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## WRITING A COMMUNITY GUIDEBOOK FOR EVALUATING LOW- GRADE GEOTHERMAL ENERGY FROM FLOODED UNDERGROUND MINES FOR HEATING AND COOLING BUILDINGS

Edward Peace Louie  
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WRITING A COMMUNITY GUIDEBOOK FOR EVALUATING LOW-GRADE  
GEOTHERMAL ENERGY FROM FLOODED UNDERGROUND MINES FOR HEATING  
AND COOLING BUILDINGS

By  
Edward Peace Louie

A REPORT

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In Environmental and Energy Policy

MICHIGAN TECHNOLOGICAL UNIVERSITY

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This report has been approved in partial fulfillment of the requirements for the Degree of  
MASTER OF SCIENCE in Environmental and Energy Policy.

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## **Abstract**

When underground mines close they often fill with water from ground and surface sources; each mine can contain millions to billions of gallons of water. This water, heated by the Earth's geothermal energy, reaches temperatures ideal for heat pumps. The sheer scale of these flooded underground mines presents a unique opportunity for large scale geothermal heat pump setups which would not be as economically, socially, and environmentally feasible anywhere else. A literature search revealed approximately 30 instances of flooded underground mines being used to heat and cool buildings worldwide. With thousands of closed/abandoned underground mines in the U.S. and a million estimated globally, why hasn't this opportunity been more widely adopted? This project has found perception and lack of knowledge about the feasibility to be key barriers. To address these issues, this project drafted a guidebook for former mining communities titled *A Community Guide to Mine Water Geothermal Heating and Cooling*.

## Preface

This report documents the connection between a collection of reports and grant submissions and how they all relate to the overall goal of the project. The sections in this report have been reformatted from standalone documents, grant proposals and reports prepared for the public, which have previously been published or submitted.

The *Community Guide to Mine Water Geothermal Heating and Cooling* in Appendix C is the main work product of this project. The rationale to research and produce the Guide came from a class project, the findings of which are documented in a report titled *Exploring the Social Feasibility of Minewater Geothermal in Calumet* (which has been reformatted and included here as Appendix A). The respective guidebook and report were formatted in a visually appealing magazine style, appropriate for the audience that is the general public. Appendix B is the U.S. Environmental Protection Agency (EPA) P3 grant proposal written to fund the writing of the guidebook in Appendix C. A summary of the guidebook for the EPA is contained in Appendix D. Finally, Appendix E contains the EPA P3 phase II grant proposal, which was written to fund additional improvement and testing of the guidebook and the creation of educational materials.

Appendix A contains a report titled *Exploring the Social Feasibility of Minewater Geothermal in Calumet*, which was prepared collaboratively by myself and other students as a class project. The co-authors are: Rahul Bose, Gabriela Shirkey, Travis Wakeham, Carrie Karvakko, Amanda Kreuze, Margaret Morrison, Mayra Sanchez Gonzales, David Geisler, and Professor Richelle Winkler. For the class project, Gabriela led the literature review of existing cases of mine water geothermal heat pump systems to summarize key lessons that can be learned. I led and Rahul assisted with the research on how heat pumps work, how they can work

with flooded mineshafts, and technical issues that need to be addressed in order to use flooded mineshafts. Margaret summarized the energy usage data that each member of the class collected. Margaret and I analyzed the distances from mine shafts to key buildings in the Village of Calumet. Carrie and Gabriela made the final presentation to Calumet. Amanda led the writing of the introduction, methods and conceptual approach, summary, and integration of the document, aided by Margaret and myself, who were secondary writers and team managers. Gabriela led the design and final layout of the report and power point presentation. Each member of the class conducted two interviews and transcribed them. Amanda coded and analyzed the interviews for natural capital themes. Travis coded and analyzed the interviews for social and human capital themes, Mayra for political capital, David for financial capital, Rahul for built capital, and Carrie for cultural capital. Carrie also wrote about the history of Calumet. Mayra led, assisted by Travis and myself, the integration and summary of these analysis of capital into an “opportunities and challenges” findings section. Professor Winkler and Travis wrote the executive summary. All of the team participated in the editing and revision of the report.

The EPA P3 Phase I grant proposal, Appendix B, was written principally by myself with some editing and comments from Professor Winkler and Jodi Lehman, the Assistant Director of Research Development at Michigan Technological University.

The guidebook in Appendix C titled “*A Community Guide to Mine Water Geothermal Heating and Cooling*” was prepared collaboratively by myself and students from multiple disciplines. The co-authors are: Eric Macleod, Adrienne Masterton, Melissa Michaelson, Deanna Occhietti, Nicolette Slagle, and Theresa Tran, with guidance from Professor Winkler and Mr. Chris Green from the Keweenaw Research Center (KRC). A sub-team, called the Alternative

Energy Enterprise (AEE) Geothermal Energy team, comprised of engineering student David Anna, Krista Blumberg, Andrew Garrod, Dana Savage, and Kayla Warsko, focused on the development of a spreadsheet economic calculator and a working physical model of a water-to-water geothermal heat pump setup. This sub-team was guided by Mr. Jay Meldrum and Mr. Green from the KRC.

As project leader I led and steered the writing and developed the outline to the guidebook. Since the writing and editing of the guidebook spanned the fall 2014 and spring 2015 semesters, some students left the team and new students joined with the change in semesters. I was primarily responsible for helping new members get up to speed on the project. The learning and research process can be messy, especially with students new to the process of research and learning how to self-learn. Inevitably, mistakes will occur. One of my primary responsibilities was quality assurance, and checking guidebook components to ensure they make sense.

I integrated the separate components to generate a first draft of the guidebook and ensured that pieces fit together and flowed well. With help from Nicolette, I wrote the introduction, purpose, feasibility, background, and context parts of the guidebook. The work for the guidebook that I had a major role in includes:

- Conducting the Geographic Information Systems (GIS) analysis to understand how many people this guidebook can effect
- Conducting an exhaustive literature search for existing mine water geothermal systems to develop the most comprehensive spreadsheet of existing systems
- Writing the parts explaining:
  - how heat pumps, geothermal energy, and mine water work together

- the different geothermal heat pump system configurations possible
- the carbon dioxide (CO<sub>2</sub>) savings that geothermal energy technology offers
- the concept of energy vs. exergy, and how the difference is important
- Analyzing national energy prices to determine where mine water geothermal energy use makes economic sense
- Investigating the legal considerations of mine water geothermal
- Revising the water chemistry section
- Checking the underlying assumptions of the spreadsheet calculation

Nicolette helped write the introduction, purpose, feasibility, background and context components of the guidebook. She researched funding sources and financing methods, which can be utilized to overcome the capital cost barrier to mine water geothermal systems. Through my research on another project I was able to assist her by recommending that she investigate property assessed clean energy (PACE) financing and on-bill financing. Nicolette also researched different ownerships structures that district heating and individual systems could assume, and how these ownerships structures can facilitate to different financing methods.

Eric helped investigate what aspects of water quality are relevant to the feasibility of a minewater geothermal energy system and how they impact the option to use an open loop system. He also wrote the part regarding safety considerations that should be taken into account when working around mines to collect data.

Deanna investigated the environmental concerns a community should consider when it comes to deciding which wells to use. Concerns include endangered species along the path

between the point of extracting the mine water to the building that will be heated and cooled to the point where the water will be returned.

Melissa researched and wrote about the community participatory planning process, an organizational model that a community can adopt to generate interest, leadership, outreach, and assess the assets and strengths that it can harness to explore the feasibility of mine water geothermal.

Theresa, with her background in scientific and technical communication, provided a fresh pair of eyes to the revision and editing of the guidebook, and conducted the final design and layout for the report.

Adrienne wrote up instructions for how to collect the energy demand data for a building, and how this will be used in the spreadsheet calculator to determine the size of the heat pump needed and the payback period. Adrienne was also responsible for coordinating with the AEE Geothermal Energy team, who developed the spreadsheet calculator for estimating the capital cost and payback period of a mine water geothermal system.

Besides developing the spreadsheet calculator, the AEE Geothermal Energy team was also responsible for researching and building the working tabletop model of a mine water geothermal heat pump system.

The EPA Project Summary in Appendix D was largely written by myself with editing and comments from Professor Winkler, Jodi, and Jessica Brassard, a Research Development Specialist at Michigan Technological University.

The EPA P3 Phase II grant proposal, Appendix E, was a collaborative effort by myself with input from Nicolette, Melissa, Theresa, David, Krista, Andrew, Dana, Kayla, Professor Winkler, and Mr. Meldrum, who all participated in the brainstorming of ideas on what should be the next step for furthering the guidebook project. When it was decided on how to proceed, Nicolette played a principle role in making connections, writing and getting letters of support from external contacts in organizations including the OSM/ VISTA program and the Eastern Pennsylvania Coalition for Abandoned Mines. Finally, the writing of the EPA P3 Phase II grant proposal was a joint effort between Nicolette and myself.

## Introduction

Geothermal energy has been a long time interest for me. It fascinates me because unlike other renewable energies such as wind and solar, it is not intermittent. Growing up in a home with lackluster heating and cooling, I dreamed one day that I would make myself a home that will be more comfortable and efficient. For my senior design project in civil and environmental engineering at Bucknell University in Pennsylvania, I drafted an overly ambitious project proposal to put together an interdisciplinary team to design a geothermal power plant. The proposal was not accepted but through that experience I became exposed to The Geysers in Northern California, the world's largest power producing geothermal site in the world (Calpine, 2014). My interest in geothermal energy also contributed to my pursuit of a minor in engineering geology. Through this minor I took courses in geochemistry and geophysics and became exposed to the issue of acid mine drainage, which plagues many parts of Pennsylvania.

With this background, it is only fitting that by happenstance, one of the early courses I took at Michigan Tech involved geothermal energy. The project for the fall 2013, SS4700: Communities and Research class was on exploring the social feasibility of mine water geothermal in Calumet, Michigan. Through this class I was able to interview residents, business owners, and officials in the Village of Calumet to assess their level of interest on the topic of reusing their flooded mine shafts for geothermal heating of buildings. These interviews were also used to identify aspects of mine water geothermal that the community would want to know more about before pursuing the idea further, as well as problems that the community hopes mine water geothermal can contribute to solving such as high energy costs and lackluster business development.

Besides conducting interviews, I also helped collect gas and electric usage data from business and government buildings in Calumet in order to assess the heating needs. Although the initial cost of a geothermal heat pump is high, larger capacity units are only marginally more expensive, thus it made sense to focus first on large users of heat. These users will have the largest heating costs and thus reap the greatest savings from switching to a geothermal heat pump. At this stage in the research it was not known how much a geothermal heat pump system would actually cost, nor how much individuals or businesses could actually save by investing in a system. These unknowns were clearly voiced through the interviews.

Additional tasks that I accomplished through the fall 2013 class project included: coding a fraction of the interview transcripts, researching how heat pumps work and how they could be connected to the mine water resource, and the beginnings of a literature search on existing examples of mine water geothermal systems. The interviews collectively indicated an interest in this method of reusing the infrastructure left by mining. The interviewees specifically hoped that the process of developing and implementing a mine water geothermal system would support:

- Community participation
- Collaboration with local and external agencies
- Celebration of the mining legacy
- Promotion of environmental sustainability
- Economic development and revitalization
- Tourism

The feasibility of these direct and indirect benefits from a mine water geothermal system is supported by examples of existing system from around the world (Watzlaf & Ackman, 2006; Hall et al., 2011).

Issues that community members wanted to know more about included the cost and financing of a geothermal heat pump system, technical unknowns about the feasibility, legal issues, and the degree of environmental benefits. Economic questions including “who is going to pay for it?” and “how are you going to get funding?” were common amongst the interviews. Real and perceived cost barriers were expressed as a reason why the community has not put more effort into exploring this idea. Technical unknowns about the quality of the mine water and mine shafts were cited as reasons why further exploration has not been conducted. A few community members had questions about who owns the mineral and water rights of the mines as well as who owns the mineshafts.

Besides the above unknowns, several interviews also revealed a need for greater community participation, leadership, and democracy. Interviewees expressed that the community does not lack passionate people but that those people are often reluctant to take on leadership positions. There are differing opinions about whether the current leaders adequately consider all residents’ opinions, allow broad participation in decision-making, and treat different stakeholder groups fairly.

These findings and additional details can be found in the report to the community, titled *Exploring the Social Feasibility of Minewater Geothermal in Calumet* (Appendix A).

At the end of fall 2013, the opportunity to continue this project came through as an EPA P3 grant. The P3 grant proposal that I wrote sought to continue the project by writing a

guidebook to address the unanswered questions that the community of Calumet presented, as well as offer guidance on how to enhance community participation, leadership, and democracy. The need for this guidebook was made further clear by the sparse number of former mining communities that utilize their mine water to heat and cool buildings (Korb, 2012). During the writing of the Phase I grant, my literature search had found that there were less than 20 systems worldwide (Hall et al., 2011; Korb, 2012; Watzlaf and Ackman, 2006), yet there are thousands of closed and/or abandoned mines in the U.S. and over a million estimated worldwide (Allan Johnson, personal communication, 2013; Hughes and Dietz, 2011; Wolkersdorfer, 2008). Why hasn't this opportunity been more widely adopted? Might the lack of a guidebook to help answer and address the questions and barriers identified in the Village of Calumet be the very thing that is holding up the development at thousands of other former underground mining communities? There are guidebooks for homeowners, installers, engineers, and architects on geothermal heat pump systems, such as Egg and Howard, 2011; Petit and Collins, 2011; Stojanowski, 2011; and Ochsner, 2012, however none of these guidebooks describe the reuse of flooded underground mines as a viable thermal exchange reservoir for geothermal heat pump systems. Furthermore, the Amazon reviews on these books are wide ranging and indicate that they are not adequately helpful.

Indeed, experts including Mike Korb cite the lack of information about mine water, heat pump technology, the economics of mine water geothermal energy, and the actual vs. perceived risks associated with harnessing mine water for geothermal energy as factors that are bottlenecking the development of mine water geothermal energy (Korb, 2012). George Watzlaf and Terry Ackman from the U.S. Department of Energy describe the heat in mine water as “a

valuable resource that is currently being wasted when treated (or untreated) mine water is discharged to a receiving stream” (Watzlaf and Ackman, 2006, p. 13).

One of the challenges encountered during the 2013 class project was getting everyone in the class to understand how a heat pump works, and how it can work with flooded mines. During interviews many interviewees asked the interviewer to explain how a mine water geothermal system would work. Thus, in addition to the guidebook having sections explaining in simple terms how a heat pump works and how it can work with flooded mines, the P3 grant proposal also included the construction of a working table top model of a mine water geothermal heat pump setup. This model will allow people to understand these concepts in a more immersive sense. The entirety of the EPA P3 Phase I grant proposal can be found in Appendix B.

