have had the time to equilibrate with the earth's temperature.

This results in a significant decrease of the efficiency of the heat pump. Open loop systems require that the water be plentiful, relatively clean and non-corrosive so that it doesn't damage the heat exchanger. Installing open-loop systems require that all local discharge codes and regulations are considered.

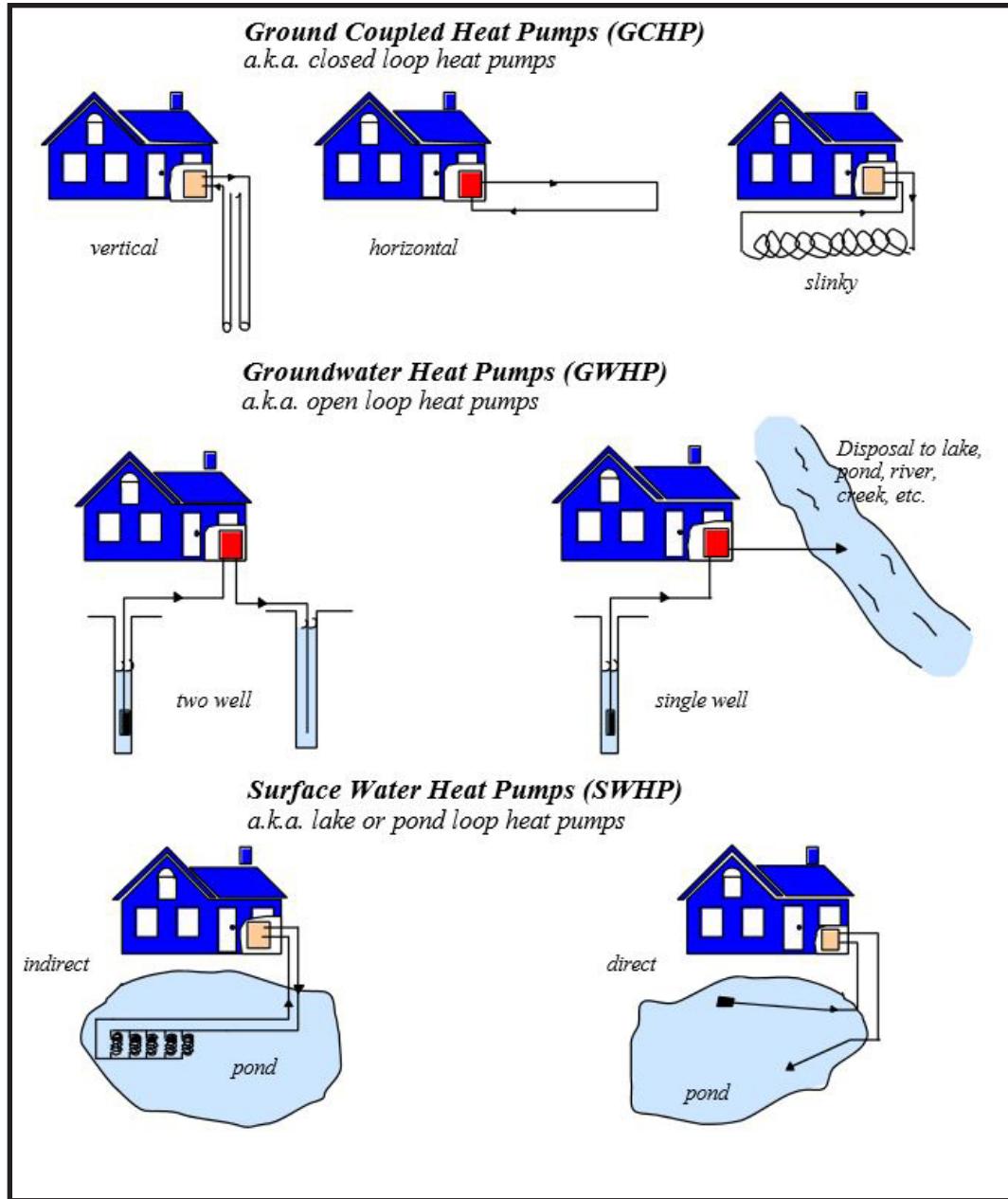


FIGURE 3. The figure above illustrates different ways and sources a geothermal heat pump system can extract heat [6].

Heat pumps can also be used with a variety of heating, ventilation, and cooling (HVAC) systems. Forced air systems and radiant heating systems are two systems easily converted to heat pump systems.

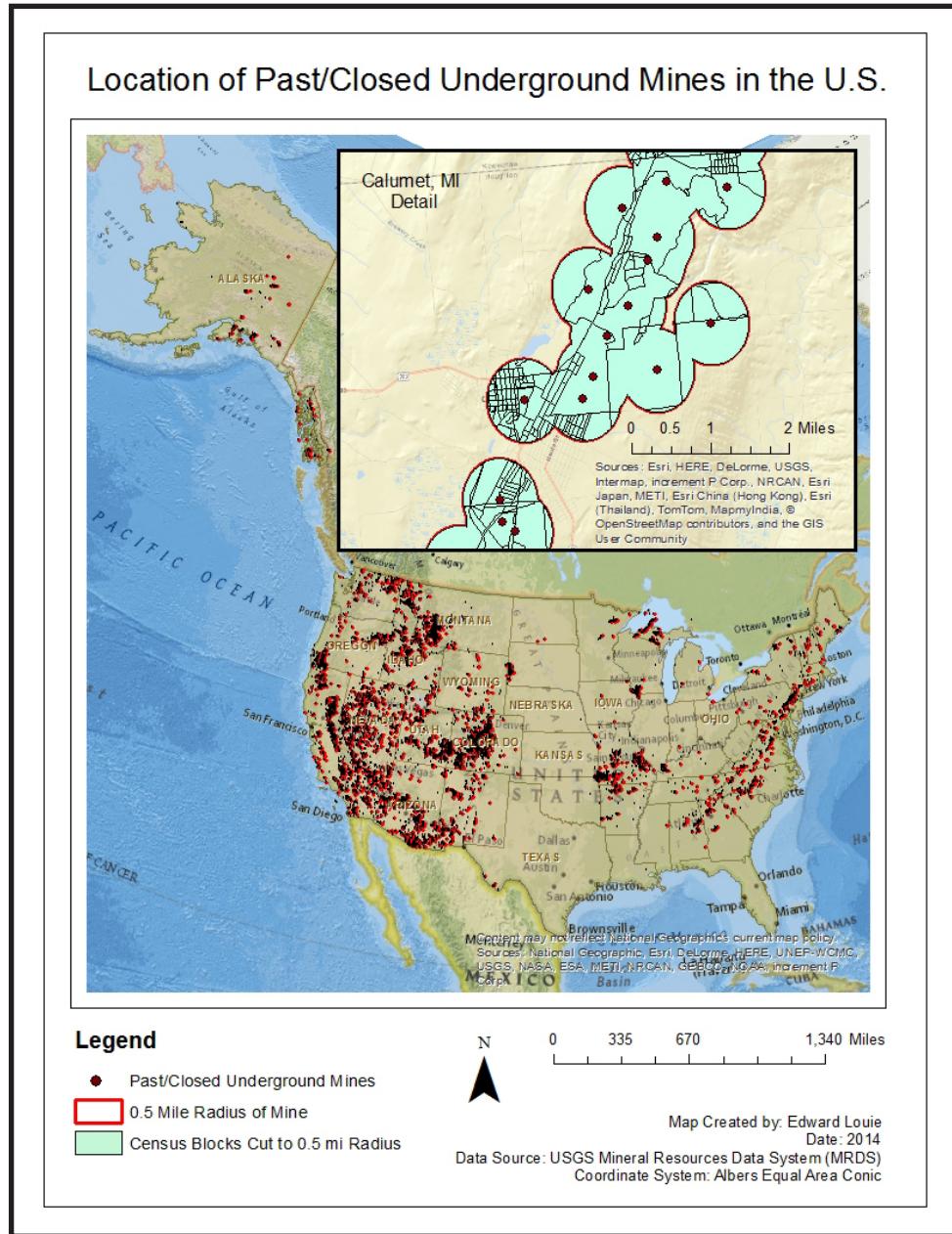
Steam boiler systems can be retrofitted with a heat pump hot water system; however, it is not recommended as heat pumps cannot concentrate heat enough to generate steam or hot water [18].

A surprising number of communities have access to mine water geothermal energy. Throughout the United States there are at least 23,000 closed, inactive underground mine shafts on private and federal lands; most of these are already flooded [19].

There are at least 2,300 shafts in the state of Michigan alone (2013 Allan Johnson personal communication; unreferenced). Comparing population data from the 2010 U.S. Census onto USGS data on the location of underground mines shows that over 764,000 Americans in 370,000 homes live within a half mile of a closed, inactive mine shaft.

The three states with greatest populations in the vicinity of a closed underground mine are Missouri, California, and Colorado with 194,000, 107,000, and 79,000 people respectively living within a half-mile of a mineshaft.

Thus a significant number of people could potentially harness the heat from nearby mine water using a geothermal heat pump. An overview of the location of these former mines is shown in Figure 4.



**FIGURE 4. Illustrated above is a U.S. Map of Closed/Past Underground Mines with a 0.5 mile Radius Buffer to Show Which Census Population Blocks are Within. Data Source: [7] and [9].**

Despite the great potential of mine water geothermal across the U.S., globally there are less than 20 documented systems; details on these systems can be found in Appendix A. The National Energy Technology Laboratory regards unused mine water as “a terrible thing to waste” [7], and yet mine water is a severely underutilized resource.

## How does a heat pump work?

Heat naturally flows from hot to cold. In order to get heat to flow from cold to hot, energy must be used. A heat pump is a mechanical device that uses a small amount of electricity to move and concentrate heat. The most common heat pump is a refrigerator. A refrigerator is not actually chilled through cooling, but rather heat is absorbed by a refrigerant which runs through the inside of the first of two heat exchangers. The second heat exchanger on the outside of the refrigerator exchanges the heat captured by the refrigerant to the air in the room. The heat coming from the back side of a refrigerator is the concentrated heat being removed from the inside of the refrigerator.

A geothermal heat pump operates in the exact same way except that it can run in both directions allowing it to heat and cool a building. It either takes heat from the ground (mine water) and moves and concentrates it into a building or takes heat from a building and releases it into the ground (Figure 2).

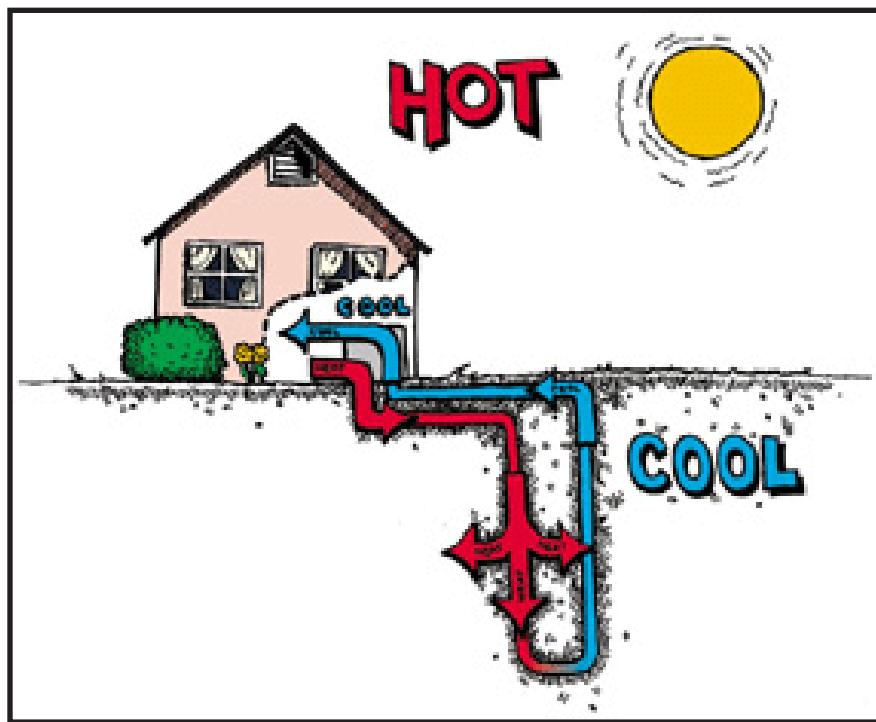


FIGURE 2. Basic Operations of a Geothermal Heat Pump System [3].