An interdisciplinary team is needed to accomplish the breadth and depth the guidebook seeks to encompass (social, economic, environmental, technical, legal, etc.) as well as the construction of the working tabletop model. To accomplish these tasks, Michigan Tech’s Alternative Energy Enterprise (AEE) Geothermal Energy Team has been in continual collaboration with a team of social scientists throughout the guidebook project. The combination of the AEE team and the social science team results in an impressively diverse array of backgrounds and expertise, including undergraduates and graduate students with majors in environmental and energy policy, geology, civil and environmental engineering, anthropology, scientific and technical communication, mechanical engineering, and chemical engineering.

The *Community Guide to Mine Water Geothermal Heating and Cooling* includes sections that address the questions and issues the community of Calumet raised in the preliminary feasibility study and that Korb (2012) identified as informational voids. The guidebook has a

section that explains geothermal heat pumps in easy to understand language and discusses the unique opportunities it can offer with regards to energy, environmental, and cost savings throughout the operating life of the system. There is a section on the different ways a mine water geothermal system can be setup. Examples of existing systems are scattered throughout the guidebook and connected to topics that are best exemplified by that system. The analysis and map, which shows that at a minimum 764,000 Americans in 370,000 homes are located within a half mile of a closed underground mine, is included to show communities the potential for minewater geothermal energy available in many parts of the U.S (U.S. Census, 2014; USGS, 2005).

The section on community participatory planning gives communities a model for spurring interest and recruiting leadership. It provides instructions for assessing the community for its strengths and existing resources that can be utilized to assist in efforts to analyze the feasibility of a mine water geothermal heat pump system.

The technical unknowns about the quality of the mine water and mine shafts that the community of Calumet raised are answered in sections on data collection. These sections provide background, rationale, and instructions on how to gather the necessary data for a preliminary analysis on the technical feasibility of a minewater geothermal heat pump system. Instructions on how to assess the mine's condition, parameters, and proximity to buildings is provided. Instructions also are provided on how to measure water characteristics, including the temperature, temperature gradient, and depth. A decision was made to move the section on analyzing the water chemistry to an appendix. This was done so that communities like many in Pennsylvania, which are plagued by acid mine drainage, don't have to be burdened with

instructions on how to determine whether an open system is feasible when it is already clear to a community.

Instructions are provided on how to collect information on the size and type of heating, ventilation and air conditioning (HVAC) equipment a building has in addition to energy consumption data. This information is used in the spreadsheet calculator, along with information about the distance between a mineshaft and the building to calculate the payback period and capital cost of a system. Instructions also are provided on how to use the economic spreadsheet calculator.

A wealth of different ownership and financing structures are described in the guidebook to give communities creative inspiration. Innovative schemes such as property assessed clean energy (PACE) financing and on-bill financing, for example, are sometimes overlooked by communities as possibilities simply because they may not know about them.

Legal concerns are addressed by showing that they are not a problem. There are at present only sparse regulations concerning the setup of a single building mine water geothermal heat pump system. The regulations concerning a district mine water geothermal heat pump system can be more burdensome, especially if the desire is to treat the distribution of the heat as a utility. In fact, the U.S. regulations on utilities can be so burdensome that Thorsteinsson and Tester (2010) cite them as a major barrier to geothermal district heating systems development in the U.S. However, no state utility regulatory commission has, to this date, looked into allowing or blocking non-utility generated heat energy. Thus there are no restrictions preventing businesses and/or homeowners from sharing a mine water circulation loop that each building's geothermal heat pump(s) would tap into. There is currently no legal precedent that treats water in

flooded underground mines differently than groundwater. States require permits for large consumptive withdrawals of groundwater, however mine water geothermal systems do not permanently withdraw water from the mines. Indeed, in a closed loop system, the mine water is not withdrawn at all. Thus, groundwater withdrawal permits will not likely apply to a mine water geothermal heat pump system. Mine water geothermal heat pump systems also do not extract any minerals from the water. Thus, legal issues regarding mineral rights are likely not going to pose a problem. The most significant legal issues a mine water geothermal heat pump system would face are the ownership rights to the mineshaft and the land that any horizontal transportation pipes would traverse. These land ownership rights can be easily looked up in land records held by the municipality.

Lastly, the guidebook directs readers to trade associations such as the International Ground Source Heat Pump Association (IGSPHA), which contain contacts to geothermal heat pump installers, designers, and contractors who can help conduct more detailed feasibility studies or design a system.

In the appendices, the guidebook gives additional information and links to resources that a community can use including:

- A table detailing known information about each of the existing mine water geothermal heat pump systems
- Links to additional resources about tools and techniques that a feasibility study team can use to help assess the community resources available, whether they be skills, infrastructure, cultural, etc.

- Links to additional information about the ownership structures and financial instruments described in the guidebook
- Examples of low-cost/do-it-yourself strategies for collecting and analyzing water quality data
- A data collection worksheet to help organize information about the mineshafts
- A water chemistry section, which describes the water chemistry parameters that are relevant to the determination of whether the mine water is clean enough for an open loop geothermal heat pump setup
- An example of a water chemistry laboratory report to illustrate what data parameters to expect. The water chemistry section describes how each of these parameters relate to the determination of whether the mine water is clean enough for an open loop geothermal heat pump setup

The EPA P3 Phase I Project Report (Appendix D) succinctly summarizes the accomplishments of the guidebook and tabletop model in 15 pages. This is the report that the EPA P3 judges and grant reviewers read in concert with the Phase II grant proposal to determine whether the project merits continual funding. This report and the Phase II grant proposal was submitted to the EPA on March 11, 2015. The EPA P3 grant features a Phase II grant proposal (Appendix E) component, which provides additional funding for a selected few Phase I projects. While the guidebook has addressed the information vacuum surrounding social, economic, environmental, technical, and legal questions that were raised by members of the Calumet community and seconded by experts including Mike Korb, the instructions have been tested in Calumet only. The guidebook needs to be evaluated and tested in more communities in order

assess what works and what needs to be revised. The Phase II grant proposal that I wrote aims to fund three key sub-projects:

1. The testing and evaluation of the guidebook in additional case communities, and to afterwards revise it accordingly
2. The development and distribution of a grade 7-9 curriculum around low-grade geothermal heat and opportunities for using mine water for geothermal energy
3. Collaboration with existing networks and national events to publish and distribute the guidebook

Unfortunately the Phase II grant funding was not awarded. The project was instead awarded an Honorable Mention at the National Sustainable Design Expo in Washington DC on April 11-13, 2015, which signifies that the EPA believes the project deserves strong merit for funding however there was insufficient funding for this project.

Even without additional funding, it is still my goal to work with existing partners including Mike Korb and identify new partners to help get news about this guidebook to former underground mining communities. In doing so I hope people will write back with comments, critiques, and suggestions on how the guidebook could be improved. I will continue to support and periodically update the guidebook and post the revised version to the following web address:

<http://aee-mtu.org/geothermal-calculator-guidebook/>

## Conclusions

In Calumet, the research found that heating with a mine water geothermal heat pump system would not be economically advantageous if a resident has access to natural gas. Given the current (April 2015) local price of electricity at \$0.24 per kilowatt hour and the price of natural gas at \$1 per therm, electricity is seven times as costly as natural gas when these two energy units are converted to a comparable unit of million BTUs. Thus, a geothermal heat pump would need to deliver seven units of heat for every unit of electricity consumed to be competitive with natural gas. However, geothermal heat pumps can only consistently deliver three to four units of heat for every unit of electricity consumed. Due to the warmer temperatures of the mine water in Calumet (53-55 °F) compared to the surrounding ground (45 °F) one can be optimistic that a geothermal heat pump setup could achieve a coefficient of performance of 4.0 to 5.0 if the pumping distance is short. Even so, the conclusion is that it is uneconomical to operate a geothermal heat pump wherever natural gas is available, under current heating fuel prices.

The guidebook however currently does not adequately consider the air conditioning benefits of a geothermal heat pump. A heat pump is the only building conditioning system that can both heat and cool, thus it eliminates the capital and maintenance costs of an air conditioning system. This advantage was not incorporated into the spreadsheet economic calculator because of the added complexity that would result. Given the cold climate of Calumet, there is a perception that air conditioning is not needed, however this may not be entirely true. Restaurant kitchens and manufacturing facilities often need or could use air conditioning during late spring, summer, and early fall periods. Indoor ice skating rinks need to be cooled year-round; a heat pump can efficiently move this heat to a place where it is needed. If the value of cooling and air

conditioning without needing a dedicated chiller, refrigerator, or air conditioner were to be incorporated into the economic calculations, it could be possible that a mine water geothermal heat pump system in Calumet would make economic sense. If this is so, the guidebook contains information about funding sources and creative financing strategies, which can make the high capital cost of a system manageable.

Another analysis worth considering in Calumet is the economic feasibility of powering a geothermal heat pump using solar photovoltaic (PV) cells. Although Calumet has high electricity prices, the State of Michigan also has favorable net metering policies where the energy fed back into the grid is credited at the full retail electricity rate. With solar PV systems calculated to have a payback period of eight years in Calumet (Kantamneni, 2014) and the levelized cost of solar PV estimated to be between \$0.13 to 0.14 per kWh (EIA, 2014; Reichelstein et al., 2013), it may be found that powering a geothermal heat pump using solar PV makes economic sense in Calumet.

Although my efforts and the work by Mike Korb in Pennsylvania and Peter Op 't Veld in the Netherlands, just to name a few, can contribute towards promoting the reuse of flooded underground mines as thermal reservoirs for geothermal heat pumps, these efforts have not received the same publicity and resources as the U.S. Department of Interior or federal and state-level departments of energy. In fact, no states or federal energy policies or promotional materials currently identify flooded underground mines as a candidate thermal resource for geothermal heat pumps. Both the Energy Policy Act of 2005 and Energy Independence and Security Act of 2007 missed the opportunity to promote the utilization of low-grade geothermal energy by provided loan guarantees and tax credits for renewable electricity generation only. I recommend

that future state and federal energy policy amendments and stimulus programs include increased promotion and incentives for geothermal heat pumps and low-grade geothermal energy, with the explicit inclusion of flooded underground mines as geothermal reservoirs. Hopefully, many more mine water geothermal heat pump systems will be developed in the near future.

This project has created a guidebook containing resources that a community with access to a flooded underground mine can use to assess the feasibility of reusing it as a thermal reservoir for geothermal heat pump systems. While the current difficult economic times makes many focus on the economic costs of a mine water geothermal system, one must not overlook the environmental, social, and indirect economic benefits such a system can create. The EPA has long identified geothermal heat pumps as the most environmentally benign method of heating and cooling buildings (EPA, 1993). Socially, the recasting of underground mines from being viewed as a burden to being a source of sustainable energy can go a long ways towards increasing community pride. The hard work of the underground miners can be celebrated for creating the unique and amazing geothermal resource. Furthermore, the economic savings from reduced heating and cooling costs can be reinvested into the community, business expansion, and job growth. These direct and indirect benefits are not just theoretical. The literature on existing mine water geothermal systems clearly indicate that they are possible. These systems have reported payback periods as short as one year (Jessop, 1995), CO<sub>2</sub> reductions can be as high as 100% when paired with renewable electricity sources (Op 't Veld et al., 2008), and one community now has to lobby for business to come and utilize their free excess heat energy (The Record, 2008). While not every former mining community will experience successes as impressive as these, all of the existing mine water geothermal heat pump systems reported some level of success.

The guidebook, spreadsheet economic calculator, and tabletop model are all invaluable resources for reducing the barrier towards exploration and utilization of flooded underground mines as thermal reservoirs for geothermal heat pumps. I hope that these resources will inspire passionate people to take on the project of exploring the feasibility of mine water geothermal heat pump systems in their community.

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# **Appendices**

Appendix A: Exploring the Social Feasibility of Minewater Geothermal in Calumet

Appendix B: EPA P3 Phase I Grant Proposal

Appendix C: A Community Guide to Mine Water Geothermal Heating and Cooling

Appendix D: EPA P3 Phase I Project Report Summary

Appendix E: EPA P3 Phase II Grant Proposal

Appendix F: Permissions to use copyrighted materials

## Appendix A: Exploring the Social Feasibility of Minewater Geothermal in Calumet



**Michigan Tech**

Michigan Technological University

# EXPLORING THE SOCIAL FEASIBILITY OF MINEWATER GEOTHERMAL IN CALUMET

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## EXECUTIVE SUMMARY

### EXPLORING THE SOCIAL FEASIBILITY OF MINEWATER GEOTHERMAL IN CALUMET

This report summarizes the results of a research project aimed at understanding the community development opportunities and challenges associated with tapping into minewater for geothermal energy in Calumet, Michigan. The project focuses on social feasibility, rather than technical design. The purpose is to encourage community discussion and to provide tools and strategies for community members to consider in evaluating potential minewater geothermal projects.

The research team reviewed active minewater geothermal projects in other locations, mapped mineshafts and calculated geographic distance between shafts and key buildings, analyzed energy demand in Calumet, and used participant observation and interviews to understand the social acceptance of minewater geothermal in the Calumet community. We evaluated these data using the Community Capitals Framework for understanding and assessing community development outcomes and potential (Flora and Flora, 2013).

Results indicate that people in Calumet are generally excited about the idea of developing minewater geothermal, but there are legitimate concerns about the cost of installation and the political process of figuring out who will benefit, who will bear costs, and how the system could be managed. People generally think of minewater as a community owned resource and minewater geothermal as a way to celebrate the cultural

legacy of mining in the area while promoting environmental sustainability. Additional opportunities include the potential to realize energy savings, attract businesses and create jobs, increase tourism, and strengthen social capital, community identity, and community participation.

There are 37 mineshafts in the Calumet area, mostly along Mine Street and along the Osceola lode along Hwy 41. Located near shafts are multiple public institutions (i.e., CLK Schools, Calumet Township offices, Calumet Coliseum, NPS, BKG Shelter home), commercial establishments (i.e., Calumet Electronics, Calumet Industrial Park), senior housing complexes, and private residences. District geothermal systems could prove efficient for the community, but require more initial investment and political coordination than a stand-alone system for a single building or small set. The community may want to consider developing a demonstration site at a key public building, which would celebrate community ownership, as a first step toward developing minewater geothermal.