The cooling mode is even more efficient because it takes less energy to move from hot to cold. Heat pumps are three to five times more efficient than conventional heating and cooling systems.

As heating and cooling accounts for nearly half of the energy consumed in households [4] and the highest energy cost component in commercial buildings (27%) [10], changing one's heating and cooling system presents significant savings potential.

### ENVIRONMENTAL BENEFITS OF GEOTHERMAL TECHNOLOGIES

The EPA conducted a study in 1993 comparing the economic and environmental impacts of different heating and cooling technologies. The study found that geothermal heat pumps have the lowest operational cost and produce the lowest CO<sub>2</sub> emissions compared to other technologies (Figure 5).

According to the EPA study, geothermal heat pumps "can reduce energy consumption and, correspondingly, emissions by 23-44% compared to air sourced heat pumps, and by 63-72% compared to electric resistance/standard air conditioning equipment" [21].

Despite these clear energy and CO<sub>2</sub> savings, low energy costs combined with a lack of experienced installers comfortable with the increased complexity of installing a geothermal heat pump system have all combined to slow the growth of this technology.

### Key Terminology - Energy and Exergy



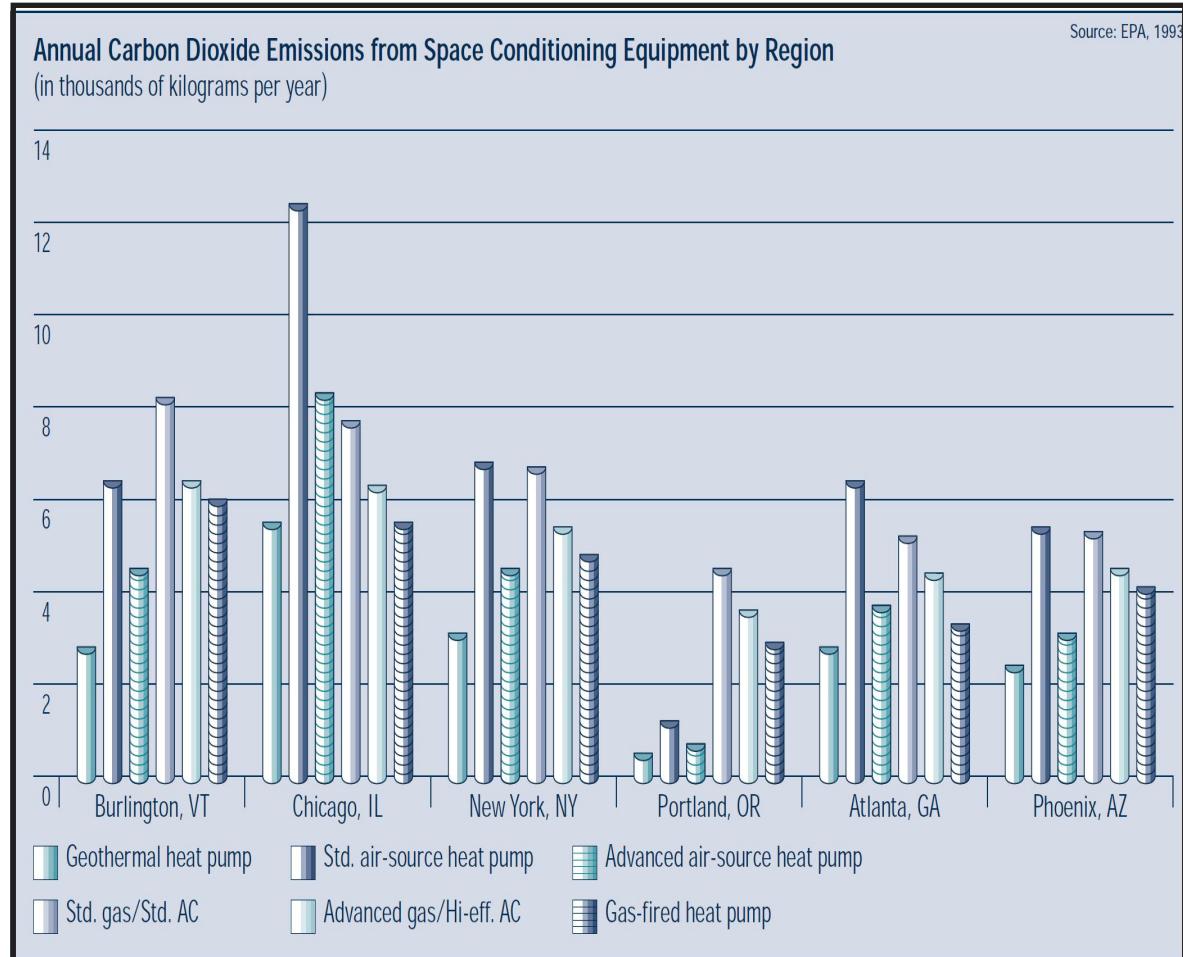
Energy is the power to do work derived from the utilization of resources to provide heat or work. Exergy is the maximum useful work possible from a resource.

From powering computers to running lights and appliances, electricity has very high exergy because its energy can be used in many different ways.

Heating and cooling has very low exergy requirements since the temperature desired is typically around 70 °F. As a result, a building can be heated using an energy source with low exergy.

Efficient heating and cooling is achieved by matching low exergy demand and supply in order to conserve high exergy potential.

Low grade geothermal energy from mine water is an excellent low exergy energy source for efficiently heating and cooling buildings, a low exergy demand.



**FIGURE 5. CO<sub>2</sub> Emissions of space conditioning technologies [21].**

Armed with a basic understanding of what mine water geothermal is, the following sections will describe the benefits of using community participatory planning to evaluate opportunities for mine water geothermal in your community.



# What is Community Participatory Planning?

## BACKGROUND

Former mining communities frequently encounter various economic, social and environmental challenges. Facing these challenges often begins with engaged, visionary, inspirational, and passionate citizens advocating for a community participatory planning model.

Community participatory planning is an organizational model where citizens lead the organization and generate ideas and solutions for their own future. Solutions and ideas defined and generated by engaged citizens are more often successful because community members are in the best position to assess the needs of their local area and have vested interest in the success of a project.

## PPSCD AND MINE WATER GEOTHERMAL

Interest in using mine water for various applications differs from location to location. Since mine water is considered a public resource it is important for a community to understand the many options for use. Participatory Planning for Sustainable Community Development (PPSCD) provides a framework to guide communities through the process of deciding how to utilize this resource [22].

The following sections give suggestions on how to assess the feasibility of using mine water for geothermal heating and cooling before involving outside consultants or contractors.

The feasibility study has the potential to build skills in community mapping, water testing, archival research, interviewing, business development, energy auditing, energy efficiency, design and installation. To begin, it is necessary to build a planning team identified.

# Building a Planning Team

The main function of a planning team is to generate interest, encourage participation, and educate people in the community. A planning team is made up of community members representing a broad range of interest groups and provides leadership and accountability throughout the planning process. Team members willingly commit time to a variety of tasks including:

- . Coordinating interest and working groups
- . Gathering information
- . Forming networks
- . Communication

Community members who possess local knowledge, technical, leadership, and communication skills are encouraged to participate. An integral part of the planning process is being sure to include many forms of knowledge, both expert and local, as it may help ensure that discussions and decisions are not dominated by one set of voices. The number of members in the planning team will likely grow as more stakeholders are identified.

## GENERATING COMMUNITY INTEREST

People are the most important part of community development. In order to involve more people, the planning team will want to generate community interest. Talking to friends, family members, and workmates among many others is an easy way to begin.

Conversations about energy efficiency or mine water geothermal systems will often bring new ideas and concerns to light. Holding a community meeting to address these initial ideas and concerns provides a forum for continued discussion and brainstorming.

Convening regular meetings will keep the community up-to-date on current developments, any progress made, and show where further support is needed.

Most communities have volunteer groups, churches, city or township officials, and established service or non-profit organizations actively engaged in community development.

Networking and collaborating with existing groups such as these saves time and resources and gets information out to more people faster.

## Participatory Planning - Calumet, MI



Since the Fall of 2013, the authors of this guidebook have been working with the community of Calumet, MI to explore the feasibility of a mine water geothermal system in their community. The community casually discussed interest in such a system for a number of years but was unsure if or how to move forward with the idea.

Members of Main Street Calumet (a local volunteer-run community organization aimed at promoting community and economic development in downtown Calumet) approached faculty at Michigan Technological University with their idea, and the community organization formed a working partnership with the university to get a better sense of how feasible this idea might be. The project started with a social feasibility study which looked at how the community perceived the idea of using the mines for geothermal energy.

Questions asked included: What is the level of interest? What concerns does the community have? Collectively these questions were asked in the form of interviews, community meetings, and a survey. The concerns and questions raised by the community made it clear that a general guidebook that communities could use to learn about and consider mine water geothermal development could be useful for many communities.

In response, students at Michigan Tech submitted a grant proposal to the Environmental Protection Agency's P3 Student Design Competition aimed at promoting people, prosperity, and the planet to support the development of this guidebook.

The development and testing of all parts of this guidebook would not be possible without the continual close partnership, participation, and support of social organizations, primarily Main Street Calumet, and the active participation of various community leaders.

Involving local media to highlight project ideas and announce meeting dates, times, and locations will inform others that may not be able to be reached by word of mouth.

Building a project website, utilizing social media sites (such as Facebook), and distributing flyers are examples of cost effective forms of communication that help generate community interest.

# Community Assessment

In order to move forward with a community-based project, it is important to know what people, organizations, and infrastructure already exist in the community that can help get a project started.

Community assessment tools are designed to help gather and analyze information about the community. Examples of these tools are:

- . Needs assessments
- . Community asset mapping
- . Oral histories

## Tools - Community Assessment Tools



Needs assessments, community asset mapping, and oral histories are tools that communities can use to facilitate a process of discovery and coming together. These tools are described more in Appendix B.

Needs assessments are conducted to discover what needs exist in a community. Community asset mapping is a process through which communities come together to map important elements, or assets, in their communities. Things that may be mapped include:

- important buildings
- landmarks
- neighborhoods
- community/neighborhood skills inventory

Oral histories are techniques that involve older generations telling their stories. These stories can be used to gather data, record history, and connect generations.

Areas and questions that communities may want to explore as they assess their strengths include:

*The Human Dimension:* Whose expertise do we need in order to answer our questions? Who has the training, education, local knowledge, or background to help us with this problem? How can we find solutions locally? Answers to these questions can be found by conducting a community skills survey.

*The Social Dimension:* What groups and organizations already exist and are willing to assist with a project? What groups or organizations can help gather and spread information to other groups inside and outside of the community? Who do we know from outside the community that will be willing to collaborate with us? To understand this dimension, you can conduct a community institutions review.

*The Built Environment:* What infrastructure already exists that can be improved or built upon? Is the accessibility of this infrastructure exclusive (available to some) or is it inclusive (available to all)? What is its condition? What are our options for improving or replacing? Is it privately or publicly owned and can that status change? To understand this dimension, communities can conduct an infrastructure assessment.

*The Environmental Dimension:* How do community members view the mine water? In what ways can we utilize the mine water? How do community members value and use nature? What is the climate? What are the heating and cooling needs of the community?

*The Cultural Aspect:* Where have we come from? Where do we want to go? How do our decisions affect various groups in our community? What are our demographics? Who has the greatest heating and cooling needs in our community?

*The Political Dimension:* Who are the power players in our community? How do power dynamics prevent people from being engaged? How can we change those dynamics? Whose support do we need to get things done? Who do we need to implement a project? Who can stop a project? How do we represent ourselves to the outside? Who sets the agenda? How can the community define the agenda?

*The Financial Dimension:* What businesses and lending resources are there in our community? Who knows about fund raising? Who understands accounting? In regards to finances, how will this benefit the community?

## Developing Assessment Indicators

While working on community development projects, it is important to come up with a way to monitor and evaluate the project. These steps are important not only to develop a database of best practices (what worked and what did not ), but also to evaluate the success of a project.

Within the participatory planning process, assessment indicators are developed by community members and are a measurement of what is important to that community (see Appendix B). For example, in a community primarily concerned with the rising costs of energy, indicators may focus on energy savings of a project.

In a community concerned with equitable access to heating and cooling, indicators may focus on the increased number of households with access to affordable heating.

Communities interested in utilizing a mine water geothermal system as an economic development tool may gather data related to jobs or new industries.

Specific assessment indicators to a mine water geothermal system might include:

1. The number of visitors to a building with a mine water geothermal heat pump designed as a showcase piece.
2. The energy bills of buildings with a mine water geothermal system.
3. The business profits of a commercial building retrofitted with a mine water geothermal system.
4. The number of employees of a business that is currently heated and cooled with mine water geothermal.
5. Reduction in the number of employee sick days.

Once assessment indicators have been developed, it is important that each phase of the project is carefully documented and revisited for evaluation. Information in the form of “progress reports” should be considered at each meeting to keep community members updated and projects on schedule. Reading through the following sections offers ideas of types of skills that will be helpful for data collection.



## Data Collection

Once a planning team has been assembled and needs have been assessed, the next step is to gather data on energy cost and options, the accessibility and condition of the water in the mine, the physical condition of the mine, and the heating and cooling needs of buildings.

Each data parameter begins with a background description and how it impacts aspects of the mine water geothermal system followed by an explanation of how to collect that information.

The data needed to evaluate the feasibility of a mine water geothermal system can be divided into three main groups:

- . Mine Characteristics
- . Water Characteristics
- . Structure Characteristics

They are specifically arranged in this order to help assess the feasibility of mine water geothermal and narrow down system options and configurations. Evaluating how the cost of electricity compares with different energy options is key to knowing whether a geothermal heat pump is cost effective.

Mine characteristics help determine which shafts are reusable and thus which buildings are within a feasible distance if no new shafts are drilled. Water characteristics help determine which geothermal system configurations are feasible. Lastly, structure characteristics are necessary for determining the retrofit cost and ease of integration.

Some pieces of data will require specialized equipment, precautions, preparation, and planning to collect. Additionally data collection will be more successful through input and participation by a broad spectrum of community members. For example, long-term community residents likely know a lot about the mines and are willing to share their knowledge and stories.

Local youth can add creativity and energy to the data collection process as well as gain experiential learning regarding energy, energy efficiency, physical sciences, the scientific process, collecting and recording data and oral histories.

For resources on how to include mine water geothermal in science classrooms and how to include community members in the data collection process refer to Appendix C.

This guidebook is partnered with a spreadsheet tool that will allow communities to generate geothermal system cost, operational cost, and payback period estimates for different system configurations.

The startup cost calculations use information including the pipe path distance from the building to the mineshaft, temperature of the mine water, depth to the water, and the angle of the shaft. The current heating system type, number of months of heating, and energy rates are used together with capital costs to estimate the payback period.

Calculated results are estimated costs and are intended to serve as a tool for guiding a community's decision on whether to pursue a professionally designed system. Neither the data collection process nor the use of the spreadsheet tool require any specialized expertise. Additional details are described within the provided spreadsheet to assist in refining the precision of the spreadsheet.

The calculator's estimates can be enhanced with input from local well-drillers and contractors. The local public works department can also be a helpful resource with maps of the locations of existing utilities and in providing information about construction costs.

As the planning team and community works through the process of collecting data, effort should be taken to present the information to the community periodically in a way that is easy to understand. This may include the use of Google Earth/Maps, graphs, charts, tables, and flowcharts.

Key aspects that may define the selection of a site or building for the system should be highlighted and their importance explained. The data can be presented at meetings to allow community members to be involved in the process.

## SAFETY

Before attempting to measure any of the mine or water characteristics, it is important to consider your safety and that of others. The evaluation and collection of data from mineshafts, flooded or not, presents potential hazards. Many mines have been covered over with unstable materials making the area susceptible to collapse.

Furthermore, though many mines are covered and capped properly, some have remaining openings large enough for a person to fall into and some may contain noxious gases. To mitigate these hazards, use caution and heed all warning signs.

The National Institute for Occupational Safety and Health (NIOSH) offers guidance on safety plans [23], but remember, the most important tool for protecting yourself is common sense.

Should you feel unsafe collecting the data, there are indirect ways to approximate the data such as researching mining company documents and oral histories. Be particularly careful if young people are participating. We encourage the inclusion of students, but we also recommend caution especially if entering the mineshaft is necessary.

## WHAT YOU WILL NEED

The following is a non-exhaustive list of equipment for gathering the data described in subsequent sections. Since each mine has its own unique challenges and obstacles, the suggested equipment may or may not be helpful for your situation.

Most of the equipment listed is affordable and easy to obtain; however, there are some pieces of equipment that are expensive and hard to find. A site evaluation is recommended to determine whether specialized equipment like a Kemmerer sampler can even be used in the given situation.

### **Key Terminology - Kemmerer Sample**

The Kemmerer sampler is a cylinder with rubber stoppers at both ends that snap into place when triggered by a messenger, a sliding weight.

To collect a sample, the Kemmerer is lowered into the shaft on a strong rope. Be sure to mark the string with measurements to know the depth at which the water sample is taken. Once lowered to the desired depth, drop the sliding weight down the line to close the cylinder. Then reel the Kemmerer back up to the surface and empty the water into the two containers wearing clean gloves to prevent contamination.



- . Safety equipment – good shoes or boots, gloves, safety glasses, hard hat, phone with service
- . Smart phone/GPS/maps
- . Camera/waterproof camera/GoPro Camera
- . Tape measure
- . Thermometer
- . Flashlight/head lamp
- . Strong rope
- . Protractor/inclinometer/Abney level (note, this type of instrument may be available on a smartphone as an app)
- . Watch/stopwatch/timer
- . Bottles/jars for water samples
- . Notebook
- . Pencil/pen/permanent marker
- . Kemmerer sampler
- . Fishing equipment – sounder, line, rod, bobber
- . Mine Shaft Assessment Worksheet (Appendix E)

Having many people thinking about and discussing the problem may bring alternate methods to mind. Pictures and descriptions of some low-cost/DIY water quality collection equipment are located in Appendix D.

Throughout the data collection process, make sure at least one person is taking notes. When it comes to documenting data, use as much detail and clarity as possible to ensure both you and other readers understand the notes later on. Notes should include the who, what, where, when, and why. Appendix E contains a worksheet to help one organize their ideas.

## Mine Characteristics

### LOCATING MINE SHAFTS

In some communities, the location and condition of mine shafts may be widely known. However, in many communities this knowledge requires researching historic maps, mining records, and asking the right people.

Once the team knows where the shafts are, the next step is to determine who owns the property and to gain permission to access the shaft. Once you have permission to enter the property, meet with other interested community members and organize the logistics. Make a clear plan for when the data collection will take place, how long it will take, and what resources are needed.

Evaluating the mine shafts will help determine which ones have accessible water and what challenges need to be overcome to access the water.

### *Mine Company Documents*

Most mining companies keep records of their shafts including maps with mine locations. These documents often include diagrams that help determine or validate field measurements of the angle of incline. They can also be used to estimate the volume of water available or potential drilling locations for accessing the mine water. These documents are typically filed with local or state government, local universities or community colleges, or in the possession of former mine employees. For further assistance in locating such documents refer to the U.S. Office of Surface Mining Reclamation and Enforcement's national mine map repository ([mmr.osmre.gov](http://mmr.osmre.gov)). While the actual maps are not available for download, the website gives an inventory of what maps are available and where the actual copy is stored.

### *Oral Histories*

In some cases, retired miners or their family members reside in the mining community. Invite them to discuss their experiences, observations, and descriptions of the mines. In addition to knowing the location of the shafts, they may know a lot about the layout of the mines and qualitative descriptions of the temperature and depth. Conversing with former miners and other mining company employees provides broader understanding and reinforces the participatory process emphasized in this guidebook.

If participants give you permission, record the conversations and interviews so that you can refer back to them. Also take notes and share the knowledge with others working on or interested in the possibility of geothermal technologies. These stories can enhance optimism in mine water geothermal and build community identity across generations.

### **MINESHAFT SITE EVALUATION**

Archived documents and oral histories contain valuable information for locating and pre-surveying mine shafts. Upon arrival to the site, the first thing to record is information about the location itself. Mark the location on a map, or use a GPS enabled smartphone to record the location using a free app like GPS Surveyor or GPS Essentials that will record the latitude and longitude location of the shaft.

These GPS coordinates can then be overlaid onto maps and satellite images available online from sources such as Google Maps. Marking these locations will help you analyze installation costs, and if drilling a new borehole should be considered.

Take notes on how easy or difficult it was to get to the shaft. For example, were you able to walk up to the site or did you need to open a locked gate? This information is important for knowing the possible complications of future data collection. For future reference, take as many pictures as possible and include a tape measure or a common object in the pictures to provide scale.

Pictures should include the surrounding landscape, land use, and proximity to buildings, nearby roads, infrastructure such as street lamps or sewers, etc. Record the date and time since time of year can impact the various measured parameters. This contextual evidence can inform expected seasonal changes. Appendix E contains a worksheet that can be helpful for organizing all of this information.

## GROUND DISTANCE

Ground distance is the distance from the shaft, or potential borehole site, to the building site of interest. Similar to depth, ground distance can drastically change costs associated with the system. Obstacles along this distance can also impact system costs. If pipes must cross a street, additional excavation and repair will be necessary. Securing permits for these activities may also increase costs. Ground distance should be calculated not as the shortest distance but the most feasible route that pipes can be installed.

## MEASURING GROUND DISTANCE

An easy way to do this is to use the GPS on a smartphone to record the latitude and longitude of each mineshaft into Google Earth. The locations will be overlayed onto Google Earth's satellite image which allows one to take into account obstacles, land cover, and terrain when evaluating the horizontal pipe path. The locations of the shafts can be shared amongst the community in the form of a publicly available Google Map. Community members can use the ruler tool to layout and measure the pipe path distances between mineshafts to any location of their choice without having to go on site.