#### *What is Minewater Geothermal?*

*Minewater geothermal involves pumping water that has been warmed by the earth out of abandoned mines. The minewater is then run through a heat exchanger in a heat pump which transfers and concentrates the heat from the minewater to other water pipes running through buildings. The minewater is returned to the mine without any outside exposure. It works similar to any other geothermal system, except that it is more efficient because you don't have to drill to access the immense amount of water stored in the mines.*

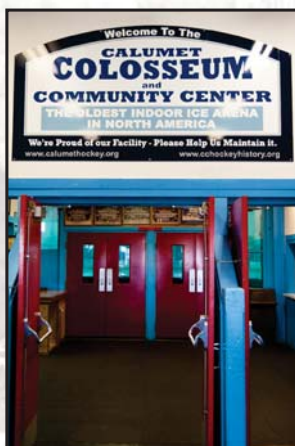


Photo courtesy of Edward Louie

## EXECUTIVE SUMMARY

Based on these findings, minewater geothermal has potential to contribute to holistic community development, but its success would depend on the degree to which a broad set of stakeholders are involved in the decision-making and planning processes.

Moving forward, our research team advises following a community planning process with broad participation to help community members and key stakeholders understand and evaluate potential alternative strategies for development (or not) and management. Along with this process, remaining technical uncertainties that could affect the cost and design of a project would be required. These issues could potentially be addressed by strengthening relationships with Michigan Technological University and partnering with local schools.

As a research group, it is not our intention to tell the community what to do. Our role is to provide an unbiased account of the potential for minewater geothermal development to enhance community development. We hope the results of this project will stimulate dialogue within the community.



*Photos courtesy of Edward Louie*

*This project is a result of a collaborative effort between Main Street Calumet and undergraduate and graduate students at Michigan Technological University. The project was undertaken during fall semester 2013. Team members include:*

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## INTRODUCTION

The community of Calumet, located in Upper Michigan's Keweenaw Peninsula, once boomed as a successful mining town. When the mining operations ended, however, the population dwindled, leaving Calumet a small, remote community. The mineshafts were closed and the mines left to fill with water. The community's history of mining remains a strong legacy in the area and the abandoned mines represent an untapped source of energy.

Geothermal energy is thermal energy generated by the earth. It provides a sustainable energy source that can be used to both heat and cool buildings. Minewater geothermal involves pumping water out of abandoned mines, which has been naturally heated by the surrounding earth. The minewater can then be run through a heat exchanger in a heat pump which transfers and concentrates the heat from the minewater to other water pipes running through the buildings. Once the heat transfer has occurred, the minewater gets returned back to the mine, without any environmental exposure outside the pipes.

*This report summarizes the results of a research project aimed at exploring the social feasibility of tapping into the Minewater beneath Calumet for geothermal energy.*

This report summarizes the results of a research project aimed at exploring the social feasibility of tapping into the minewater beneath Calumet for geothermal energy. This project is the result of a partnership between a class at Michigan Technological University titled "Communities and Research" and Main Street Calumet. The purpose of the Communities and Research class is to learn about rural communities and how they can build upon their existing assets in order to become more sustainable. The project's goal aims to explore the potential opportunities and challenges associated with minewater geothermal energy in the Calumet area. Rather than emphasizing the technical feasibility of minewater geothermal, this project primarily investigates the social and economic aspects of how minewater geothermal may or may not benefit the Calumet community.



*The Calumet Theater reminds us today of the wealth of culture brought to Calumet through the mining industry. Photo courtesy of Edward Louie*

## MINEWATER GEOTHERMAL: A REVIEW OF ACTIVE CASES

While seasonal temperatures can be extreme, the temperatures a few feet below ground remain nearly constant year round at approximately 45°F for the latitude of Calumet. Heat can be exchanged with this constant temperature sink and moved and concentrated by a geothermal heat pump. As with traditional air to air heat pumps, geothermal and water-source heat pumps are able to heat, cool, and, if so equipped, supply hot water to a home or business. The U.S. Department of Energy rates geothermal heat pumps as “one of the most efficient and durable options on the market to heat and cool” (U.S. DOE, 2011). Using mineshafts to access water heated by the earth is more efficient because you do not have to drill to reach the resource, and because the amount of water stored in the mines can be immense.

Minewater geothermal has been implemented at several locations around the world as a means to reduce heating and cooling costs and lower the carbon footprint. In small, remote communities, geothermal energy has also been shown to increase economic development and reduce the costs of conventional energy prices (Manson, 2009). This section briefly reviews minewater geothermal projects across the country and worldwide focusing on what we can learn about their social and economic outcomes that could inform decisions about whether or not to implement minewater geothermal projects in Calumet.

Overall, the projects reviewed show that the technical installation is feasible and that geothermal technology presents clear advantages for heating and cooling resources as opposed to other means. Investment costs can be large, but the capital return payback can be in as little as a few years (Jessop, 1995). Geothermal's

high installation costs are due to the cost of the heat pump and the excavation/drilling to create the geothermal exchange field. The reuse of mineshafts eliminates the latter cost translating to significant savings (Mason, 2009). Funding may be eligible from federal and state organizations to help defray these costs (DSIRE, 2013). Also, a number of communities with a history of mining have utilized their minewater with positive results such as economic savings and increased community development (Hall, 2011).

Minewater geothermal energy in Canada started in the 1980's with a pioneering study at a plastic factory in Springhill, Nova Scotia. Ropak Packaging, a plastic container manufacturer, heats approximately 150,700 ft<sup>2</sup> from an old coal mine's production well 459 feet deep. The system handles 11 heat pumps used for heating and cooling. Springhill's Minewater is 64.4°F when pumped out of the mine and is returned into the mine 33 yards below the surface at 54°F (a heat load of 84 kW) during the winter and at 77°F (a

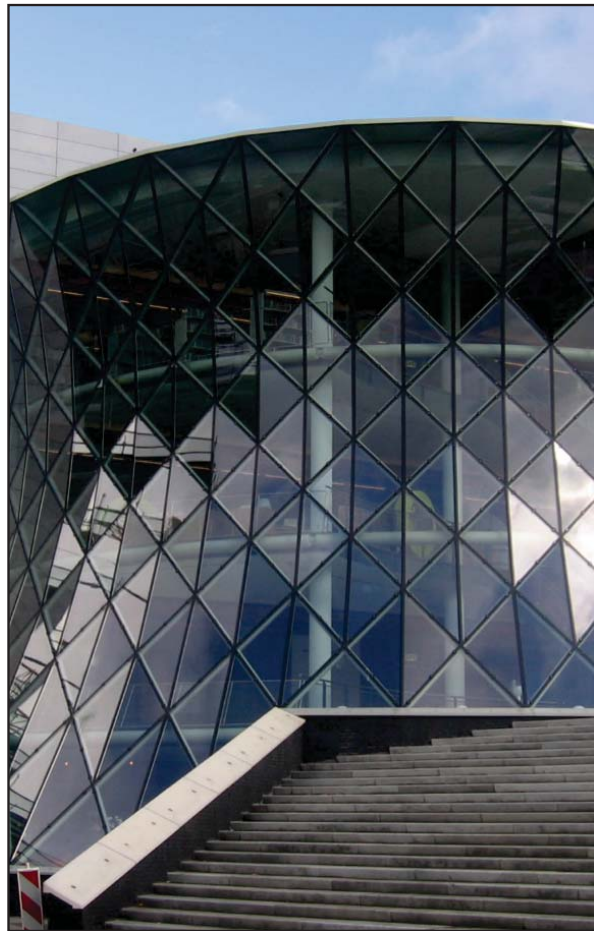


*The Dr. Carson and Marion Murray Community Center houses an NHL size ice rink and saves \$70,000/year in energy costs and \$45,000/ year in maintenance when they switch to minewater geothermal heating and cooling. Photo courtesy of [www.worldisround.com](http://www.worldisround.com)*

cooling load of 120 kW) during the summer. The geothermal system saves the company an estimated \$160,000 per year in energy costs when compared to a typical oil furnace system, a reduction of 60% in energy costs (Jessop, 1995). Their capital was paid back in less than one year (Jessop, 1995). Since Ropak's success, outside investors entered Springhill and the Industrial Park attracted more businesses looking to benefit from geothermal energy, which has increased economic prosperity in the local community. The Springhill Geothermal Industrial Park has thus simultaneously benefited from reduced energy costs and attracted businesses looking to benefit from geothermal energy (Mason, 2009; Ewart, 2003).

In addition to the Industrial Park, Springhill's NHL sized ice rink and community center installed minewater geothermal and became the largest facility to do so in Canada. Heating and cooling with geothermal has saved the complex \$70,000 per year in energy costs and \$45,000 in annual maintenance cost (Gorman, 2013). Today, over a dozen local businesses either have access to or choose to use geothermal energy in Springhill (Thompson, 2013).

The largest minewater geothermal district heating project is in Heerlen, Netherlands which began in October 2008. Using minewater from an abandoned coal mine, the system heats and cools 350 residences, 40,900 ft<sup>2</sup> of commercial space, and 174,400 ft<sup>2</sup> of community buildings as well as healthcare and educational buildings (Hall, 2011). The innovation was funded by Heerlen, Midlothian, Weller, BRE, WFG Kreis Aachen, BRGM, Bönen and 48% financed by the EU Interreg IIIB-programme.(Op't Veld, 2007; Sanner, 2008). The project has reduced Carbon Dioxide (CO<sub>2</sub>) emissions by 50% and spurred development of additional buildings surrounding the geothermal energy provider (Op't Veld, 2007). It has attracted investors, providing a new economic income for the community. Moreover, the Heerlen project serves as an interpretive



*Heerlen in the Netherlands is the largest district heating system in the world to run on mine water geothermal. Photo courtesy of [www.upload.wikimedia.org](http://www.upload.wikimedia.org)*

demonstration site and has become an attraction for tourists, engineers, and researchers from around the world.

Locally, Michigan Technological University's Keweenaw Research Center (KRC) has successfully implemented a geothermal system within their 11,000 sq. foot building near the Houghton County Airport from the New Baltic No.2 Mineshaft. The supply is pumped from 300 feet below at a temperature between 55°F and 65°F year round. Their system returns water back to the mine at a depth of 60 feet. The system cost

5

about \$100,000 to install during the building's construction phase. KRC roughly estimates cost savings of about 30% over a conventional natural gas system and a payback period of three to five years (Jay Meldrum, personal communication).

Worldwide, geothermal is a leading fuel source in renewable energy and environmental stewardship. In the United States, a total of approximately one million geothermal projects have reduced CO<sub>2</sub> emissions by 5.8 million metric tons annually and have saved an annual 8 million kWh (Ohio Department of Natural Resources). In this context, federal and state agencies have been increasingly supportive of geothermal energy development through grants and loans. For instance, the American Recovery and Reinvestment Act of 2009 (ARRA) increased federal funding, loan guarantees, and tax credits for investment in energy efficiency and renewable energy. Moreover, efforts to utilize the untapped resource of flooded mines have been funded by the Department of Energy (DOE) with grants and funding.

Overall, our review of the literature related to active minewater geothermal cases indicates that significant carbon emission and energy cost savings can be realized. While the capital costs are higher than a natural gas or electric system, the operational savings can result in a payback period as low as a year, however, in most cases the payback period is six or more years. Payback periods are shorter if the cost of dehumidification and cooling are taken into account. While the capital cost of a district heating may be much greater than an individual system, the additional benefits provided to the community may make it worthwhile.

## CALUMET CONTEXT

Calumet, originally called, "Red Jacket," was incorporated in 1875 when the Calumet and Hecla (C&H) Mining Company opened copper mining operations (National Park Service, 2008). The

*Locally, Michigan Tech's Keweenaw Research Center (KRC) has successfully implemented a geothermal system within their 11,000 sq foot building near the Houghton County Airport from the New Baltic No.2 Mineshaft. The supply is pumped from 300ft below at a temperature between 55°F and 65°F year round.*

Keweenaw copper boom happened between 1840 and 1860 when thousands of explorers and speculators flocked to the region, riding on the so-called 'copper fever'. As an outcome of the discovery of the Calumet Conglomerate lode, the treaty of Lapointe was ratified establishing a mineral land office at the Keweenaw Point (Williams, 2012; Lankton, 1991). As the prosperities of copper mining increased, C&H was not the only mining company that took interest in the area. The Tamarack Mining Company and Osceola Mining Company also operated in this region, however, C&H remained the largest and most profitable mining company in Calumet. These mining companies created 37 shafts in the local Calumet area, with the largest concentration found along Mine Street (Johnson, 1998). Due to the availability of work, many people of differing backgrounds settled in Calumet and life was centered around the mines. According to the Keweenaw National Historical Park, "Its streets echoed with the sounds of Polish, Finish, Croatian, Norwegian, Italian, Lebanese, Syrian, Chinese, and other voices from around the world." (National Park Service, 2008, p. 13). These people and their work in the mines helped enhance the rich cultural identity that Calumet has today. The last mine to close down was Calumet and Hecla mine in 1968 and all of the area's mineshafts were thereafter abandoned and left to fill with water.

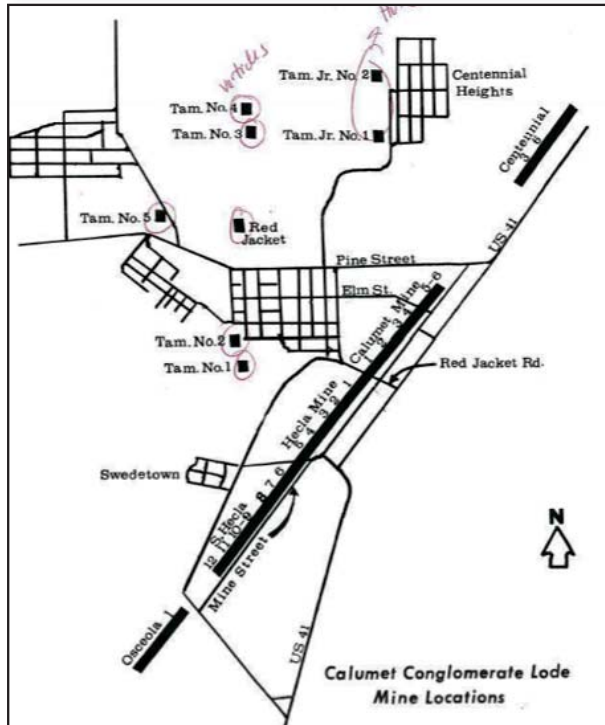


Figure 1. The Calumet area has 37 mineshafts. Those located on the Calumet Conglomerate lode are shown here. Photo courtesy of Michigan Tech Archives

The use of minewater for heating or cooling in Calumet is technically possible, but there are several considerations that would affect how it might be done, the upfront costs, environmental benefits, and potential cost savings. Technical considerations that affect the feasibility of mine-water geothermal development include sufficient supply, demand, and favorable conditions such as temperature, location, access, and water quality (Op't Veld, 2007; Ghoreishi, 2012). Additional money will be saved if there is easy access to the minewater and if the buildings are well insulated (Op't Veld, 2007). Investigation about the mine's condition, the thermal dynamics of both the system and the mine, and the design stage are all critical when planning a geothermal energy system (Madiseh et al., 2012). The primary purpose of this report is not to analyze these technical considerations, but we do offer a brief summary

| Name of Shaft              | Depth (ft) | Length (ft) | Width (ft) | Number of Compartments |
|----------------------------|------------|-------------|------------|------------------------|
| Calumet & Hecla Red Jacket | 4900       | 14.5        | 24.5       | 6                      |
| Tamarack #1                | 3409       | 8           | 16         | 3                      |
| Tamarack #2                | 4355       | 8           | 16         | 3                      |
| Tamarack #3                | 5253       | 8           | 16         | 3                      |
| Tamarack #4                | 4450       | 8           | 16         | 3                      |
| Tamarack #5                | 5309       | 7           | 29         | 5                      |
| Tamarack Junior #1         | Unknown    |             |            |                        |
| Tamarack Junior #2         | 3360       |             |            |                        |

Table 1: Known Specifications of Vertical Shafts on the Calumet Conglomerate Lode (Adapted from Lane, 1909)

of issues that would need to be considered and summarize what is known.