### GPS locations of Calumet Mine Shafts

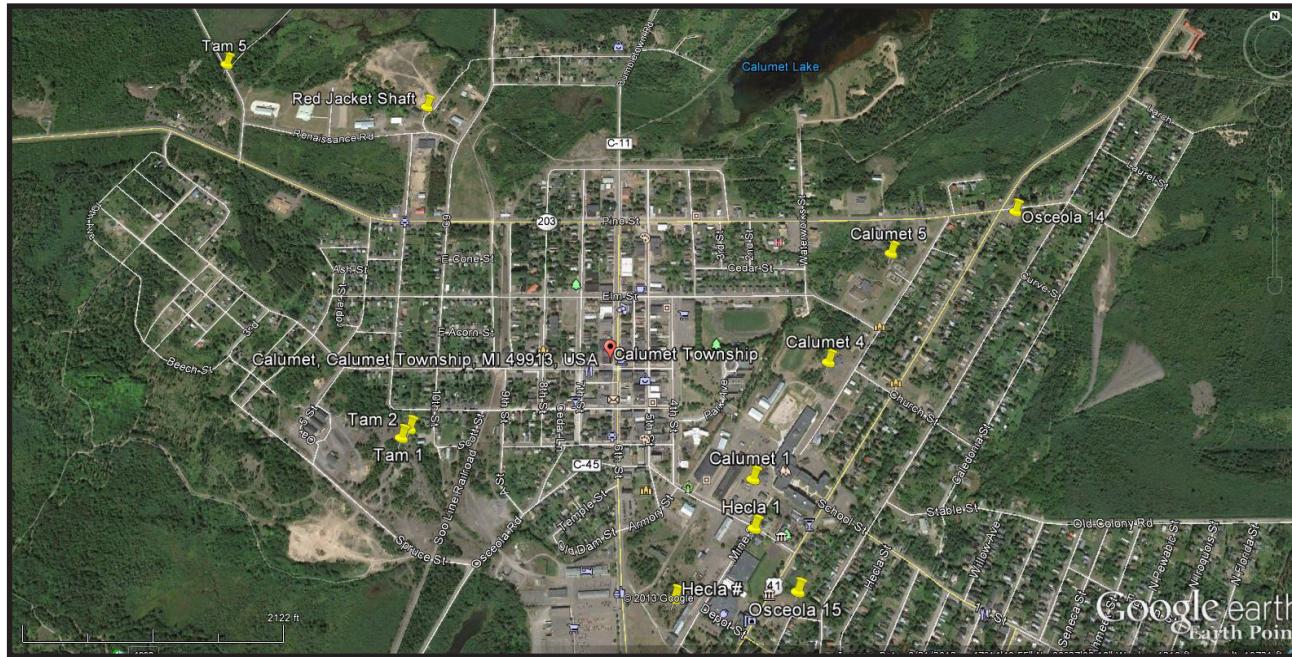


In Calumet, the location of several mine shafts was obtained from historic maps and local knowledge. The team visited shaft locations in person and took cell phone GPS readings. The GPS points were then overlaid onto a publicly available Google Map as shown in Figure 6.

This detailed visualization allows the data collection team to share visuals with other community members and improve understanding of possible mine water geothermal locations. It also allows anyone to calculate distances between shaft locations and any other location within the Google Map platform using the measurement tool. This sort of analysis informs discussion about when and where the community might install a mine water geothermal system.

Rather than a few decision makers choosing a location and then presenting a limited set of options to the public, allowing anyone in the community to participate in this planning process enhances transparency and democratic power in decision making. The interactive version of the map in

Figure 6 can be accessed via the following link, <https://mapsengine.google.com/map/u/0/viewer?mid=z4tp4KtKUVk.kJFVv08ehSWo>.



**Figure 6. Detailed Map of Mineshaft Locations in Relations to Present Day Buildings and Infrastructure. Location: Calumet, MI [24]. Map data: Google earth, Earth Point, August 21, 2013.**

### ANGLE OF INCLINE

The angle of incline is the angle that the length of a mineshaft forms with the horizontal ground surface. If an existing inclined shaft is used, the submersible pump will need to be propped off the wall of the shaft. The process of sliding pipes and a pump down an incline littered with mining debris is potentially challenging.

The cost and challenges associated with installing a pump in an existing inclined shaft should be weighed against the cost of drilling a new vertical well to access mine water. The smooth walls of a new well casing would then ease pump installation and associated labor costs.

### MEASURING ANGLE OF INCLINE

Using an inclinometer or Abney level will provide the most accurate measure of the incline angle. However, with a smartphone, there are dozens of free apps with adequate precision for measuring angles. The cell phone apps turn the phone into a spirit/bubble level which is useful if there is a representative smooth edge to measure from.

The inclinometer works by simply looking through the inclinometer at a far distant central point of the shaft. The values of the angle appear on the inside of the inclinometer. The Abney level works similarly. Look through the eyepiece at a central point deep in the shaft. Then adjust the level on the outside until the level bubble in the viewfinder lines up with the level line. Finally, look at the angle indicated on the exterior markings to determine the angle.

A string and weight tied to a protractor is another simple tool for estimating the shaft's angle of incline. Tie one end of the string to the center point of the protractor. Tie the weight, something as simple as a few washers would do, to the other end of the string. Rotate the protractor until the weighted end of the string lines up with the ninety-degree mark- this is your plumb line. Then, by visual estimation, line up the shaft's trajectory with the straight edge of the protractor and read the angle on the protractor that the free-hanging string touches.

Subtract that angle from 90- the result is the angle of incline. This process could be enhanced with a longer straight edge, like a meter stick, to compare the shaft's angle to the protractor. In addition, attaching a straw along the straight edge to use as a viewfinder can help line up the protractor with the shaft. Figure 7 below shows the basic set up.

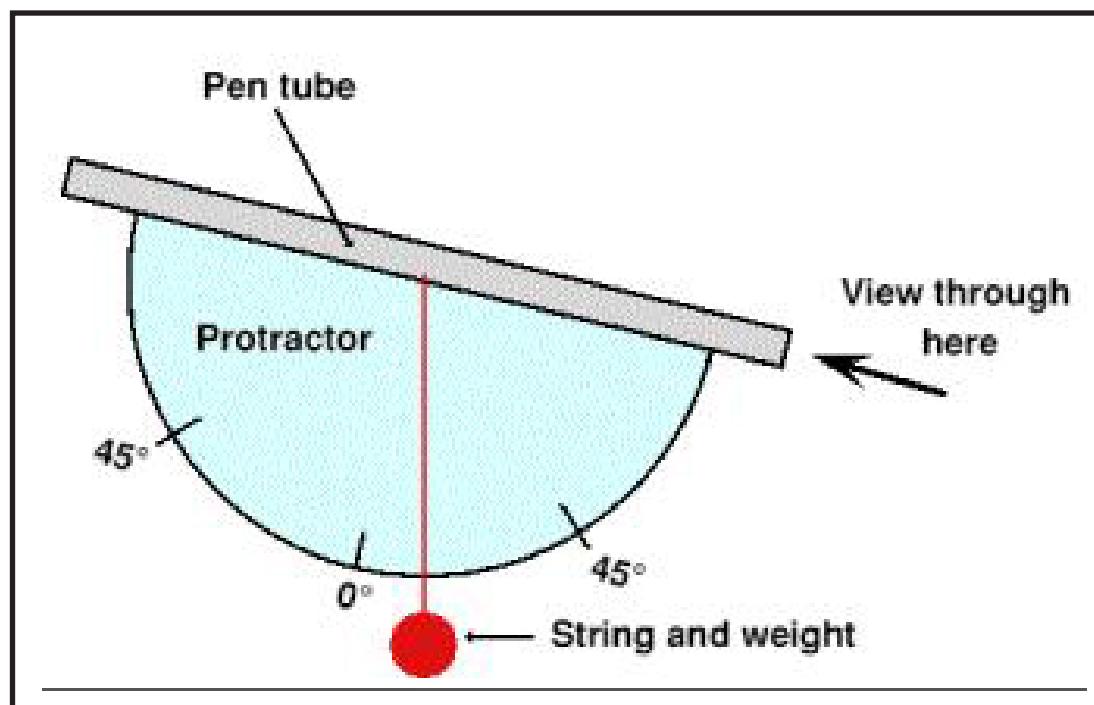


FIGURE 7. A DIY Inclinometer [25]

# Water Characteristics

The water characteristics of temperature, temperature gradient, and water level are important regardless of the geothermal system setup selected. If an open loop system is to be considered, refer to the water chemistry section for details on water chemistry analysis and measurement in **Appendix F**.

## TEMPERATURE

Water temperature is one of the most important factors for assessing the feasibility of mine water geothermal. The temperature of the water represents the energy present in the water and thus the energy available for transfer into heating or cooling a building. When heating a building, the heat pump concentrates heat from the water and transfers it to the building.

In the cooling mode, the heat pump concentrates heat from the building and transfers it to the mine water. Geothermal heat pumps are designed to work most efficiently for both heating and cooling when using water with a temperature between 45°F and 75°F [26].

In many cases, mine water temperature typically fluctuates only by a few degrees across the seasons. The relative stability of mine water temperatures provides a consistent source for heat in the winter and a sink for heat in the summer.

## WATER TEMPERATURE GRADIENT

The water temperature gradient is how the water temperature changes with depth. In some locations, the temperature is relatively uniform throughout the depth due to natural convective mixing; however, in other locations, there are large temperature gradients. The only way to know is to measure the temperature of the water at different depths. For places with uniform temperatures, the intake pipe needs to only go as deep as the water's surface. Where the water temperature changes quickly with depth, the design process becomes more complex.

The increased capital cost (more piping and bigger pumps) of accessing deeper water must be compared to the increased heat pump efficiency from using warmer water. The increased heat pump efficiency can result in needing a smaller, less costly heat pump. The volume of water needed to be pumped decreases with warmer water which would decrease costs. On the other hand, lifting water from greater depths increases costs.

Disturbance to the water temperature gradient can occur if warm water is extracted for heating and then cool water is returned into the same shaft. By replacing the initially warm water with cool water, the temperature begins to shift.

If cooling is the predominant need, returning warm water to the mine may raise the temperature of the water near the top thus affecting the temperature gradient. To preserve the temperature gradient, it may be necessary to use one shaft for withdrawing water and a second shaft for returning water.

At times, it may be best to drill an additional shaft if two shafts with the desired separation distance are not available. Alternatively, it may be feasible to mitigate this problem by withdrawing and returning water at different depths in a shaft.

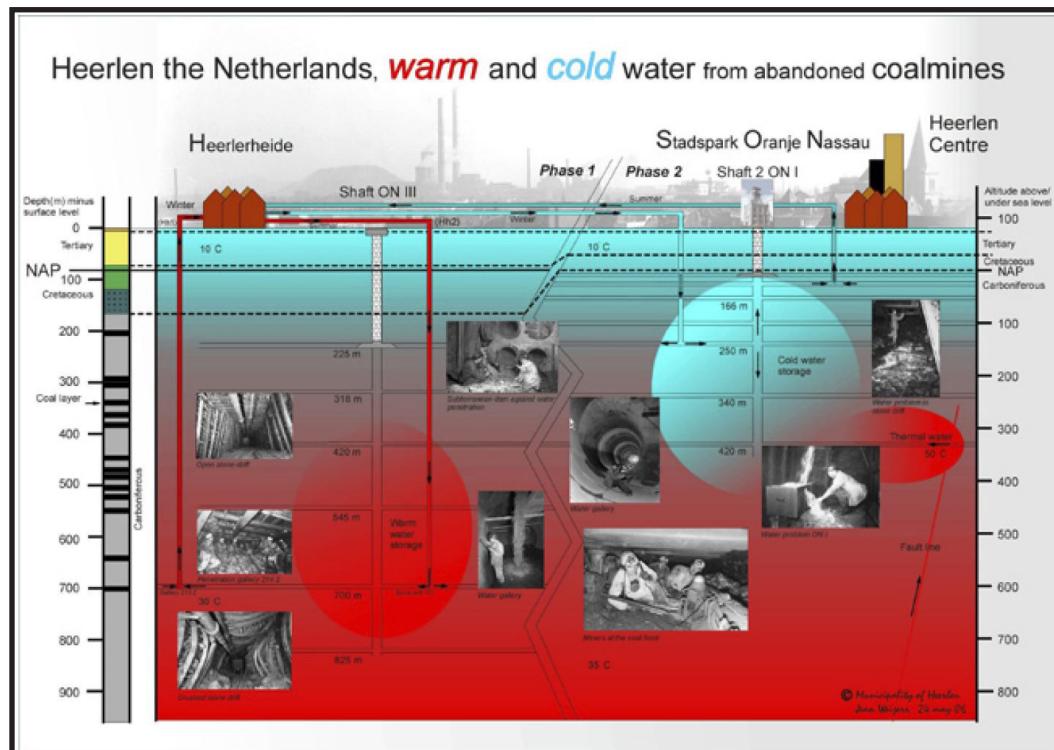


FIGURE 8. Schematic of the Heerlen mine water Geothermal System [27].



## Maintaining The Temperature Gradient



### Heerlen, the Netherlands

The largest and most famous example of a mine water geothermal system can be found in Heerlen, the Netherlands. The mine water in Heerlen has a pronounced water temperature gradient. Because the location and condition of existing mine shafts were not ideal, five new wells were drilled to take full advantage of the temperature gradient.

Two hot wells were drilled 2,300 ft deep to take advantage of the warmer water (82°F) for heating. Two shallower wells were drilled 820 ft deep to take advantage of the cooler (61°F) water for cooling. The fifth well was drilled to 1150 ft and used to return hot water that had been significantly cooled or cold water that had been significantly warmed to a temperature range of 64°F-72°F.

These efforts to carefully manage the temperature and location of the returned water helped Heerlen ensure that the advantageous temperature gradient would remain intact throughout the lifetime of the system. A schematic of this system is given in Figure 8 [27].

### MEASURING TEMPERATURE GRADIENT

The mine water temperature can vary with depth as well as with season. The best way to gather this data is with a submersible thermometer with data logging capabilities. This equipment may be too expensive for a community to purchase, but there are DIY techniques that can help estimate this information.

A logging thermometer will take measurements at a preset interval, record it with time, and store that data internally. Using a logging thermometer in combination with a tape measure and a watch allows one to record the temperature at different water depths. To link temperature with depth, simply lower the logger to the water surface and record the time and the depth at which the logger hits the water surface. Continue to lower the thermometer by set intervals noting the time at each stop.

The thermometer needs a certain amount of time to respond and stabilize thus one should hold the thermometer at a given depth long enough for this to occur. When reading the data, match the time and depth to the time and temperature given by the logger.

If possible, repeat this process for all seasons as the temperature gradient may change depending on the season. If a waterproof data logging thermometer cannot be obtained, there are other homemade versions that will be less precise.

The Colorado 4H Sport Fishing Program has created a guide for constructing a homemade device to measure water temperature at various depths. The detailed instructions for which can be found at the following link [28].

The homemade device is a thermometer inside a weighted, perforated container. The weight of the container allows it to sink to a chosen depth. The perforations allow the container to fill with water once submerged and thus helps insulate the thermometer from the air temperature while it is being brought to the surface for reading and recording.

The price of this device is a great advantage but it does take more effort and time to record the temperature gradient using the homemade device because the device must be brought to the surface to read each measurement. Harness the creativity, skills, and resources within your community to consider other methods of collecting information on the temperature gradient.

### *Water Level*

The water level is the vertical distance from the surface of the ground to the top surface of the mine water. The water level represents the minimum amount of vertical piping and relates to the power needed to pump water to the surface, thus affecting its expense. The pump will also need more power for higher flow rates and more water per minute which will be necessary for less desirable water temperatures.

### *Measuring Water Level*

The water level may or may not be visible by looking down the mine shaft. If the water is visible and relatively shallow, the end of a tape measure can be lowered until it touches the water's surface. For rough or debris ridden inclined shafts where the water is visible, a long pvc pipe is an effective tool for reaching or estimating the distance to the water's surface.

For a deep vertical shaft, fishing equipment may be an affordable DIY tool. Using a fishing line to lower a bobber into the shaft it is possible to measure the length of the line to get the distance. Some fishing reels have a line counter which will measure the distance automatically.

Another tool is a sounder which is specifically made to locate the water surface in wells. It is a reel with a probe at the end that makes a sound once it hits water. The length is marked off like a tape measure for easy recording. Ask around the community to see if anyone owns a sounder.

Inclined shafts where the water is too deep to see are the most difficult to measure. If it is smooth, try to slide connected pieces of pvc pipe down the shaft with a sounder attached. If the walls are rough and/or debris and obstructions are visible, consider foregoing the shaft as an option for mine water geothermal.

### *Volume of Water*

Volume is important because the temperature of the water can change over the life of the system if the volume of water is relatively small. A cooling trend can occur in the mine water if the system is typically used for heating. This happens because the water returned to the mine is colder than the water already in the mine. Over time the colder return water can cool the overall temperature. The opposite effect is observed when the system is used predominantly for cooling buildings.

If the volume of water is small, a separate return well may need to be used to eliminate the risk of changing the temperature of the water. Available water volume can be estimated by examining old mining documents (the available water volume will roughly coincide with the amount of material removed over the life of the mine).

# Structure Characteristics

## EXISTING SYSTEM

Energy demand is the amount of heating and cooling a building requires. Knowing the current demand is an important building specification because it indicates the size (and number) of heat pumps required as well as the needed thermal capacity of the mine water. It is also a good idea to estimate future use if there is a desire to expand the system. With such predictions, the installed system can be designed to accommodate more users as time goes on.

The existing system refers to the type of heating, ventilation, and air conditioning (HVAC) system currently being used in a building. This information is important in terms of cost because some HVAC systems have components that can easily be retrofitted to a heat pump system.

Forced air and many hot water based systems (those that operate using hot water below 140°F) lend themselves to retrofit integration with a heat pump. You will often find hot water systems using either wall mounted radiators or embedded heating coils in the structure. These include radiant heated floor slabs, walls, and ceilings. Hot water radiant heat systems are the easiest to retrofit because very little of the building's existing heating infrastructure needs to be changed.

It is simply a matter of replacing the natural gas or electric hot water heater or boiler with a water-to-water geothermal heat pump. A forced air furnace system is also equally easy to retrofit by simply replacing the furnace with a water-to-air heat pump but it is not as energy efficient.

Cost and ease of retrofit should not be the only factors to consider when evaluating the feasibility of a heat pump system. It is beneficial to examine whether the existing HVAC system adequately provides the occupants with satisfactory year round comfort.

In some cases, it may be cost effective to replace the current system with a new, more efficient system. Often times, there are incentives for upgrading to more efficient HVAC systems.

For example, if the existing HVAC system is not able to provide cooling during summer, and this is something that the occupants desire, this fact should be noted. Another important thing to note is whether there are areas that need cooling/heating at the same time. With multiple heat pumps or innovative heat pump designs, heating and cooling can be done simultaneously, a feature not found in any other HVAC system.

### Innovations in Heat Pump Design



Traditional water-to-water systems are more efficient than water-to-air systems. With a good pipe layout and an electronically controlled circulating water pump, heat can be delivered at less than a tenth of the energy required to operate a blower delivering the same amount of heat [29]. However two recent innovations in heat pump design have greatly increased the efficiency of water-to-air systems.

One innovation is the elimination of inefficiencies associated with moving air through ducts. The solution is achieved by moving the heat exchanger and fan where the heat is released to each room and pumping refrigerant via thin, flexible, and insulated pipes from a central compressor. The second innovation has to do with the ability to use excess heat from one part of a building to heat another part, i.e. the ability to simultaneously heat and cool different parts of the building.

A water-to-air system also has the advantage of being able to provide cooling whereas a water-to-water radiant heat system cannot effectively perform cooling.

# Measuring the Existing System

## ENERGY

Energy costs for the purposes of this guide pertain to understanding and comparing the costs associated with running different heating/cooling systems. Energy comes in many forms: electricity, natural gas, propane, fuel oil, etc.

Comparing them can feel like comparing two completely unrelated things especially since they are measured and billed in different units. For example:

- . Electricity is billed by the kilowatt-hour (kWh)
- . Natural gas is typically billed in therms (thm)
- . Propane and fuel oil are billed in gallons

Besides being in different units of measure, the energy content of each unit is also different. A common unit of measure to convert to is a BTU (British Thermal Unit).

Since geothermal heat pumps use electricity, the cost of electricity compared to other options should be the first evaluation tool. Due to its efficiency, a modern geothermal heat pump can easily move 3.3 or more units of heat energy for every unit of electricity it consumes [30].

The precise efficiency of a heat pump, measured in a term called coefficient of performance (COP), depends on the temperature of the water it is extracting heat from, the temperature it needs to concentrate the heat to, and the efficiency of the heat pump itself.

If the cost of energy from electricity is more than 3.3 times the cost of an alternative source of energy then it is possible that mine water geothermal may not be the most cost effective means to heat and cool buildings.

In the process of writing this guidebook (2014/2015) natural gas prices were at a low while electricity prices were high; even so, 44 out of 50 States had electricity and natural gas price averages which favored geothermal energy [31,32].

It is also important to consider expected future energy costs since a building's HVAC system is a long-term investment. Knowing these costs can help assess the payback period for geothermal systems that generally require high capital cost but low operating costs.

## MEASURING ENERGY COSTS

The present cost of energy can be found on utility bills and on the utility's website. The Energy Information Agency has created a useful spreadsheet available online at [www.eia.gov/tools/faqs/heatcalc.xls](http://www.eia.gov/tools/faqs/heatcalc.xls). The spreadsheet converts the unit of measure of all fuels to "Fuel Price Per Million Btu" allowing one to compare the cost of heating across fuel sources.

The values in the yellow cells of the column "Fuel Price Per Unit (dollars)" need to be changed to reflect the local fuel prices. The values in the "Efficiency Rating or Estimate" column should also be changed if more specific values are known. Otherwise, the default values are adequate for a first estimate.

As described above, the default efficiency of a geothermal heat pump, COP of 3.3, is a reasonable value to use when a specific heat pump has not been selected. When a specific heat pump has been selected, the COP of that geothermal heat pump should be entered.

While the cost differential between energy sources is important, it is necessary to know how much energy the building uses for heating and cooling in order to calculate the payback period of a mine water geothermal system for the building.

The current operating costs to heat and cool a building can be estimated from utility bills. Since the utility is often used for purposes other than heating and cooling, a good way to estimate the heating and cooling portion is to take a month with insignificant heating and cooling and subtracting it from the rest of the months.

For example if natural gas is used for heating and cooling, by subtracting July's natural gas usage from the other months, it will result in an estimate of how much natural gas is used for heating.

If electric heating is used, the increase in electricity consumption in the winter is primarily due to heating since one does not significantly increase other electricity uses between the seasons. Subtracting the month with the lowest electricity usage, a month with minimal heating and air conditioning, from all other months of electric bills will result in an estimate of the energy used for heating.

This method of estimation is a little tricky to apply to cooling. To do so, identify the month with the lowest electricity usage. If it coincides with a month with minimal heating and cooling needs, it can be used to subtract from the summer months of energy bills. The remaining is an estimate of the energy used for air conditioning.

These annual heating and air conditioning costs are necessary for calculating the payback period of a mine water geothermal energy system using the calculator application. Such estimations may be more difficult for community buildings or businesses where other sources of energy use may be high thus masking the energy used by heating and cooling.

Building operators will often know the details about the building's sources of high energy usage and whether such estimation techniques are applicable.

The size of the existing heating and cooling system is a great starting point for estimating the size of the geothermal heat pump needed. The sizing and capital cost of the geothermal heat pump in the calculator application is based on the size of the existing heating system.