At the Keweenaw Research Center (KRC), the temperature of the minewater for the first few hundred feet is 55°F, while the ground has a temperature of 45°F. Similar temperatures were found at the Hancock #2 shaft in Hancock. The temperature of the minewater in Calumet is predicted to be similarly elevated. Natural convective mixing of surface water with hotter water from depth is invaluable for replenishing the surface water with heat as it gets used in a geothermal system (Jes-sop, 1995).

Figure 1 shows the location of mineshafts on the Calumet Conglomerate load. Vertical shafts are circled in red, with the other shafts primarily descending at a 30° angle. The size of the shaft openings and the depths are shown in Table 1. Many of these shafts are located near businesses, community buildings, or residential homes.

*The use of minewater for heating in Calumet is technically possible, but there are several considerations that would affect how it might be done and what the upfront costs, environmental benefits, and potential cost savings would be.*

Some minewater projects in other regions have experienced problems with shaft stability and erosion, however, Calumet's shafts range from excellent to unknown (Johnson, 1998). The ones in excellent condition are concrete lined and still contain the skip car railings, air and water lines, and ladders. Their stability is enhanced by the fact that they are in hard basalt rock.

It is important that the intake and the return of the minewater be kept at a distance apart from one another in order to prevent the cold water return from being withdrawn prior to being reheated. Methods of accomplishing this include: pumping and returning from separate elevations, as the KRC's system does, or better yet drawing and returning from different compartments or shafts.

Tests of minewater at KRC found drinking water quality. Records of results from water samples conducted in the Calumet Conglomerate load in the early 1900s reveal the presence of sodium and chloride in the water in concentrations ranging from seawater to relatively fresh water (Lane, 1909). No published results of recent water samples could be found. Saline water and high levels of impurities will result in the corrosion of pumps, pipes and heat exchangers in an open-loop system. The purity of the water is one aspect that must be assessed to determine the suitability of an open-loop system versus a closed-loop system.

Another challenge associated with developing minewater geothermal is availability of information about the thermal behavior such as the geometry of the underground mine and the heat transfer within its rock walls. More importantly, the heat capacity for a mine is limited and the intended heat extraction should be measured. If the mine is exploited beyond capacity, its heat can be exhausted (Ghoreishi, 2012; Mason, 2009). In cases where heat demand is high (i.e. an industrial park with several high volume users), a numerical method is suggested to measure the peak demands and create heat extraction and

exploitation scenarios (Ghoreishi, 2012; Michel, 2007).

Further site-specific research in Calumet is needed to resolve several technical unknowns. For instance, temperature gradients and water volumes need to be measured, water quality needs to be analyzed, heat demand requires more formal analysis, the condition of mineshafts needs to be surveyed, and the rate of heat loss in transmission pipes needs to be estimated. Fortunately given adequate surveying, exploration, data collection, and modeling, all of these unknowns are resolvable. Measurements of the temperature gradient, water sampling, and surveying of mineshafts can be accomplished with appropriate instrument probes, working together with Michigan Technological University's engineering department and/or outside firms.

If Calumet decides to implement a minewater geothermal system, we recommend that the construction design include the ability to monitor the performance of the system. The performance of a geothermal system is highly location dependent. Due to the limited number of systems in place globally, there is insufficient operational performance data. The generation of this data in Calumet would provide valuable insight for further development of minewater utilization projects in the Keweenaw and around the world.

## RESEARCH METHODS

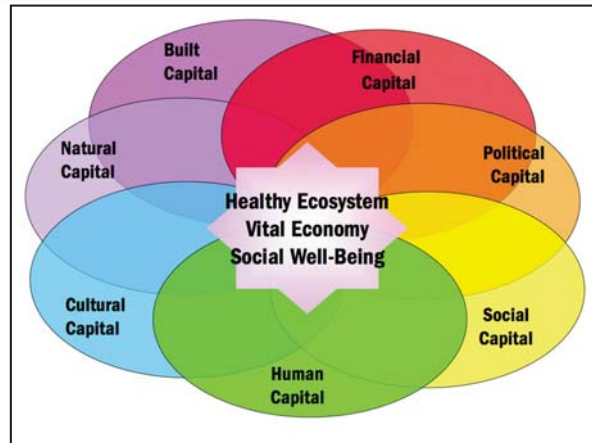
Our research team employed a variety of data collection and analysis methods, including: literature review of existing cases of minewater geothermal, energy demand analysis, geographic analysis of shaft locations, interviews, and participant observation. In addition, we collaborated with a class of engineering students at Michigan Technological University (the Alternative Energies Enterprise Team) who studied technical design options for minewater geothermal in Calumet. We gained further expertise by consulting regularly with Jay

Meldrum, a mechanical engineer and Executive Director of the Keweenaw Research Center which runs an active minewater geothermal system for heating and cooling.

Case studies of other minewater geothermal energy projects were reviewed with the purpose of finding the benefits and challenges other projects experienced and thus insight into the potential for tapping minewater geothermal energy in the Calumet area. We estimated potential demand for geothermal energy and current heating costs in the Calumet area by analyzing natural gas usage data from SEMCO Energy gas company, which provides natural gas to the Calumet area. Geographic analysis of mineshaft locations was performed by taking GPS readings of various mineshafts. We then used Google Earth to map these locations and analyze the distances between the mineshafts and several key buildings for which community members expressed interest.

The class conducted a total of 16 interviews with Calumet community leaders, volunteers, business owners, and residents. Most participants were selected using a snowball sampling process, beginning with community leaders. Three interviews were randomly drawn from addresses in the Village of Calumet. Questions asked about Calumet community vision, social acceptance of minewater geothermal, and opportunities for community change (refer to Appendix to see list of interview questions). Interviews were audio-recorded, summarized, transcribed, and coded for key themes related to community development and related opportunities and challenges associated with minewater geothermal.

Finally, students engaged in participant observation during three full day field trips to Calumet where students took tours of local buildings, including the NPS Visitors Center, the Coliseum, and the Calumet Theater; walked the downtown; explored mineshaft locations; driving tours of the Calumet and Laurium areas; and



*Above is an image referencing to the integration of the capitals used in the research methods. Photo courtesy of [www.bushfoundation.org](http://www.bushfoundation.org)*

spent time in local coffee shops, restaurants, and bars. Students recorded field notes from these experiences and shared with one another for analysis.

In order to make sense of the data we collected and determine how minewater geothermal could impact community development, we analyzed all of the data following the Community Capitals Framework. The Community Capitals Framework is a well respected community development strategy and tool for analyzing community development made popular by Cornelia and Jan Flora (Flora and Flora 2013). The framework provides an effective way to analyze community structures and develop ways to invest in existing assets in order to ensure a healthy ecosystem, strong economy, and the social well-being of communities. This approach focuses on seven different assets that communities hold and that can be developed and balanced in an effort to contribute to a broad “spiraling up” process whereby investment in one capital fuels positive outcomes across the community. The capitals a community has include: natural, cultural, human, social, political, financial, and built.

Natural capital includes the natural resources and environmental aspects of a community. Cultural capital symbolizes the way people ‘know

the world' and how to act within it. Human capital consists of the skills and abilities of the people in a community. Social capital represents the connections among people and organizations of a community. Political capital corresponds to the ability to influence standards, rules, regulations and their enforcement. Financial capital consists of the financial resources available in a community. Built capital is the infrastructure that supports the community. Each capital represents different aspects of the community, but are all interconnected. Good spiraling up of a community's capitals is cumulative so that investing in one community asset encourages investment in other related assets and contributes to a holistic type of community development that benefits a broad cross-section of community members.

By carefully analyzing our interviews, field notes, and other data sources according to the Community Capitals Framework, we summarized how the community feels about the idea of using minewater geothermal energy and synthesized key opportunities and challenges associated with developing minewater geothermal. The class analyzed data by considering what it meant for each of the seven different community assets (or community capitals). In this process, we concentrated on data indicating potential positive or

*By carefully analyzing our interviews, field notes, and other data sources according to the Community Capitals Framework, we summarized how the community feels about the idea of using minewater geothermal energy and synthesized key opportunities and challenges associated with developing minewater geothermal.*

negative relationships between minewater geothermal and the community capitals. This line of thinking was used to determine the potential effects, both positive and negative, that may occur from investing in minewater geothermal energy.

## FINDINGS

### GEOGRAPHIC ANALYSIS OF MINESHAFTS

Mineshafts are scattered amongst the Calumet area, with the largest concentration being found along Mine Street. In order to evaluate geothermal possibilities for Calumet, we assessed the distances from the shafts to the buildings. In order to do this, the class took GPS readings of numerous shafts in the area and uploaded them to Google Earth. Google Earth was then used as a tool for calculating the distance between key buildings that community members determined to be of interest and the nearest mineshaft (see Table 2).

Because of the concentrations of shafts and the number of public and commercial buildings in the Mine Street area, Mine Street is arguably the most desirable location for geothermal development. Alternatively, several shafts along the Oseola lode are located along Highway 41 in primarily a residential area. These are the closest shafts to Laurium.

In addition to existing buildings near shafts on Mine Street, several open areas could offer opportunities for constructing new buildings designed for minewater geothermal use. For example, the open area behind the Calumet Fire Department is near Hecla 2 and the area behind the National Parks Library is near Hecla 1, both of these areas are roughly 200-300 feet away from the shafts mentioned. Some shafts are also sitting on open acres, such as Calumet 4 and Osceola 15. The Calumet 1 shaft is located in an empty parking lot near CLK Schools, Calumet Township offices, and the Coliseum. The empty areas mentioned could be utilized to make a new building, such as a recreation center with a pool,

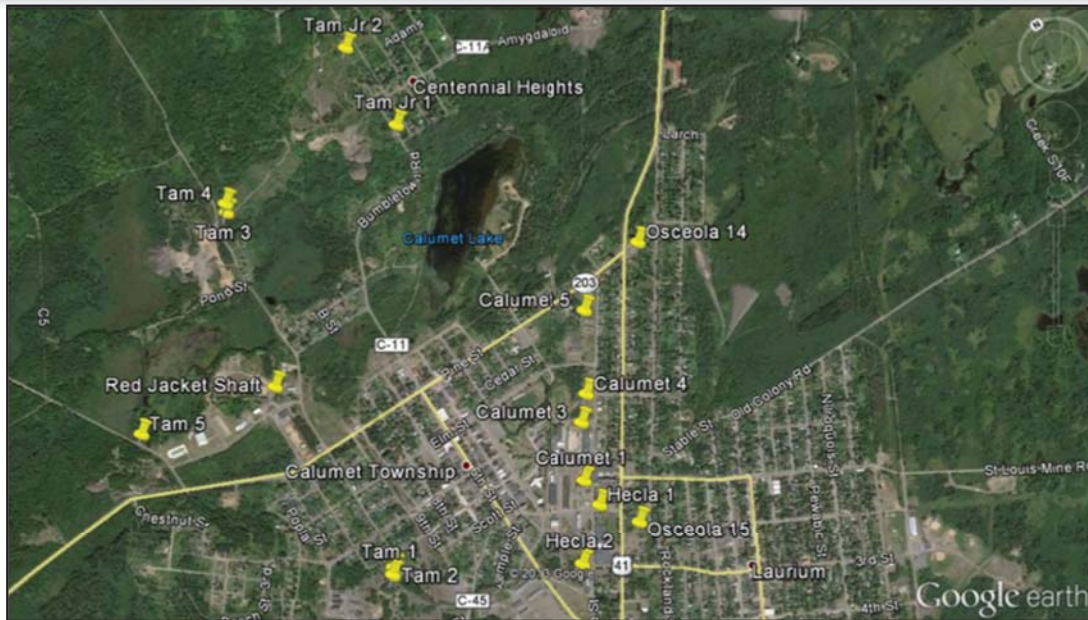


Figure 2: Shaft locations along Mine Street and surrounding areas

Table 2: Distances of shafts from community buildings

which could be entirely heated using geothermal energy. Alternatively, a demonstration center showcasing how minewater geothermal works, its environmental impacts, and celebrating its relationship to the cultural legacy of mining dedicated to geothermal energy could be constructed at one of these sites to draw in tourism and to serve as an educational facility.

The Red Jacket Shaft could also be used to increase development in the area, as it is located in the Industrial Park. As Table 2 notes, the shaft is roughly 230 feet away from the REL Building, and 65-300 feet away from the other industrial buildings in the area. Bare space also exists in this area, so if more buildings were to be put in they could utilize the geothermal energy which the Red Jacket Shaft could offer, similar to the Springhill Geothermal Industrial Park in Nova Scotia. Figure 2 shows a map of the shafts we considered in this analysis. This map is publically accessible at <http://tinyurl.com/n6c9zgw>, where one can see and calculate distances from these shafts to any address.

| Shaft            | Building                             | Distance (FT) |
|------------------|--------------------------------------|---------------|
| Calumet 1        | Township Office Building             | 106           |
|                  | CLK Schools                          | 210           |
|                  | Mishawauk Club                       | 250           |
|                  | NPS Warehouse                        | 280           |
|                  | Coliseum                             | 330           |
|                  | NPS Headquarters                     | 400           |
|                  | NPS Visitor Center                   | 790           |
| Calumet 3        | CLK School                           | 80            |
|                  | Michigan House Cafe                  | 1,530         |
| Calumet 5        | Golden Horizon Apartments            | 50            |
|                  | GardenView Assisted Living           | 215           |
| Hecla 1          | NPS Library                          | 30            |
|                  | Calumet Electronics -Business center | 95            |
|                  | Barbara Kettle Gundlach Shelter      | 165           |
|                  | NPS Warehouse                        | 205           |
|                  | NPS Visitor Center                   | 1,000         |
| Hecla 2          | Calumet Fire Department              | 175           |
|                  | Calumet Electronics-Roundhouse       | 310           |
| Osceola 15       | Aspirus Keweenaw Hospital            | 1,250         |
|                  | Vertin Gallery                       | 1,850         |
| Red Jacket Shaft | REL Building                         | 230           |
|                  | Other Industrial Buildings           | 65-300        |

Average Annual Therm Use for 2011 & 2012

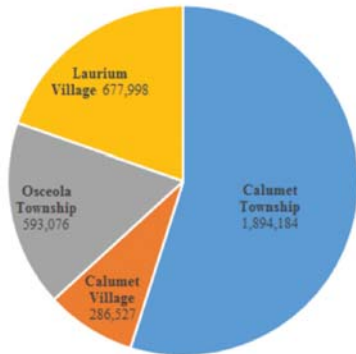


Figure 3: Average annual therm use by location

#### ENERGY DEMAND ANALYSIS

In order to evaluate the advantages of installing a geothermal system, it is critical to first understand the demand for energy in the area. The Calumet area (including Calumet Township, Calumet Village, Laurium Village and Osceola Township) used an average of 3,642,099 therms worth of natural gas each year over the last two years (2011 and 2012). The cost of paying for this energy at current natural gas rates is roughly \$1,456,840 per year. Natural gas, provided by SEMCO, currently meets most heating needs in the local area, but some people burn wood or rely on propane or fuel oil. The therm use, broken down by location, is shown in Figure 3 below (one therm equals 100,000 Btu). The method for gathering this data can be found in the Appendix.

Data was also obtained on monthly natural gas use for eleven buildings in the Calumet area through collecting and evaluating SEMCO bills. These buildings, along with their square footage, average annual therm use, and average annual heating cost, are shown in Table 3. Average annual heating costs were calculated using natural gas rates from 2012. It should be noted that additional heating using electric or other sources are not captured in the table, so this is a

| Building                             | Square Footage (approx) | Average Annual Therm Use | Annual Heating Cost |
|--------------------------------------|-------------------------|--------------------------|---------------------|
| Calumet Township Clerk Office        | 2,960                   | 2,736                    | \$1,086             |
| National Park Warehouse #1           | 4,000                   | 4,068                    | \$1,614             |
| National Park History Center         | 10,430                  | 4,380                    | \$1,738             |
| Calumet Township Fire Hall           | 4,500                   | 4,524                    | \$1,795             |
| Calumet Electronics -Business center | 15,000                  | 9,240                    | \$3,667             |
| National Park Headquarters           | 11,500                  | 10,500                   | \$4,167             |
| National Park Union Building         | 13,200                  | 14,100                   | \$5,595             |
| Michigan House                       | 7,500                   | 17,328                   | \$6,876             |

Table 3: Buildings assessed for heating use

conservative estimate for heating demand.

Results from interviews with business and residence owners revealed the significance of energy costs on operating expenses and family budgets. To better understand this, we estimated the average monthly heat demand and cost for a typical commercial or public building and for a typical residence in Calumet (see Figures 4 & 5). Please refer to the Appendix to find more information about how we gathered and calculated the monthly therm use for these buildings.



Photo Credit: coppercountryexplorer.com

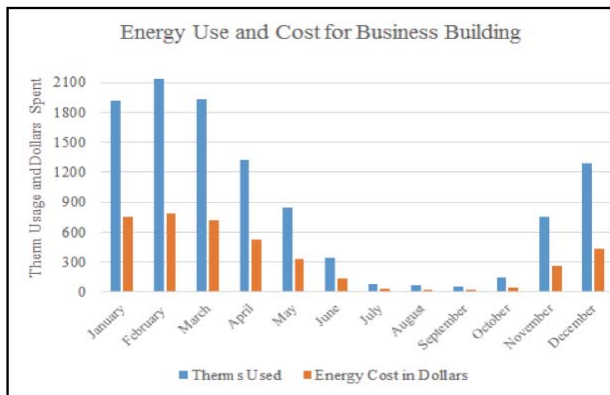


Figure 4: Average monthly heat usage and cost of an 11,000 ft² public building for the year 2012.

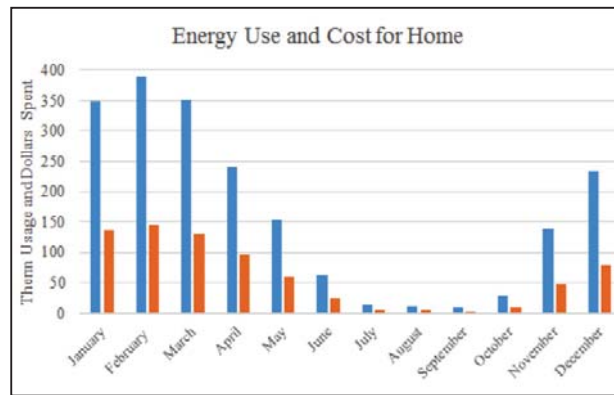


Figure 5: Average monthly heat usage and cost of a 2,000 h home for the year 2012.

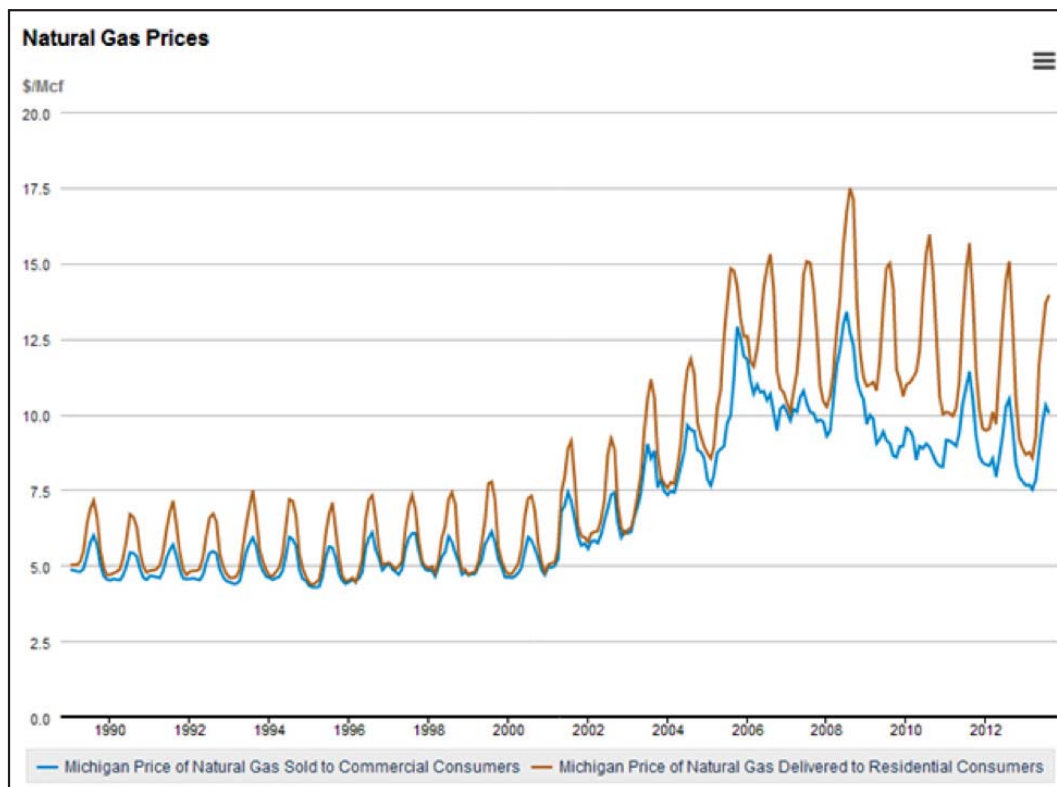


Figure 6: Michigan natural gas prices from 1990 - 2012. Photo courtesy of [www.eia.gov](http://www.eia.gov)

## COMMUNITY OPPORTUNITIES AND CHALLENGES

Tapping into the billions of gallons of minewater beneath the Calumet area presents several key opportunities and challenges for community and economic development. The following sections summarize the opportunities and challenges our research team uncovered. The potential opportunities include: (1) strengthen social capital, community identity, and participation (2) a way to celebrate the cultural legacy of mining while promoting environmental sustainability; (3) increase economic development by attracting businesses and realizing energy savings; (4) increase tourism to the area; and (5) offer synergistic opportunities for related community development. The key potential challenges include: (1) resolving some remaining technical questions that could affect the cost and design of a project; (2) financing the installation costs; and (3) negotiating political decisions around where and how a minewater geothermal system should be installed, how it would be managed, who would benefit and who would bear the costs.

### OPPORTUNITIES

We found a general sense of excitement about the potential for developing minewater geothermal in Calumet. The key opportunities discussed below, represent the key themes that the interviewees saw as the potential opportunities that minewater geothermal could bring to Calumet.

*Strengthen social capital, community identity, and participation*

The people we spoke to in Calumet spoke about the minewater underneath the community as a common pool resource that their ancestors toiled to create. It belongs to “the community.” As a community resource, it is something that requires careful management. Community members will



*Miners for Calumet and Hecla Mining Company  
Photo Courtesy of Keweenaw Archives*

need to work together to make decisions about how best to use it, or not. Developing a minewater geothermal system would require significant community effort and involvement. Calumet residents have a strong community identity and a commitment to improving the community, described as “real passionate people to carry out to make things happen” by one Calumet resident. The community already works together in running successful large-scale events like the CopperDog 150 and PastyFest.

In order to implement a minewater geothermal system in Calumet, not only would the community need to collaborate together, but it would need to partner with external agencies (such as Michigan Technological University, engineering firms, and/or state agencies) to help design the system as well. The process of engaging in practical work both within the local community and partnering

1. Resource belongs to community and community must manage
2. Community works through visioning process with partners from external agencies with technical expertise
3. Create new educational and work opportunities
4. Energy savings and tourism earnings re-invested into community projects
5. Political action to further develop and sustain the community

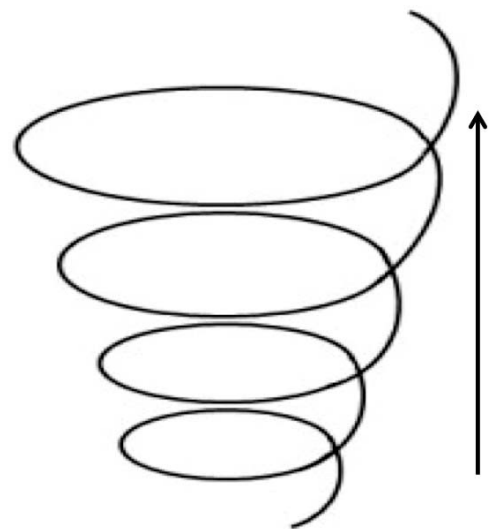


Figure 7: Spiraling up in Calumet could result in community revitalization

with external agencies has the potential to build and strengthen relationship and to create bridging relationships between communities and agencies. Investments in social capital are one of the most important ways to spur widespread community development. Working together on a key project like a minewater geothermal energy system can strengthen social capital and in turn begin a “spiraling up” process of community revitalization.

*Celebrating mining’s legacy while promoting environmental sustainability*

Calumet’s rich cultural heritage, derived in part from the copper mining industry, is highly valued and is a source of pride in the community. This is clearly demonstrated through several local events including: the 100th Anniversary of the 1913 Copper Mine Strike, PastyFest, and Heritage Days. The legacy of the copper mining industry is also reflected within the community’s infrastructure. The mineshafts that once spurred expansive development in the area could now be reused to extract a sustainable energy source through geothermal energy. One interviewee commented, “...we are sitting here with this

unused resource, let’s find a way to use it.”

Minewater geothermal presents an opportunity to celebrate the legacy of mining as a present day environmental asset that can be used to increase sustainability. One interviewee made the remark that geothermal energy represents “a nice way to try to use something that you’ve already got that’s a natural resource that they are getting some benefit from after the mines are gone and not just have to look at slate piles or abandoned buildings.” Mining used to be the primary use of natural capital and the marks of the industry still remain noticeable today. The abundant supply of minewater under Calumet represents another natural resource. The minewater could be transformed into geothermal energy to stimulate economic growth, similarly to how mining did in its past.

Geothermal is a sustainable source of energy that could reduce the community’s reliance on outside sources and fossil fuels, reduce the local carbon footprint, and contribute to self-sufficiency and the preservation of the natural environment of the area. If designed correctly, this system could be sustained indefinitely, because the minewater

is recycled and reused. Some research and exploration of the mines have been conducted to look into the possibilities of opening up the area to mining again. Should mining come back to the Keweenaw area, it would not be utilizing the shafts, and thus minewater geothermal and mining can coexist.

#### *Potential for Economic Development*

Minewater geothermal could potentially expand employment in the Calumet area. The construction, maintenance and management of the system would generate new jobs. Outmigration of young people to other areas in search for jobs is a concern for the community as one interviewee said: "I wish young people stay in town and do not have to leave because of lack of jobs." The implementation of a geothermal energy system could attract locals (especially youth) to remain within the community and entrepreneurs seeking exciting new opportunities in the Calumet community.

The 37 mineshafts in Calumet could serve as easy access points to pump the warm water to the surface, as one interviewee pointed out: "There was some type of a heat system that ran for the mining company homes. So it sounds like this was in place during those days. So if it could happen 100 years ago, it could certainly be even better today." Indeed, reusing the mineshafts would significantly reduce the initial cost required to install a geothermal system. Minewater geothermal holds the potential to reduce the cost of heating and cooling for public facilities (such as the National Park Service, Calumet-Laurium-Keweenaw Schools, and Township and Village owned properties), which could ultimately reduce tax burden. It could also reduce heating and cooling costs for residents and for businesses located in the downtown and industrial district as previously mentioned. These savings could then be reinvested back into the community. It could reduce heating and cooling costs for potential new community projects, such as the development of

a community greenhouse that could grow local produce year round, a recreation center, or for the development of the Red Jacket Educational Institute.

#### *Increasing Tourism*

Calumet's cultural legacy, beautiful scenery, wildlife, and the nearby Lake Superior make it a popular tourist destination. Calumet offers thousands of acres of recreational areas for tourists to mountain bike, hike, ski, snowshoe, skate, dog sled, and snowmobile to name a few. Minewater geothermal holds the potential to increase tourism because the facilities using minewater geothermal could be promoted as a touristic attraction that would draw people interested in alternative energies, sustainable development, technical engineering, and mining legacies at the same time that it would reinforce current heritage tourism efforts by contributing to Calumet's mining legacy.