The answers to the following key questions about the size and adequacy of the existing HVAC system is needed to size the heat pump and determine which buildings would most benefit from a mine water geothermal system:

- . What equipment is currently being used to heat and cool the building?
- . What is the size of the current heating and cooling system?
- . The heating or cooling unit will have a sticker that states the size in BTU, ton, or watt.
- . Is the current system providing satisfactory heating and cooling of all spaces year round?
- . At any given time, are there areas that need to be cooled and others that need to be heated at the same time?
- . How old is the HVAC equipment?

The maintenance staff of a municipal or community building will often know the answers to these questions. Similarly, many homeowners and business owners know where to look for the answers to these questions.

If the current heating and cooling equipment is providing the right amount (comfortable) of heating and cooling then it is likely to be properly sized. If it is not comfortable, for example it is too hot or too cold, the temperature fluctuates, or the air at the vent is too hot, then it is likely that the original equipment was not sized correctly.

The size of a heating and cooling system needed for a building is calculated using a series of equations which are often embedded into spreadsheets or software. The size of the system is determined based on estimates of the heat loss of the building by accounting for dozens of factors including the size and shape of the building, amount of exterior surface, level of insulation of the walls, and the number of windows.

The process of estimating the heat loss of a building is slightly different for residential versus commercial buildings. However the process is standardized into what is called the Manual J methodology which is used to estimate the heat loss of residential buildings and the Manual N methodology for commercial buildings.

While it is a tedious and time consuming process to measure the many factors that go into calculating the heating or cooling load of a building, the process is not difficult. In fact, there are online resources, such as loadcalc.net, which walks through the parameters one by one.

# Using the Spreadsheet Calculator

Accompanying this guidebook is a spreadsheet tool that calculates the capital costs, operational costs, and payback period of a mine water geothermal system compared to the existing system. The tool can be accessed by visiting the following link: <http://aee-mtu.org/geothermal-calculator/>

The capital cost is comprised of the cost of the piping, the water pump, the geothermal heat pump, and the associated installation costs. The cost of piping and installing the pipe is determined by the depth to the mine water, angle of the mine shaft, and the length of the pipe path from the mine shaft to the building.

The size and cost of the geothermal heat pump is determined by the size of the current heating system. The size of the pump is determined by the depth to the mine water, the length of the horizontal pipe, and the flow rate needed by the heat pump. The flow rate needed takes into consideration the temperature of the mine water. The system factors in the savings realized by the 30% federal tax rebate which is applicable to everyone in all states.

In order for a mine water geothermal system to make financial sense, it must cost less to operate than the current system. Using the cost of electricity and the COP range of geothermal heat pumps, the calculator will determine estimated operating costs of the heat pump system. The size of the water pump determines how much electricity will be consumed.

The operating costs assume that the geothermal heat pump system will run 50% of the time. Additionally a fixed annual maintenance cost of \$100 is factored in. The payback period is calculated by comparing the operational cost of the geothermal heat pump system divided by the annual cost savings of the geothermal system.

This tool provides approximations and makes a number of assumptions. Details on the assumptions are summarized in the spreadsheet tool however it will provide a useful estimated figure.

The spreadsheet calculator contains a number of assumptions resulting in an estimate that is sufficient for a first order analysis. For example the calculator assumes the heat pump will be used 50% of the year for heating and does not include air conditioning which would reduce the payback period since a geothermal heat pump is extremely efficient in cooling mode.

The calculator assumes an open system design which has better heat transfer efficiency but may have higher pumping costs. On the other hand, a closed system requires more piping costs which can be offset by a smaller pump.

The accuracy of cost estimations by a professional geothermal heat pump system designer for a system may also be limited. This is due to the limited, direct experience and the diverse set of opportunities for cost savings and potential issues that can raise costs as discussed in previous sections of this guidebook.

At best, a geothermal system designer will use cost experience from traditional open and closed loop geothermal heat pump systems to estimate the cost of a system that uses mine water. If the mine water is found to be suitable for an open loop, the cost will be estimated using cost information from open loop geothermal heat pump systems that use water wells as its thermal exchange medium.

For a mine water system that is a closed loop, the cost of a system can be estimated using cost information from vertical closed loop geothermal heat pump systems which does not include the cost of drilling.

The spreadsheet is designed to size and analyze costs for a system that serves a single building. However, this spreadsheet can also be used to inspire decisions on how to setup a district system. The capital cost and return on investments of a host of buildings can be determined by running data for each building through the spreadsheet one at a time.

Buildings can be prioritized based on capital cost or payback period for inclusion in a district system. The cost of each individual system can also be added to get an estimate of the total cost of a district system. Because this method of estimation assumes each building will have its own set of pipes from the mine water, water pump, and heat pump, it will be a very conservative cost estimate.

Use this estimate knowing that the real cost would likely be significantly lower since in a district system, each building will not need its own pipes and pump to the mine shaft. A district system may incur higher consultant and overhead costs due to the greater number of legal hurdles especially if the system is to become a utility.

The planning team can encourage the community to use this spreadsheet tool in conjunction with data displayed on Google Earth. Encourage all interested members to experiment with the tool by evaluating different buildings and pipe layouts. If there are people in your community interested in more detail or more accurate estimates, the calculator can be modified.

Community members can also use the more complex, but more accurate, calculator created by ClimateMaster , a manufacturer of heat pumps[33]. The community can then get together to discuss favorable configurations, considering the environmental impacts of construction, ownership, financial, and legal barriers and opportunities each option may possess.

Furthermore, local HVAC contractors are likely to have their own calculators and may be willing to conduct feasibility studies at low costs in hopes of getting a large installation contract.

### **Water Quality - Avoiding Potential Problems**

Research on mine water has found that the water quality of some mine water can change for the worse once an open loop mine water geothermal system is installed. The cause of this chain reaction is due to the introduction of oxygen to the mine water. This can occur if an open loop system is configured such that the water is returned in a manner that it free falls from the ground surface to the water surface which causes splashing.

This discovery was made from analyzing the mine water of two geothermal systems in Scotland. Fortunately those systems were designed such that the water would not become exposed to oxygen and operational experience found mineral precipitation to not pose a problem to heat pump systems [34].

## Putting It All Together

This section helps community member begin to envision how a geothermal system can fit into their community. Looking at the information gathered on mine water, potential access points, and current energy and HVAC systems should help the community answer the following questions:

- . What shaft(s) can be used? If no shafts are suitable, where are potential drill sites?
- . What building(s) are most cost effective to retrofit? Which building(s) does the community want to retrofit?
- . Are the desirable buildings close enough together to warrant a district system?
- . What system designs (open or closed loop) are possible based on the water quality data?
- . What social, cultural, and/or economic impacts are possible at each potential location?

These decisions can be made through participatory planning. Community meetings can be held to share data about mine water and make decisions about what buildings could be retrofitted and how the community wants to fund the project.



## Ownership Structures

The ownership of a geothermal system can impact who benefits from the system and can present available funding opportunities. The simplest ownership structure would be an individually owned system installed in one building. This could be a private residence, a publicly owned building, a community building, or a privately owned business. The benefits of these types of setups would primarily be to the owners of the system (who may or may not be the users).

There would also be community benefits through lower carbon emissions and possible training on geothermal systems. If the project was part of a larger energy efficiency weatherization program, training on these aspects could also be provided. If the system was installed in a community building, it could serve as a focal point for energy efficiency education programs.

Systems installed in community owned buildings could also provide savings in tax dollars. Buildings that are owned by organizations providing social services could benefit from reduced energy bills which would increase their budget allocations to their services. More about various system configurations and ownership structures are outlined below.

### Showcase building Example



**Municipal Building  
(Individual system, single owner/user)  
Park Hills, Missouri**

Heated and cooled by water from a flooded lead mine, this 8,100 square feet building was completed in 1995. The flooded mine contains an estimated 70 billion gallons and lies 35 to 435 feet below the surface of the city. While the water has high levels of iron, the lead does not leach into the water because it is not acidic (pH 6.0-6.5). The temperature of the water is a constant 57 °F. The system utilizes a 400 feet deep supply well, a plate-and-frame heat exchanger, and a second return well.

The heat exchanger prevents the mine water from being contaminated (it is also used as a source of drinking water) and keeps the iron in the mine water from being deposited in the heat pumps. The internal loop is a closed loop water system that circulates throughout the building. There are nine water-to-air heat pumps that extract heat from the internal loop and transfers it to the building. For cooling, the process is reversed.

The building maintains nine different temperature zones and has successfully provided building comfort even when the outside temperature ranges from 108 °F to -10 °F. The building cost \$700,000 to construct with the heat pump system costing \$132,000.

Part of the costs (\$20,000 each organization) of the system were paid for by the Union Electric Company (the local utility) and the Electric Power Research Institute (EPRI). A comparable conventional system would have costed \$110,200. Estimated energy savings are in the range of \$4,800 a year giving the system a 4.6 year payback period even without the financial contributions from Union electric and EPRI [35].

#### SINGLE BUILDING

The following examples are for situations where the system is installed in one building. In some of these situations, the owner of the building may not be the user of the building. This may be the case for rental properties or civic buildings.

#### *Showcase building*

This could be a community building (a sports arena, museum, library, etc.) that is used by a large section of the community and is frequently visited by out-of-towners. A side objective of this type of project would be to attract tourists to the area. This project could be a combined project between the municipality and the owner/manager of the building.

Some difficulties associated with this type of project include the coordination between the municipality and the owner/manager of the building. Benefits could include lower membership fees, energy savings for the building owner/manager, and political good will.

#### *Municipal or Community Building*

This could be a building such as a government office building, a school, library, recreational center, or community center. While it would also serve as a showcase of the technology, the installation and utilization of a geothermal system could provide savings for the municipality and taxpayers.

This system could also reinforce a community's commitment to the environment and celebrate local history. This system could also benefit the users of the building through reduced fees.

#### *Private building*

There are many private buildings including residential homes, apartments, industries, and businesses that could benefit from a geothermal system. Buildings with large numbers of computers or other intensive cooling needs stand to benefit the most.

Various manufacturing plants can also utilize geothermal heat pumps to do simultaneous heating and cooling of different areas and processes. Residents can benefit through energy savings. Private systems can benefit the community through direct or indirect job creation. These systems can be privately funded or supported by the municipality as part of a revitalization/economic development initiative.

#### **DISTRICT HEATING SYSTEMS**

There may also be cases where the system is designed to heat or cool a number of buildings. This is known as a district heating system. These systems have been used in various municipalities and locations throughout the country. District heating systems can benefit more people through the heating and cooling actions.

Members of the system would also benefit from more stable energy prices and utilities would benefit through more stable energy demands. Ownership structures of these systems could also be single party or multiparty. The following examples are for district heating systems. These systems would be installed in a number of adjacent buildings.

District systems may be owned by a single entity (such as a municipality) or a group of owners (such as a business association).

### *Business district*

In some communities, a downtown business district heating system may be feasible. This system could be owned by business owners that have come together to finance the system. Possible ownership structures will be discussed in the next section.

Alternatively, the system could also be financed, installed, and owned by a municipality or local community economic development corporation (CEDC). In this case, the municipality or CEDC could own the system as an economic development tool.

### *Educational district*

In former mining communities, educational institutions could also benefit from mine water geothermal. The installation of these systems could also incorporate training and development of new curriculum.

This system could be funded through incentives from the local utilities, local municipalities, energy-efficiency research organizations, and alumni among many other sources. In this scenario, the system could become an integral part of the institution's courses. Elementary and secondary schools could use the system to teach about geothermal, energy efficiency, and weatherization.

A vocational/technical school could teach courses about geothermal systems, heat pumps, radiant floor heating, energy efficiency retrofits, and other renewable energy sources. A community educational program could also host other outreach activities.