Overall, this project could strengthen political action to promote community independence through local ownership and reduced reliance on outside companies to provide heating and cooling services. One of the benefits of geothermal energy compared to fossil fuel based sources such as natural gas or oil, is its low variable and operating cost, thus creating a more secure economic solution. The increased partnerships within and outside of the community, jobs, education, sustainability, and financial savings could all be opportunities gained from geothermal heating. Although there are many opportunities connected with minewater geothermal, there are challenges that must be considered as well.

#### **CHALLENGES**

A main concern related to minewater geothermal is the cost of the implementation. The Village, Township, local business, and residents of Calumet have questions such as: "How would it cost to people?", "Who is going to pay for it?", "How are you going to get the funding?" High poverty rates

and a low tax base does not provide Calumet with many funds for such a project. Depending on the system configuration that gets implemented, different financial options are available including grants, loans, bonds, tax credits. The Database of State Incentives for Renewable Energy (DSIRE) catalogs a comprehensive source of information on state, local, utility, and selected federal incentives. Interviewees mentioned that money is more easily spent when from outside sources, but that spending can be misused, unorganized, and unreliable when working with private investors or using government grants.

Some community members may be hesitant or opposed to this change because of Calumet's current financial distress and the requirement to make a financial investment. The idea of tapping the minewater for geothermal has come up before in the past, but due to real and perceived financial issues, lack of a wider community support and outside expertise, and lack of broad community participation in discussion and planning the idea has never been fully explored.

A number of technical unknowns still exist regarding water quality, water temperature, and depth to water surface, and the maximum sustainable heat extraction rates. Some of these parameters have been ascertained at a few shafts but most have not been assessed.

*The key challenges of implementing this system in Calumet include: resolving the technical aspects and remaining unknowns, addressing how to pay for the initial costs of installing the system, climate, and need to increase community involvement in decision making processes.*



*Cultural celebration in Agassiz Park  
Photo Courtesy of Main Street Calumet*

These specifics are needed in order to carry out a detailed technical and economic feasibility analysis. For an example, a high concentration of minerals may limit the design to a closed loop system to prevent clogs or corrosion of pipes.

A few community members had questions about who owns the mineral and water rights of the mines as well as who owns the mineshafts. However, the minewater geothermal system does not permanently extract minerals or water from the mines, so these concerns are most likely not applicable, though because this is a relatively rare situation there is little legal precedence on the matter. The Michigan Department of Environmental Quality has established a system for determining when and what permits are required. This system is outlined in the flowchart seen in Figure 8.

Calumet's cold weather and high amounts of snowfall may make this project challenging. A number of community members brought up concerns over the possibility of pipes freezing during the winter. This concern can be alleviated by burying the pipes below the frost line, but the cold weather may still lead to some reductions in the maximum distance a demand source can be located from a shaft opening due to greater heat loss from the water. A few community members

raised concerns that using the minewater for geothermal heating might de-water the mines or cause water contamination. Neither would occur, as the water would be recycled back into the mine to be reused again, with no outside exposure to the minewater.

An important challenge to the implementation of minewater geothermal in Calumet is the concentration of power in some local institutions. Calumet Township, Mainstreet Calumet and the Village of Calumet are institutions residents perceive as key power holders. Many people believe they make final decisions about whether and what things will happen or not in the town. For instance, a resident made the comment, “if they don’t have that (good opinion of using minewater geothermal) or if the council or the... village leaders aren’t behind it, it’s not going to happen”. There is some concern about whether or not these leaders fully consider the variety of resident opinions, allow broad participation in decision making, or treat different stakeholder groups fairly so that potential benefits of minewater geothermal would be open to all.

Although using minewater geothermal in Calumet presents many exciting possibilities, the potential challenges presented above need to be considered and resolved prior to final decision making. The key challenges of implementing this system in Calumet include: resolving the technical aspects and remaining unknowns, addressing how to pay for the initial costs of installing the system, climate, and need to increase community involvement in decision making processes. If desired and willing, the community can pursue solutions to these challenges and decide whether or not implementing minewater geothermal would be practical and desired.

## SUMMARY

The Village of Calumet and surrounding areas contain 37 mineshafts, which are filled with billions of gallons of water. This minewater has the potential to offer Calumet with a new energy source.

SEMCO bills of buildings in Calumet revealed the lofty financial burden many community members face during the winter months. Implementing geothermal energy could reduce heating costs while celebrating the cultural legacy of mining and community identity, promoting environmental sustainability, and strengthening social relations within the community and with key external partners.

We found general excitement in the Calumet community about the idea of tapping into the minewater for geothermal energy, though certain hesitancy remains. Challenges include the need to resolve some remaining uncertain technical aspects, funding the installation costs, and improved community involvement in the decision making processes. The community could apply for grants, form a cooperative, or sell bonds to help pay for the initial start up costs.

If these challenges could be resolved, the opportunities minewater geothermal could bring to Calumet are great. It could provide energy savings, sustainability, self-sufficient energy production, celebrate a cultural legacy, and strengthen social capital, a known way to improve community development. The success of such a project would, however, depend in part on the degree to which a broad set of stakeholders are involved in the decision-making and planning for minewater geothermal development.

This class hopes to spur discussion within the community about the utilization of minewater geothermal energy in Calumet. Working together on a project like this would build upon the social capital, spurring the “spiraling up” process, which can stimulate positive community development. The community must carefully review the opportunities and challenges and thus determine whether or not they think utilizing minewater for geothermal energy is a desirable option for Calumet and then initiate a visioning and planning process through which community members work together to determine the goals of the community.



*Michigan House Cafe & Red Jacket Brewing Co.  
Photo Courtesy of Edward Louie*

Moving forward from this study, we recommend a broad community discussion in the form of a planning workshop to decide whether or not to further pursue the idea of minewater geothermal. If decided to pursue, we advise the creation of a committee to further evaluate issues including the locations that would participate, technical design issues, economic analysis, funding and management structures. These issues could potentially be addressed by strengthening relationships with Michigan Technological University and partnering with local schools.

Located near mineshafts are multiple public institutions (i.e., CLK Schools, Calumet Township offices, Calumet Coliseum, NPS, BKG Shelter home), commercial establishments (i.e., Calumet Electronics, Calumet Industrial Park), senior housing complexes, and private residences. There

are many different ways a minewater geothermal system could be setup, such as whether to setup a district system of a single building system. A district heating system may be more capital intensive and complicated to implement, however it may have additional social benefits that may make it worthwhile. The community may want to consider developing a demonstration site at a key public building, which would celebrate community ownership, as a first step toward developing minewater geothermal.

As a research group, it is not our intention to tell the community what to do. Our role is to provide an unbiased account of the potential for minewater geothermal development as a way to enhance community development. We hope the results of this project will stimulate dialogue within the community.

## ACKNOWLEDGEMENTS

The Communities and Research class would like to thank Larry Lankton, Al Johnson, Jay Meldrum, Elmore Reese, Dave Geisler, Sam Lockwood, Kraig Marhley, Kathleen Harter, John Rosemurgy, Mike Hale, Paul Bracco, Chris Green, those individuals we conducted interviews with, community members who provided their utility data, the Geothermal Enterprise Team, and Calumet Schools for hosting the community presentation.

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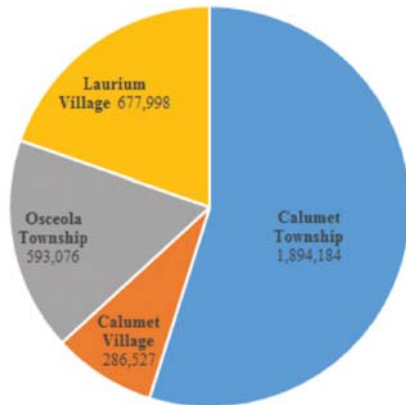
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## APPENDIX

### ESTIMATING COST AND ANALYZING THERMS

Average Annual Therm Use for 2011 & 2012



In order to break down the therm use per location census data was retrieved for each area. The number of households of each location were divided by the total number of households for the entire Calumet area, to give a percentage of how many houses they contribute to the area. The percentage of households per location was then multiplied by the monthly gas use for the Calumet area, to give the total amount of gas used per month and per location. The monthly totals were then added together to give the total amount of natural gas use per location, per year, for the years 2011 and 2012.

Figure 3: Average annual therm use by location

### FLOW CHART OF PERMITS

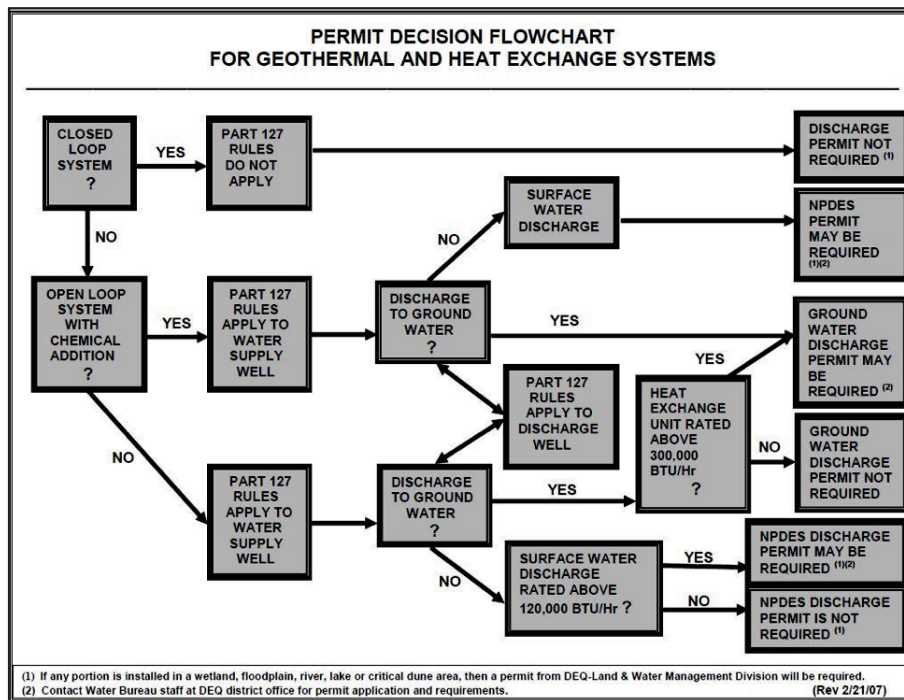


Figure 8: The Michigan Department of Environmental Quality has established a system for determining when and what permits are required. Photo courtesy of Michigan DEQ, 2007)

## INTERVIEW PROTOCOL

1. How long have you lived in Calumet?
  - a. If always, why did you stay here?
  - b. If moved in, why did you move here?
  - c. If grew up here then left and came back, why did you come back?
2. I don't know much about this community. What can you tell me about Calumet? What kind of place is it?
3. What do you like most about Calumet (or this area more broadly)?
4. What are some things that you would like to see different about Calumet?
5. When good things happen in Calumet, how do they get done? Who or what makes things happen?
  - a. Can you tell me about any other innovative projects that the Calumet community has been engaged in? How did this happen? How has it worked out?
6. What kind of future do you see for Calumet?
7. You may have heard that some people in the Calumet community (and around the Keweenaw Peninsula more broadly) are interested in exploring the idea of tapping into the minewater under the village for geothermal energy. This energy could be used for heating or cooling buildings or greenhouses, or possibly for converting to electricity. What do you think about this idea? [is it worthwhile to look into it? Why or why not?]
8. If the Calumet area were to tap into the minewater for geothermal energy, how would you like to see it get done? What would be important things to consider?
9. What do you see as the primary opportunities that minewater geothermal could potentially bring to Calumet?
10. What do you see as the major challenges that would make minewater geothermal difficult or problematic?
11. Do you believe that Calumet (or maybe the Keweenaw Peninsula more broadly) is capable and ready to be an innovator or leading community for sustainable energy sources? Why or why not?
12. Is there anything else that you think I should know?

## Appendix B: EPA P3 Phase I Grant Proposal

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See Grants.gov

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## Abstract

**Research Category:** *P3 Awards: A National Student Design Competition for Sustainability Focusing on People, Prosperity and the Planet*

**Funding Opportunity Number:** EPA-G2014-P3-Q1-Energy

**Title:** Developing a Guide for Harnessing Low-grade Geothermal Energy from Minewater for Heating and Cooling Buildings

**Principal Investigator (PI):** Richelle Winkler: [rwinkler@mtu.edu](mailto:rwinkler@mtu.edu)

**Student Team:** Brian Delrue, [bcdelrue@mtu.edu](mailto:bcdelrue@mtu.edu), MS student  
Edward Louie, [eplouie@mtu.edu](mailto:eplouie@mtu.edu), MS student  
Krista Blumberg, [kablumbe@mtu.edu](mailto:kablumbe@mtu.edu), BS student  
Kayla Warsko, [kmwarsko@mtu.edu](mailto:kmwarsko@mtu.edu), BS student

The remaining student participants will be recruited through a multidisciplinary campus-wide search, and a targeted search for an environmental engineer and an economist.

**Institution:** Michigan Technological University (MTU) in Houghton, MI

### **Student Represented Departments and Institutions:**

Brian Delrue: Environmental and Energy Policy, Social Sciences Dept (MTU), B.S. Mechanical Engineering (MTU, 2004)

Edward Louie: Environmental and Energy Policy, Social Sciences Dept (MTU), Civil and Environmental Engineering (Bucknell University)

Krista Blumberg: Chemical Engineering Dept (MTU)

Kayla Warsko: Chemical Engineering Dept (MTU)

**Project Period and Location:** August 15, 2014 - August 14, 2015

The majority of the sustainability framework components will be developed by the project team on the MTU campus in Houghton, MI. Collaborations with partners will take place in Calumet, MI and Houghton County, MI. The project work timeline will take into consideration academic semester start and end dates with the fall 2014 semester beginning on September 2 and ending on December 12 and the spring 2015 semester beginning on January 12 and ending April 24.

**Proposed EPA Project Cost:** \$14,490

**Total Project Amount:** \$19,530

### **Project Summary:**

**Objective:** The overall goal of the proposed student design project is to develop educational materials to assist former mining communities in evaluating the technical and social feasibility of tapping water in abandoned mines for geothermal heating and cooling. Geothermal heating and cooling systems are regarded as the most efficient and an environmentally benign alternative to burning fossil fuels, which emit air pollution and contribute to climate change (U.S. DOE, 2011; Hanova, 2007). Yet, geothermal remains underutilized due in large part to high costs of installation and a general lack of common knowledge about how these systems work, especially for low-grade

sources (Hanova, 2007). Minewater geothermal is an innovative approach that uses existing shafts in order to reduce or eliminate any required drilling; thus installation costs are significantly reduced. It also provides an opportunity to connect alternative energy development to the cultural legacies of mining, attracting interest from the broader public and increasing knowledge of geothermal energy amongst multiple constituencies. One of the greatest challenges for implementing minewater geothermal is the fact that there are only a few successful models globally and no feasibility framework or guide to help communities and stakeholders evaluate the local potential for developing a system. We propose to develop such a guide and to create table top models demonstrating how minewater geothermal works.