### *Industrial park*

Industries are often located near one another due to zoning. Manufacturing plants are often large buildings with large cooling and/or heating needs. In almost all industrial and manufacturing facilities, there is a need for cooling at one process or part of the plant and heating in another at any given moment in time. The three factors combine to make industrial parks a good place for a district system.

Even if regulations restrict the development of a district system, the massive cost savings which can be discerned by harnessing the near limitless thermal heat sink capacity of a flooded underground mine will sell itself.

That is the case in Springhill, Nova Scotia, Canada home to Ropak Packaging a manufacturer of plastic containers.

### **Case Study - District heating systems Example Heerlen, the Netherlands**

This multi-building project was co-sponsored by the European Union (EU) as a demonstration site for renewable energy technologies. This multistage project began in 2008 by conditioning two large buildings: the Central Bureau of Statistics office (237,000 sq ft) and the Heerlerheide Center (323,000 sq ft).

The Heerlerheide Center is a multi-use building which houses residential space, a supermarket, offices, a community center, and restaurants. Between 2012 and 2013, two additional large buildings and 350 single family homes (355,000 sq ft total) were added to the system.

An office building and datacenter added 344,000 sq ft to the system. A new college building also added 323,000 sq ft to the system. At present, Heerlen has already met its initial goal of conditioning a million square feet of buildings.

The capital cost and the first few years of operational costs of this system were awarded by grants from the EU. The lessons learned from this experience paved the way for the creation of a private mine water corporation. Discussion is still underway on the responsibilities of this corporation. At minimum, it will be responsible for connecting customers to the geothermal energy grid.

The charge for this service will be based on the capital and operational costs of connecting to and running the pumps on the grid which supplies warm (64°F to 72°F) and cool (61°F) water in two loops.

There are two potential future ownership structures for this system: 1) building owners will own and manage their own heat pumps and pay for the electricity associated with running it or 2) the corporation will own the heat pumps and pay for the electricity cost. Under this inclusive model, ratepayers will be billed for the BTUs of heating and cooling supplied.

The rate-tariff will be based on the avoided cost of operating gas boiler or electric chiller. The corporation will profit by being able to take advantage of cost savings from simultaneous heating and cooling, purchasing electricity and gas at bulk prices, as well as investing in renewable energies like wind and solar [27] [38].

The mine water geothermal system saves the company \$160,000 annually. News about Ropak's success spread quickly leading to a dozen other businesses and institutions installing systems including Surrette Battery Company Ltd. and the Dr. Carson and Marion Murray Community Center which uses geothermal energy to cool its indoor ice rink [36] [37].

### *Residential district*

A residential area may also be an appropriate area for a district heating system. This system could be installed and owned by a municipality, a local utility, a housing cooperative, or a homeowner's association.

## BUSINESS/ORGANIZATIONAL MODELS

In the case of single owner systems, ownership structures are straightforward. In situations where there is a partnership formed to install and finance the system (such as a community building with several users), a new ownership/management structure may need to be formed. Communities that are looking at district systems may also need to develop innovative ownership structures for their systems.

This section will describe ownership structures some communities may find applicable for their situation. Many times, communities have resources to assist in business development. There may be a local community economic development corporation (CEDC), small-business association (SBA), or a university extension office that can provide assistance.

### **Triple Bottom Line Reporting**

In typical business structures, the financial bottom line is the primary way the success of the business is evaluated. In triple bottom line reporting, businesses evaluate their success based on financial, environmental, and social impacts.

There are many different indicators that businesses can use to evaluate their triple bottom line. Some municipalities have developed their own "green business" certifications and there are also national and international standards.

There is also a growing network of social entrepreneurs and social enterprises that can help. More information on these resources are included in Appendix B.

The purpose of establishing a corporate or business structure is to control liability and pool resources. Typical incorporated businesses have profit as their primary driving force. More and more, alternative business/organizational structures have been developed for businesses seeking to utilize triple bottom line reporting.

## BUSINESS PHILOSOPHIES

### *Social Enterprises*

A social enterprise is not necessarily a business model so much as a business philosophy. The aim of a social enterprise is to achieve social goals through unique funding structures. Typically, social goals are addressed through the formation of a non-profit. While these structures are useful for tax purposes, they are limited by how they can raise funds for their budgets.

There are many different forms of social enterprises but they typically consist of a for-profit corporation that donates profits to a separate non-profit. Utilizing a LLC or cooperative structure is a potential way to combine both organizations under one structure.

### *B-Corporation*

A B-Corporation is a third party certifying and incubating organization for triple bottom line businesses. Information about the criteria can be found on the following website [39].



## Legal Considerations

# Construction Impacts

Environmental conditions should be researched and identified prior to finalizing a site location. For example, new habitats may have formed since mining activity have ceased and these may be sensitive to mine water chemistry and inadvertent contamination.

Ensuring the mine water geothermal system does not negatively impact such habitats could alter many different aspects of installation, design, and operation. This includes the route of the pipe network and the construction equipment used.

These mine conditions, listed in no significant order, include flowing conditions of water in the mine, aggregate deposits, pre-existing groundwater or mine water contamination, and general layout of the mine shaft.

The aesthetic, ecosystem health, and recreational use of the environment are also important so deciding upon a location that would not impede on local vegetation and animal life should be taken into consideration. As many previous mine sites are located in areas that have been left to their own devices, plant life may have reclaimed some of the surrounding locations, and from this, wildlife may have introduced itself back into the area as well.

Environmentally conscious construction and operational practices should prevent these sensitive habitats from being greatly affected by geothermal operations. For example, by not clearcutting the proposed site for the mine water geothermal system, an ecosystem can then continue to thrive without being jarred into rapid removal from the area.

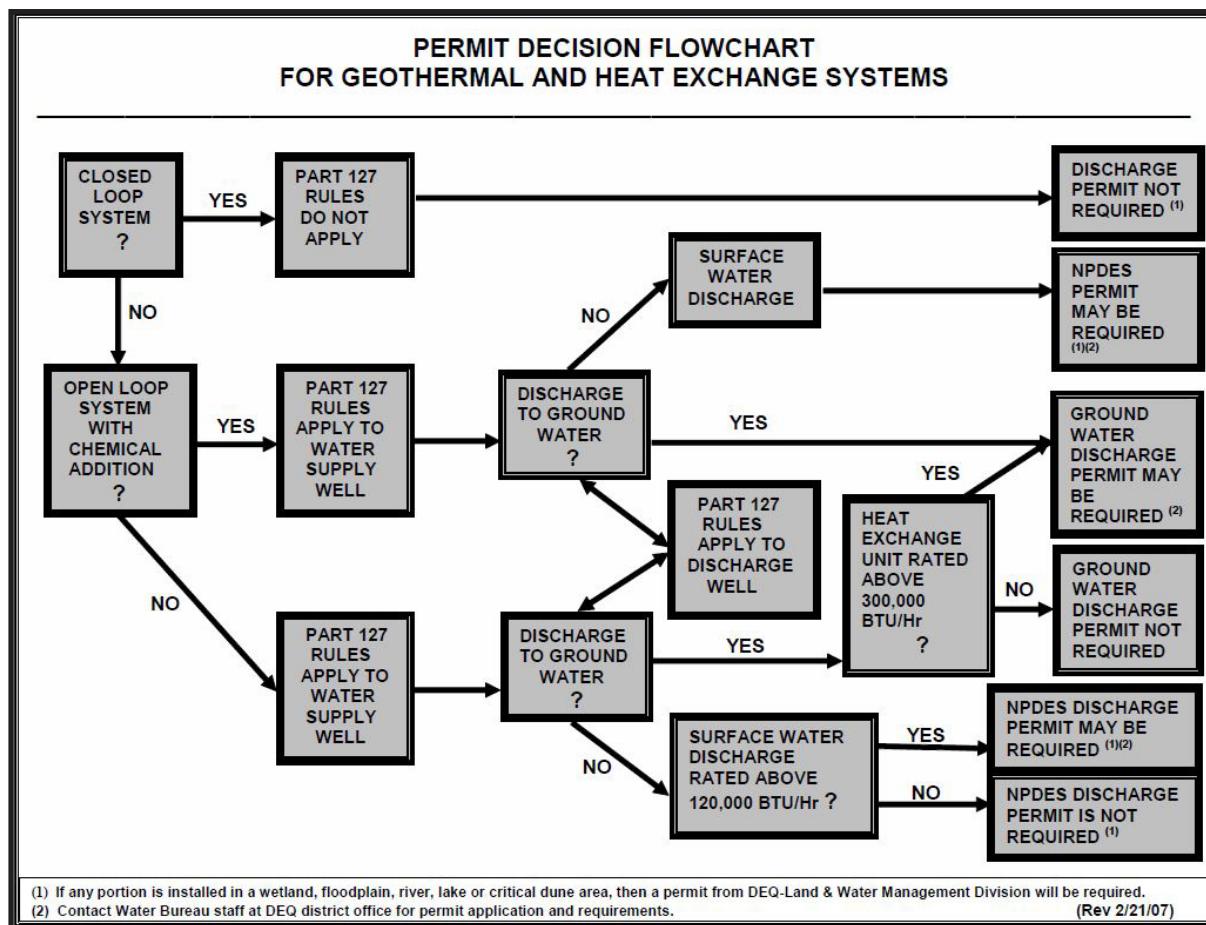
## WATER, LAND, HEAT, AND MINERAL REGULATIONS

While there are no specific legal regulations on mine water geothermal, regulations that may impact projects can be extrapolated from regulations that affect traditional geothermal systems. On the federal level, National Pollutant Discharge Elimination System (NPDES) permitting may be required for surface water discharge.

Most states have groundwater regulations, underground injection regulations, and mineral rights that may apply. Locally, building codes, zoning laws, and construction permits vary from one municipality to another. Site selection, system type, and size can also impact necessary permits.

This section covers some rules and regulations that are relevant to the planning of a mine water geothermal system.

In general, an open loop system is more likely to be subjected to more water permitting rules than a closed loop system as shown in Figure 9. Regulations that may restrict system design options are primarily concerned with large releases of heat into the environment. Some states regulate how much groundwater can be extracted by one user while other states require permits for any injection into the subsurface. Both open and closed loop system may need to be permitted.



**FIGURE 9. Permit Decision Flowchart: Michigan DEQ (Individual states' policies will vary)[41].**

Ground surface and subsurface ownership rules vary from state to state based on mineral rights. While mine water geothermal systems do not extract minerals from the subsurface, the thermal capacity of the mine water may be owned through mineral claims, thus making it important to understand your state's mineral rights [46].

In many ways, a mine water geothermal system does not fit into predefined categories from a regulatory perspective. As a result, it is important to work closely with the various regulatory agencies to learn about the proposed system in order to secure the proper permitting.

In the case of a district heating system, it will be important to know your state and local regulations on utilities. Most utilities across the U.S. are regulated monopoly franchises. In this system, the state gives a utility an exclusive right and obligation to serve a certain service territory. Inside this territory, no competition is allowed and, in exchange, the utility will be regulated by the state utility commission.

The utility is guaranteed a fair return on investments it makes to serve its customers. Customers that try to organize and supply energy service to each other, in this case heat and cooling, represent a loss of energy sales to the utilities.

No state utility commission has, to this date, looked into allowing or blocking non-utility generated heat energy. Multiple states have examined the sale of electricity to adjacent neighboring properties by a non-utility. For example, think of a residential or commercial electric customer wanting to sell power they generated to their neighbor.

States that allow retail choice have generally allowed service to neighboring properties while non-retail choice states have generally not allowed such transactions.

These policies apply only to electricity sales- at present, no state has examined whether they should also apply to heat energy sales. If states decide they do, then non-retail choice states will not be able to setup a traditional district heating system without becoming a utility.