Description: The proposed project aims to increase knowledge and promote the implementation of geothermal energy systems, which would reduce the burning of fossil fuels and thereby reduce air emissions and mitigate climate change (**protecting the planet**). Historically, in a vast number of domestic and international sites, when mining operations closed they left behind severe economic and environmental challenges. We hypothesize that geothermal energy has the potential to economically benefit many impoverished rural areas where mining was once a major economic activity, because of the potential for energy savings and attracting businesses and tourism (**prosperity**). Minewater geothermal also contributes to **quality of life**, by offering energy savings which allow people to maintain more comfortable temperatures in homes and public spaces (warmer temperature settings in winter and allowing for cooling in summer). Furthermore, minewater geothermal celebrates the cultural heritage of mining while at the same time promoting environmental sustainability. The cultural importance of mining in many communities means a great deal to the local sense of place and community identity which are important components of quality of life.

Results: The interdisciplinary student design team will 1) develop a guidebook for evaluating the potential of tapping into minewater geothermal for renewable energy, and 2) design table top models for education and instruction (outputs). These materials would be targeted for communities around the U.S. located near abandoned mines who could use them to evaluate and understand the social and technical feasibility of installing a minewater geothermal system. Partnering with engineering team members, social science team members will collaborate with community members and political leaders to understand the sociocultural and political acceptability and challenges. Hence, the project outcomes are to assist former mining communities in working towards developing minewater geothermal systems, which would reduce reliance on fossil fuels (and carbon emissions), contribute to energy savings and increase job opportunities in impoverished rural areas, strengthen community identity, and reduce basic costs of maintaining comfortable temperatures through heating and cooling. Evaluation of project success will be based on 1) the ability of the guide to reproduce operational data from working minewater geothermal systems, and 2) formal evaluations of the guidebook by community leaders and professional engineering firms identified as partners.

**Relevance to EPA Mission:**

This project will further the goals of the Clean Air Act and Clean Water Act through substantial reductions in electricity usage and associated air and water emissions by promoting alternative, renewable energy using minewater and geothermal heat pumps.

**Supplemental Keywords:** geothermal, mine water, guide, alternative energy, community development, mining

## Project Design

Heating and cooling accounts for over half of the energy consumed in households and thirty percent of the energy costs in commercial buildings (EIA, 2013). Most buildings are heated by either electricity or natural gas; however, geothermal heat pumps can provide heat at 3 to 5 times the efficiency of either systems but is rarely chosen due to the high upfront costs (Self, 2013; Hanova, 2007). Geothermal has long been recognized by the DOE and others as the most energy efficient method to heat and cool a building (U.S DOE, 2011). A major source of capital cost is the excavation and/or drilling needed to create the geothermal exchange field (Luce, 2011). By reusing existing flooded mineshafts this capital cost can be reduced or eliminated translating to cost savings and decreased environmental impacts. Throughout the U.S. there are as many as 500,000 abandoned mines on private and federal lands; most of them are already flooded. There are 2,300 mines in the state of Michigan alone (Johnson, personal communication). Each flooded mine can contain from millions, up to a trillion gallons of water at temperatures equal to if not greater than the surrounding ground making them suitable geothermal sinks (Hall, 2011). Despite their abundance, the use of minewater for geothermal heating and cooling has been implemented in only a handful of systems in Canada, Germany, Netherlands, Norway, Scotland, and the US with the most well-known system in Heerlen, Netherlands (Hall, 2011). A literature search reveals that these few systems are inadequately documented and thus are not a good guide for further development in other areas. Without a guide, those with nearby access to a flooded mine struggle to evaluate the social, economic and technical feasibility of implementing a minewater geothermal system. Minewater is a severely underutilized resource; Terry Ackman and George Watzlaf (2007) from the National Energy Technology Laboratory said U.S. mining regions are the “Saudi Arabia of Geothermal Energy” and regarded unused minewater as “a terrible thing to waste” (p. 1, 19).

The objective of this project is to develop a guide for determining the sustainability of utilizing low-grade geothermal energy from flooded mine shafts for heating and cooling buildings. The goal of this framework is to significantly reduce the challenges of translating this technology to a community with access to mineshafts. This framework will allow different system setups and configurations to be analyzed and compared. For example, it would allow one to compare between a district heating configuration versus select buildings given the location of the mineshafts, thermal capacity of the thermal sink, distance of buildings from the mineshafts, and heat and cooling loads of the buildings. This will allow communities interested in developing minewater geothermal to determine the optimal or ideal technical setup when considering the financial, social, and political limitations and how these vary across different types of systems.

The increased efficiency of geothermal not only translates to lower electricity costs but reduced air and water pollution since the electricity mix in most parts of the US is dominated by coal. Burning coal to produce electricity sends a host of toxic pollutants, including mercury, nitrous oxides, sulfur dioxide and particulate matter, into the atmosphere which leads to water pollution and acid rain. The development of minewater geothermal would result in air and water pollution reduction, giving it statutory authority under the Clean Air Act and Clean Water Act. Reducing electricity demand through improved energy efficiency is the cheapest, and most effective way to reduce pollution. The reuse of flooded mineshafts for geothermal takes pollution reduction one step further compared with a traditional geothermal system by reducing the carbon footprint of installation. Furthermore, because heat pumps operate on electricity, communities can integrate solar photovoltaic and wind power projects for additional pollution prevention. The intermittent

nature of both renewables is not a problem since a momentary lapse in heating and cooling will go unnoticed.

The scientific/technical soundness of utilizing low-grade geothermal from flooded mineshafts for heating and cooling buildings has been demonstrated in a handful of systems in the world (Hall, 2011). A literature search on the few published feasibility studies reveals trade-offs and a general overemphasis on technical feasibility with insufficient effort towards understanding economic, political and social feasibility. Most feasibility studies were conducted for projects that never moved forward or conducted after the fact by academics to prove that a system is technically sustainable as shown in Table 1. The city of Yellowknife in Northwest Territories, Canada for example, conducted a quarter million dollar feasibility analysis on using the Con Mine for a district minewater geothermal heating system. However due to insufficient community support it was not implemented. A system that benefited key businesses at a high cost to taxpayers was proposed, it garnered support from businesses and political leaders but not enough support from citizens who voted against financing the implementation of the proposed system (SAIC, 2009; CBC News, 2011). Current methods are inadequate- neither conducting a feasibility study after the fact nor one that doesn't adequately include all stakeholders are good approaches. The framework we propose is innovative because it takes a multifaceted approach to feasibility analysis by combining technical, economic, social, and political components of sustainability to minewater geothermal energy. In doing so, this guide will spur dialogue and collaboration between political leaders, the general public, technical experts, and investors to create a new wave of community development and revival.

**Table 1.** Feasibility Studies Conducted

| Sites   | Study                          | Pre or Post Study | Implemented |
|---|--------------------------------|-------------------|-------------|
| Ropak Can-Am Ltd. Springhill, Nova Scotia, Canada | Jessop, 1995                   | Post              | Yes         |
| Springhill, Nova Scotia, Canada                   | Madiseh, 2012;<br>Michel, 2007 | Post              | Yes         |
| Canadian underground mines                        | Koufos, 2012                   | Pre               | No          |
| Yellowknife, Canada                               | SAIC, 2009                     | Pre               | No          |
| Gaspe Mines, Quebec, Canada                       | Raymond, 2008                  | Pre               | No          |
| Lorraine, France                                  | Hamm, 2010                     | Pre               | No          |
| Heerleen, Neatherlands                            | Bazargan Sabet, 2008;          | Pre & Post        | Yes         |
| Asturian coal mining basins, NW Spain             | Loredo et al., 2011            | Pre               | No          |
| Freiberg Castle, Germany                          | Kranz, 2010                    | Post              | Yes         |
| Coal Mines, Upper Silesia Poland                  | Malolepszy, 1998               | Pre               | No          |
| Zasavje, Slovenia                                 | RCR, 2010                      | Pre               | No          |
| Quincy Mine, Michigan                             | Hockings, 1983                 | Pre               | No          |

## Challenge Definition

A literature review on the handful of existing minewater geothermal systems revealed gross lack of complete data on capital and operational costs, configuration details, performance data, and community and economic benefits making it impossible for them to be used as examples for further development. A compilation of data on documented minewater geothermal systems to date shows incomplete data on even basic information on the few existing systems as shown in Table 2. This is to be expected since building operators typically have no incentive to document and publish performance result or conduct economic and environmental comparisons. Installation firms also lack an incentive to conduct and publish studies if the client does not demand one. The challenge for those considering minewater geothermal today is that there is no literature, guide, book, or resource to help one determine whether a system financially, environmentally and socially beneficial system could be built. Thus, the development of a sustainability framework guide for harnessing low-grade geothermal from minewater for heating and cooling buildings is needed to overcome this technical challenge.

**Table 2. Documented Minewater Geothermal Systems To Date**

| Date  | Country     | Sites   | Water Temp (C)                         | Depth (m) | Pump Rate              | Mine Type | System Capacity   | End Use     | Loop Type | Number of Heat Pumps | Total Area Heated (m2)  | Upfront Cost (\$) | Annual Savings (\$)         | Payback period | Some Feasibility Analysis? |
|-------|-------------|---|--|-----------|------------------------|-----------|---|-------------|-----------|----------------------|---|-------------------|-----------------------------|----------------|----------------------------|
| 1981  | USA         | Kingston Recreation Center  |  | 30        | 90 gpm                 | Coal      |   |             |           |                      | 1579  |                   | 6000 vs Gas                 |                | No                         |
| 1984  | Germany     | Heinrich, Heisingen   |  |           |                        | Coal      | 350 kW  | Heat        |           |                      |   |                   |                             |                | No                         |
| 1980s | Canada      | Ropak Can-Am Ltd. Springhill, Nova Scotia, CA                         | 18                                     | 1350      | 1000 m <sup>3</sup> /d | Coal      | 45 kW   | Heat & Cool | Open      | 11                   | 16700   | 110,000           | 160,000                     | <1 year        | Yes                        |
| 1994  | Germany     | Ehrenfreidersdorf, Sachsen  |  |           |                        | Tin       | 1 School  | Heat        |           |                      |   |                   |                             |                | No                         |
| 1995  | USA         | Park Hills, MO  | 14                                     | 120       | 75 gpm                 | Lead      | 1 Muni Bldg   | Heat        | Open      | 9                    | 753   | 132,400           | 30,844                      | 4.6            | No                         |
| 1997  | Germany     | Ehrenfreidersdorf, Sachsen  |  |           |                        | Tin       | 82 kW, Museum   | Heat        |           |                      |   |                   |                             |                | No                         |
| 1998  | Norway      | Foldal Mine, Hedmark  |  | 600       |                        |           |   |             | Closed    | 1                    |   |                   |                             |                | No                         |
| 1999  | Scotland    | Shetteston  | 12                                     | 100       |                        | Coal      | 16 Houses   | Heat        |           | 2                    |   |                   | 80% saving                  |                | No                         |
| 2000  | Scotland    | Ochilview, Lumphinnans  | 14.5                                   | 170       |                        | Coal      | 18 Houses   | Heat        |           |                      |   |                   | 80% saving                  |                | No                         |
| 2000  | Germany     | Zolverein, Katernberg   |  |           |                        | Coal      | 1 School  | Heat        |           |                      |   |                   |                             |                | No                         |
| 2004  | Canada      | Dr. Carson and Marion Murray Community Centre Springhill, Nova Scotia | 18                                     | 1350      |                        | Coal      | 96 Tons   | Heat & Cool |           | 8                    |   |                   |                             |                | Yes                        |
| 2007  | Germany     | Shaft 302, Marienberg Mine, Sachsen                                   | 12                                     | 144       |                        | Uranium   | 1 swimming pool + 690 kW supplement to district heating | Heat        |           |                      |   |                   |                             |                | No                         |
| 2007  | USA         | John Wesley Church, Pennsylvania                                      | 14                                     |           |                        |           |   |             |           |                      |   | 80,891            | 80% on Heating, 50% cooling |                | No                         |
| 2006  | Canada      | Goyer Quarry, Quebec  |  |           |                        |           | 36 Apartments   | Heat & Cool | Open      |                      | 6039  |                   | 50%                         |                | No                         |
| 2009  | Russia      | Novoshaktinsk   |  | 400       |                        |           |   |             |           |                      |   |                   |                             |                | No                         |
| 2009  | Netherlands | Heerleen, Netherlands   | 30-35 deep shafts; 16-19 shallow shaft | 700       |                        | Coal      | 700 kW  | Heat & Cool | Open      |                      | 350 Houses, 3800 m <sup>2</sup> commercial space, 16,200 m <sup>2</sup> community space |                   |                             |                | Yes                        |
| 2009  | Germany     | Castle Freudenstein, Freiberg   | 10.2                                   | 60        | 3 L/s                  | Coal      | 170 kW  | Heat & Cool | Open      | 2                    |   |                   |                             |                | Yes                        |
| 2010  | USA         | Marywood University   |  | 104       |                        | Coal      |   |             |           |                      |   |                   |                             |                | No                         |

## Relationship of Challenge to Sustainability

### People

To conduct a sustainability analysis of minewater geothermal in a community involves an open dialogue with the community. Through open dialogue, more stakeholders will learn about low-grade geothermal, the efficiency of geothermal over other forms of heating and cooling, and the feasibility of minewater geothermal in their community.

Settlements near areas of mining are often a direct result of the mining. Since mining is an inherently unsustainable activity, these towns often suffer economically and socially once the mine closes (Freudenburg and Wilson 2002, Humphrey et al. 1993). Mines are often located in remote areas where energy must be transported or transmitted a long distance contributing to high costs.

The combination of unemployment, high poverty, and high energy costs makes many of these areas among the most depressed regions in America. Despite the immense capital invested to create underground mines, they are perceived to hold little value after closure. The sustainable reuse of these mines for geothermal would provide value back to these mines calculated in terms of the environmental benefits and reduced economic cost of excavation/drilling geothermal wells and operational cost savings.