# Legal Designations

## LIMITED LIABILITY CORPORATION (LLC)

LLCs differ from other forms of incorporation in how revenue and liability is distributed between the owners. In a typical corporation, revenue and assets are owned by the corporation while in an LLC, revenue and assets are owned by the owners of the LLC. LLCs do not have to be organized for profit.

## NON-PROFIT

A non-profit (501(c)3) is an organization formed primarily to address social issues. A 501(c)3 is a legal, tax exempt status that allows activities undertaken by a non-profit to not be taxed. The registration of a 501(c)3 limits the fund raising and income generating activities a non-profit can undertake. As a result, non-profits must rely on donations and grants to achieve their budgeting requirements. This results in a "non-profit treadmill" where more and more time of the staff is consumed by seeking funders rather than actually filling the organization's mission.

## COOPERATIVE

A cooperative (co-op) is a flexible business/organizational structure that seeks to pool resources to achieve a purpose. The co-op structure in America stems from rural electrification projects. Co-ops are funded by members and non-member users. In a co-op structure, profit goes back to the members.

Typical examples are rural electric co-ops, grocery co-ops, and agricultural co-ops. Increasingly, the co-op structure is also being used for biomass/biofuels projects.

There are four basic co-op models:

- . Consumer co-ops: where members benefit from combined buying power
- . Producer or Marketing co-ops: where members benefit through shared resources
- . Worker co-ops: where workers own their business
- . Housing co-op: where members share living spaces or community spaces

Co-ops are guided by seven principles (known as the Rochdale Principles):

- . Open, voluntary membership
- . Democratic governance
- . Limited return on equity
- . Surplus belongs to members
- . Education of members and public in cooperative principles
- . Cooperation between cooperatives
- . Concern for community

There are many different organizations around the country that help interested parties in forming co-ops. A list of these organizations can be found in

#### **Appendix B.**

### **COMMUNITY OWNED UTILITIES**

In some situations, a municipality or private company may want to establish a geothermal heating/cooling utility. Regulations on district geothermal energy systems only take effect if the operator is considered to be a utility company as defined by the state utility commissions.

The regulations surrounding a district heating system are contingent on a number of factors:

- . Whether the area/territory is already claimed by a utility
- . Whether it will be for profit or non-profit

Regulations on these issues vary from state to state details of which can be found by contacting your state's Public Service Commission or Public Utility Commission.



Financing

Along with the growing movement towards triple bottom line business practices, there is a movement to develop innovative funding structures for community projects. Traditionally, most community projects have been funded through grants, or more recently, public-private partnerships. Examples of these would be community block grants or corporate sponsorship of non-profits.

Increasingly, communities are looking for ways to leverage local resources to fund projects. One mechanism utilized to accomplish this goal is community-based financial institutions. These institutions include community foundations, community/economic development corporations, and micro-funding organizations.

These institutions can provide low-interest loans or other investments in community projects. Local governments also have several innovative funding mechanisms available to them to achieve social goals. Improvement districts and property assessed clean energy financing districts can be set up to promote adoption of geothermal systems through tax breaks.

A community can sell municipal bonds to finance system installation. These bonds would guarantee investors a modest interest rate but could not be cashed out for a set period of years. They could be sized such that many local people can afford to purchase a piece. This model may require new regulations to be developed however the result is a financial system that is not a hand-out but a sustainable financial structure.

Systems can also be funded through Crowdfunding sites such as Kickstarter or GoFundMe. Communities can also develop renewal zones and provide tax incentives for infrastructure improvements. How can we afford this?

It is important for a community to fully understand how many different elements go into the development of a geothermal project so that they can begin to develop funding plans for the project. The following are various aspects that will need to be funded along with some potential funding sources.

### **Innovative Funding Structures: A.M.E Zion Church Pittsburgh, PA**

The A.M.E Zion Church in downtown Pittsburgh, PA had suffered from Acid Mine Drainage (AMD) seeping into its basement from the nearby Hill District coal mine.

As part of a larger local revitalization and mine water drainage mitigation project, the church applied for and received a Pennsylvania Energy Harvest Grant. This project funded a low-grade mine water geothermal heating/cooling system for the church and a nearby 40,000 sq ft addition.

The addition was to be part of the larger Herron Avenue Corridor Coalition. The project also received funding from the Foundation for Pennsylvania Watersheds.

The project utilizes water from the mine through a drainage system installed through a Bureau of Abandoned Mine Reclamation project.

The Herron Avenue Corridor Coalition also received a grant from the Urban Land Institute to develop a development plan for the site of the project. The Pittsburgh Urban Redevelopment Authority, along with the Carnegie Mellon University partnered to develop this site/project [40].

# How Can We Afford This?

## CONSULTANTS

Throughout the design and implementation of a geothermal system, a number of technical consultants may need to be utilized. These include: engineers for the design of the system, lawyers to help navigate the permitting requirement and developing ownership structure, and accountants to set up individualized financing structures. While fees for these services will have to be covered by the operating budget of the system owner, there may be a possibility to develop partnerships with educational institutions or pro bono consultants.

## CAPITAL COSTS

The capital costs of the system are the most expensive elements of the project. The drilling and installation of pumping and piping to mine water could be up to a third of the up-front cost or approximately \$8 per square foot for an average sized installation [10] [43] (2014 Seenti, Bruce and Ison, Barry from Mitsubishi Electric Personal Communications). These costs will change based on system configuration and the required number of wells.

Other capital costs of systems include the geothermal heat pumps and components as well as the piping to and the retrofitting of buildings. Many of the capital costs may be funded through federal, state, local, and utility funds for energy efficiency projects.

Funding in the form of tax credits, property assessed clean energy (PACE) loans, on-bill financing, loans, community bonds, and grants could also cover the capital costs. A list of the available financial incentives is located in Appendix H.

One can also search for the most up-to-date listings from the Database of State Incentives for Renewables and Efficiency (DSIRE), <http://www.dsireusa.org/>, website.

## OPERATION & MAINTENANCE

The main costs associated with the operation of geothermal system is the electricity for the water pump and geothermal heat pump. While the efficiency of the system will reduce electricity usage, sourcing the electricity from renewable sources can yield additional savings.

Depending on the size and the scale of the system, there may also be periodic maintenance costs. If the system utilizes an innovative ownership structure, there may be long-term accountant fees or other retainer fees. As operational costs should be minimum, for long-term sustainability, they should be completely covered by the operating budget of the system owner.

These guidelines are not meant to be an exhaustive list of all the costs of a system. Costs will vary from system to system but the basic categories of design, installation, and operation will remain the same.

How the ownership of the system is structured, the overall goals of the project can open up different funding possibilities. For example, if the project is part of a larger revitalization effort, state funds for renovations of buildings may be available. If the project is part of a larger energy efficiency effort, federal energy efficiency funds may be available.

## **Mine Water Geothermal as a Sustainable Economic Development Tool**

Sustainable economic development focuses on projects that improve a community's triple bottom line. Mine water geothermal projects have the potential to achieve this goal. The impact of a system will be affected by the scope of the project.

Utilizing a multiphased project can yield the greatest economic benefits. This type of project would strive to improve the lives of the greatest number of community members. An idea for a multiphased project is outlined below.

### **Phase One: Low-income Energy Efficiency Education and Improvement**

This would include teaching community members about weatherproofing and help train them to install improvements in their homes. Younger community members could be given hands-on training by improving homes of the needy. This could be anything from caulking to insulation.

Funds for this could be raised as an energy efficiency/youth development project. This could also potentially develop into a company or organization that charges businesses for their services.

If the project gains a lot of support, a local insulation manufacturer may be started. This phase can leverage funds for energy efficiency projects from federal, state, local, and utility sources.

The home weatherproofing teams could be supported through AmeriCorps programs or other funds available through the Corporation for Community and National Service.

### **Phase Two: Development of a Geothermal District**

After a group of adjacent buildings/homes have been weatherized, a district system could be set up. This phase would include the retrofitting of the buildings. This activity could also provide training opportunities for youth in the community.

A geothermal co-op could be set up where members are users of the system. Members could buy into the co-op through membership fees or sweat equity. Lower-income members could be subsidized through higher fees for business users or funds for low-income heating assistance programs. Local businesses could support the co-op as members, or through corporate giving programs.

## ENERGY EFFICIENCY FUNDING

Financial opportunities, incentives, and instruments change based on many factors including political climate, energy or environmental crises, energy prices, and evolving energy and/or environmental regulations. As of the writing of this guidebook, natural gas prices are at a historic low, yet concerns about climate change are at an all-time high.

Communities should evaluate national issues as well as local issues and how they affect the financial opportunities and favorability of installing a mine water geothermal system now or in the future. A national issue that will likely lead to direct and indirect effects that improve the financial outlook of mine water geothermal systems is the proposed EPA regulations on CO<sub>2</sub> emissions from power plants.

In 2014, the EPA released its Clean Power Plan which requires states to implement a carbon reduction plan. This plan requires a 30% decrease of carbon emissions below 2005 levels. States must have a plan submitted by mid-2016, be showing progress by 2020, and meet this target by 2030. States are allowed flexibility in how it will achieve this.

For many states, their strategy is to shut down the most polluting power plants and implementing energy efficiency to reduce electricity demand. The Clean Power Plan's mandates has and will further stimulate states and utilities to offer financial incentives for energy efficiency upgrades. This makes mine water geothermal systems a very timely issue.

## Moving from Talk to Action

Once the planning team and the public has come to a consensus on how to move forward with an installation, those decisions should be written down in an action plan/report. The report should address topics such as: how the project will be funded, how ownership of the system works, installation plans, and an operation and maintenance manual.

The planning team should become familiar with the International Ground Source Heat Pump Association (IGSPHA) which is a trade association comprised of many geothermal heat pump installers, designers, and contractors. Their website contains a database of accredited installers and certified designers which can be searched by state [43]. This is a good place to start finding people with the expertise to do the detailed design and to install a system.

The planning team can refer to the IGSPHA Design and Installation Standards for background on the standards and test terminology a designer and/or installer would likely refer to when working with the planning team [44].

After construction, installation specs and an operation and maintenance manual should be developed and maintained. The planning team may shift into an oversight team to monitor and evaluate the performance and long-term effects of the mine water geothermal system. If the plan for the mine water geothermal system included a multistage expansion or implementation plan, a planning team should remain together to ensure design and decision continuity of these future developments.

Republishing your action plan/report every couple of years is recommended to stay up-to-date with new technology and funding opportunities and to recognize where further adjustments may be needed. Reviewing your indicators will show where progress has been made, where more progress is needed, and if the project continues to reflect the goals of the community.



## Conclusion

The authors of this guidebook hope you have found this guidebook helpful. We hope communities will share the data and knowledge gained from exploring their mine water with the authors and the world. Information about water quality, data collection strategies, on-going monitoring, and evaluation will assist other communities interested in mine water geothermal.

The reuse of flooded mine shafts in geothermal energy systems remains largely untapped. As a result, the optimal means and methods to most effectively harness this unique opportunity is still being established. There is no doubt that as more communities learn about this opportunity and go through the process of evaluating the practicality of using flooded underground mines for geothermal heat pump systems, lessons learned from the process will reveal additional opportunities and challenges.

Evidence from existing systems around the world show that using low grade geothermal energy from flooded mine shafts can result in many benefits such as: cost savings, increased sustainability, innovation, community building, the stimulation of building improvements, and revenue sourcing.

Each example case began with proactive, visionary leadership which inspired commitment and investment from the community. Terry Ackman and George Watzlaf (2007) said U.S. mining regions are the "Saudi Arabia of Geothermal Energy" and regarded unused mine water as "a terrible thing to waste" (p. 1, 19).

Reusing the flooded mines can be the beginning to a series of cascading benefits that can contribute to renewed economic vigor, environmental leadership, and community empowerment while celebrating the mining legacy.

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