Culturally, reusing the mines represents a transition from unsustainable to sustainable, a connection between the past, present, and future, as well as a source of hope and pride. Cultural ties, sense of place, and community identity are important components of quality of life and community development (Flora and Flora 2013). Minewater geothermal provides an opportunity to celebrate the cultural legacy of mining and reinforce community identity, while at the same time promoting environmental sustainability and fossil fuel independence. By associating the mining past with something positive for the future, rather than the more typical environmental degradation and contamination associated with mining histories, minewater geothermal offers opportunities for developing a strong and positive sense of place that may attract tourists, in-migrants, and reduce young adult out-migration (Manzo and Perkins 2006).

Furthermore, minewater geothermal could support multiple synergistic community development activities that would improve human health, comfort, and safety. The heat from the mine water can not only be used for geothermal but also to melt snow, heat hydroponic, aquaculture, and greenhouse systems which can provide jobs, improve sustainability, safety, and accessibility. With reduced transportation costs and increased availability, fresh vegetables and fish may become more accessible translating to a healthier diet.

As research and demonstration sites have shown, geothermal results in energy savings that translates to reduced air and water pollution from coal power. Carbon dioxide, sulfur dioxide, nitrogen oxides, particulate matter, and mercury are pollutants predominantly from coal combustion. Sulfur dioxide and nitrogen oxide exposure leads to increased asthma symptoms. Fine particulate matter commonly increases respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing however it can also lead to premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, and decreased lung function. The health and environmental impacts of air and water pollution are not confined to the area in which it is produced; they can be transported by winds and in rivers and impact society as a whole.

### ***Prosperity***

A literature review of minewater geothermal systems reveals impressive economic savings. The Ropak facility in Nova Scotia, Canada had a capital cost of \$110,000 but resulted in an annual savings of \$160,000 per year, a 60 percent reduction over the equivalent oil-fired furnace system. The economic advantage is further enhanced when the abated cost of dehumidification are taken into account (Jessop, 1995). Since Ropak's success outside investors entered Springhill and the industrial park attracted more businesses looking to benefit from geothermal energy, which has increased economic prosperity in the local community. In addition to the industrial park, Springhill's NHL sized ice rink and community center installed minewater geothermal and became the largest facility to do so in Canada. Heating and cooling with geothermal has saved the complex

\$70,000/year in energy costs and \$45,000 in annual maintenance costs (Gorman, 2013). Today, over a dozen local businesses either have access to or choose to use geothermal energy in Springhill (Thompson, 2013). In the U.S., the minewater geothermal system installed at the John Wesley AME Zion Church in Pittsburg, PA cost \$80,000 but reduced heating costs by 80% and cooling cost by 50% (Ohio DNR, 2011). The system in Park Hills, MO cost \$132,400 but saves \$30,844 annually (Ohio DNR, 2011; Koufos, 2011).

The payback period of a traditional geothermal system is typically between 6 and 20 years depending on capital costs, energy prices and energy price increases (Self, 2013). Due to the capital savings and increased operational efficiency due to warmer temperatures than the surrounding ground, minewater geothermal systems will have shorter payback periods. Published payback periods can be as short as less than a year in the case of Ropak to 4.6 years for Park Hills, MI (Jessop, 1995; Ohio DNR, 2011).

Due to the lack of experience in minewater geothermal, most locations with this resource have not made any effort towards exploring its use for this purpose. The motivation for creating a systematic framework for determining the suitability, benefits, and costs of a minewater geothermal system stems from the hope that it will catalyze efforts to explore and utilize this resource. This framework will be utilized to analyze sites in Calumet, MI. Should it reveal a sustainable site, the goal will then be to work with partners to construct a full scale system. This system will be well instrumented to provide performance and cost savings data. Success at this site will spur interest in the development of additional systems.

### ***Planet***

A geothermal heat pump has been identified by the DOE as the most energy efficient system for heating and cooling a building. The DOE has determined that a traditional geothermal system will result in a 50% reduction in CO<sub>2</sub> compared to electric heat. Electricity use represents a significant source of pollution especially in areas where power from coal forms a large part of the electricity mix. The development of this framework will result in more municipalities and individuals exploring the possibility of utilizing minewater geothermal leading to higher adoption resulting in a reduction in electricity use and pollution reduction. Furthermore unlike natural gas and oil, minewater geothermal systems gracefully lend to collaboration with other renewable energy projects such as wind and solar which do not release emissions during operation.

### **Education and Interdisciplinary Aspects**

One of the barriers to geothermal energy and especially minewater geothermal energy is a lack of education on the subject. When one hears the term geothermal many instinctively think of Yellowstone, Old Faithful Geyser, and hot springs. But most don't think of their backyard as possessing any geothermal potential. These perceptions, combined with the unaffordability perception, are two social barriers this project seeks to overcome. The proposed project specifically seeks to incorporate community dialogue into the development of our feasibility guide and into the processes covered in the guide. In this fashion, we will specifically encourage broad based discussions and education efforts about geothermal technologies. Communities that follow our guide will likewise engage in dialogue within their community about mine water geothermal.

Through conversation, reading the instructive guidebook and the physical models, more stakeholders will learn about low-grade geothermal, the efficiency of geothermal over other forms of heating and cooling, and the potential feasibility of minewater geothermal in their community. They will be empowered by the knowledge that they can play a key role in air and water pollution reduction and climate change mitigation through improving efficiency and energy savings.

The proposed project includes a partnership with Calumet-Laurium-Keweenaw Schools, a K-12 school district in an historic mining region where the school building is located less than 100 feet from a flooded mineshaft. The school district will serve as one of the community partners in Phase 1 and is interested in evaluating mining geothermal as both a means for energy savings and an educational opportunity for their students. Such partnerships present opportunities to educate the next generation about sustainability and geothermal energy while tying into place-based learning strategies.

The development of the proposed guide will require the collaboration of an interdisciplinary set of researchers and sustained community participation. Likewise, the use of the guide will require users to engage in interdisciplinary teams and to integrate technical expertise with community relations and input. It is critical that alternative energy projects directly integrate social science perspectives on social acceptance and social impacts in order to understand and evaluate technical solutions. At the same time, expertise from engineers of various backgrounds will be vital for meeting the various design components required in developing a technical guide. The proposed project will specifically include social scientists, chemical and mechanical engineering students, students with backgrounds in civil and environmental engineering, and a faculty partner in mechanical engineering. In addition, we will recruit an economist or accountant. We have also built strong working partnerships with community organizations in a former mining town and an engineering firm specializing in implementing small scale alternative energy projects.

Our team already has significant experience in working together as an interdisciplinary unit in partnership with community members. The project PI, faculty partner, and two of the students on the proposed design team are currently involved in a pilot project to understand the feasibility of accessing minewater geothermal in Calumet, Michigan. This project includes the collaboration of multiple disciplines, including energy and environmental policy, environmental engineering, chemical engineering, mechanical engineering, and geology. The current work identified the need for a framework that encompasses economic, social and environmental feasibility that communities and partners could use to analyze opportunities for developing minewater geothermal. In Calumet, community members have been interested in the idea of minewater geothermal for years, but they have not known where to begin with evaluating its feasibility. A local community organization (Main Street Calumet) invited our current study as a way to broaden understanding and discussion. Over the course of the project and reviewing related sites, we have learned that scant data and resources exist about minewater geothermal efforts. Likewise, the use of this sustainability framework will require the collaboration of an interdisciplinary set of individuals and sustained community participation.

## Results Outputs and Outcomes

The objective of this project is to develop a guide for harnessing low-grade geothermal energy from minewater for heating and cooling buildings. Our proposed project will have two outputs. First, we will produce a guidebook for evaluating the potential of harnessing low-grade geothermal energy from minewater for heating and cooling buildings. Second, we will develop table-top models to show how different configurations of geothermal energy work. These two products will be targeted at communities around the U.S. located near abandoned mines who could use them to evaluate and understand the technical, economic, and social feasibility of installing a minewater geothermal system. Partnering with engineering team members, social science team members will collaborate with community members and political leaders to understand the sociocultural and political acceptability and challenges. Hence, the project outcomes are to assist former mining communities in working towards developing minewater geothermal systems, which would reduce reliance on fossil fuels (and carbon emissions), contribute to energy savings and increase job opportunities in impoverished rural areas, strengthen community identity, and reduce basic costs of maintaining comfortable temperatures through heating and cooling.

The technical and economic components of the guide will be evaluated based on its ability to reproduce performance results from the Keweenaw Research Center (KRC). The KRC and executive director Jay Meldrum are partners in the proposed project. KRC is a research and testing center on the Michigan Tech University campus that has been heating and cooling with a minewater geothermal system since 2010. Being a research center, the KRC's system is more instrumented than most giving the project a plethora of data for tuning analysis tools.

Technical components of the proposed guide will also be reviewed by a professional engineering firm (Progressive AE) that has experience in designing and installing geothermal systems. The social and political components of the guidebook will be formally evaluated by community organizations in Calumet, MI, including Main Street Calumet, CLK Schools, and Calumet Electronics to confirm their usability.

Without a guide, the risk of implementation is an obstacle to system development and questions of feasibility and end-user buy-in remain challenging. Preliminary research in Calumet, MI (a village of 700 people set atop billions of gallons of minewater and 37 local shafts) highlighted how social, economic and technical questions left unanswered are barriers to initial development steps. Culturally, reusing the mines represents a transition from unsustainable to sustainable, a connection between the past, present, and future, and a source of self-sufficiency. The results from this process will be a good estimate of the cost of implementing a system, the payback period compared to electricity and natural gas, and the carbon savings versus electricity and gas. As described in the letters of support, there are businesses in Calumet including Calumet Electronics Corporation, who is in a position to implement a minewater geothermal system should the project find the return on investment to be within the company's criteria and result in lower energy costs.

Since the geometry of each reservoir (mine galleries and shafts) varies greatly and is highly site-dependent, a successful system at one site cannot be easily transferred to another. However, the techniques for developing a thermodynamic model of a mine remain the same regardless of the reservoir geometry. The same can be said for the framework for the economic analysis and framework for evaluating social and political acceptance. Thus the proposed guide for harnessing

low-grade geothermal energy from minewater for heating and cooling buildings will be readily transferable and scalable.

The guidebook will be further tested in Phase II, when townships and municipalities with access to minewater will be solicited with the offer of using the developed framework to evaluate the sustainability of implementing a geothermal system. Success will be measured by a project review team and quantitative and qualitative assessment from community members, and political leaders.

## **Project Schedule and Milestones**

Developing the components of this guidebook will fully utilize the skills of each project team member. Additionally some tasks will require skills and knowledge outside the scope of the team's ability as thus will require partnerships with external experts.

The first major milestone is to gain an understanding of the population that could benefit from this effort. To do this, maps of Michigan and the U.S. showing the census block will be combined with maps locating areas of historic mines in GIS to estimate the population living in close proximity to shafts. Subtasks will include developing a database of archives where one can look up historic technical drawings and information of mines, information about the mining companies. Edward will take the lead on this task.

Another major milestone is the development of a tool or model for determining the maximum sustainable amount of heat that can be extracted from a mineshaft. This task will be lead by a mechanical engineering student Brian and involves partnering Zhen Liu who has experience with thermodynamic modeling. The computer model will be developed using data from the KRC's system.

Parallel with the previous task is the development of a spreadsheet for estimating energy demand in the area near a mineshaft, this is will allow one to determine whether the maximum sustainable yield of a shaft will be exceeded or not. Kayla will lead this task.

While the KRC's existing system is well instrumented, modeling an uninstrumented well will require a host of data collection. A major task involves developing a list of products and procedures that can be used to measure the temperature gradient and sample water at depth. Additionally, a discussion on the relevant water chemistry tests that should be conducted and a database of water quality laboratories to send samples needs to be developed. Chemical engineering students will be in charge of this task, specifically Krista will lead this task.

Developing the tools to analyze the capital cost, estimated savings, payback period, and return on investment is a major milestone of this project. It begins with the development of a database of equipment costs. This task will involve partnering with Progressive AE a company with experience in designing and installing geothermal systems. The second step involves developing a spreadsheet for sizing buried insulated pipes, heat pumps, heat exchangers, circulation pumps based on demand and distant to mineshaft. This task will involve a partnership with Keweenaw Research Center and using their system to understand how to setup the spreadsheet. Using the GIS model developed in

the first step the distances of buildings to mineshafts can be calculated. With the previous information, calculations on the operational savings vs. electric and natural gas, payback period, rate of return on investment can be calculated. An assisting partnership may be consulted to conduct this task. Edward will lead this task however it will involve skills and knowledge from the rest of the team.

Stemming from the development of the economic analysis framework will be a spreadsheet for calculating the carbon savings vs. electric and natural gas heat. Kayla will lead this task.

Decisions are made based on socio-cultural and political basis as much as technical feasibility. It will be vital to consider how these decisions get made. To do so, interviews with community members in Calumet, MI and the wider Houghton County area will be conducted to better understand the socio-cultural and political components that are important to consider. Edward and Brian will collaborate with faculty PI Winkler on this task.

In addition to the many parts of the guidebook a major milestone of the project involves the construction of table top modes of an open-loop system, closed-loop system, district and single building systems. These models will be instructional aides to explain geothermal energy systems to the community. The model will also be able to explain how all the components of the guidebook are needed in order to evaluate a system. Kayla will take the lead on constructing these models.

Some additional minor tasks in drafting this guidebook include the following:

- Table 2 contains a list of sites with an active mine water geothermal system. Although little has been published documentation exist regarding these systems perhaps much more is known about some of these systems. A task will be to contact these sites for additional information and to write a summary literature search on the existing systems. A goal is to expand and fill in the missing pieces in Table 2. Edward will lead this task.
- A literature search reveals a lack of clarity on the issue of who owns the rights to the minewater and mineshafts. A discussion on mineral and water rights with respect to minewater geothermal will be written in consultation with a partnership with an environmental lawyer. Brian will lead this task.
- Development of a database of state and federal grants and loans and who is eligible for each. Brian will lead this task.
- Development of a decision matrix (pros & cons) for the different financing methods (bonds, tax, loan) and for the different ownership methods. Edward will lead this task.

After completion of key milestones, the project team will meet with the advisory board (key business and community partners discussed below) to solicit feedback.

Looking over the horizon into Phase 2, the use of the guide and models developed in Phase 1 would be used to analyze the sustainability of a minewater geothermal heating and cooling system at some or all of the following partnership locations:

- Partner with Keweenaw Geothermal Research Group and use the framework on their rock house showroom.
- Partner with Calumet and use framework
- Partner with Finlandia University
- Modify and improve the guidebook from lessons learned by conducting these analyses
- Document findings
- Present findings
- Publicize the guidebook through internet, a webinar, and presentation at one or more professional meetings. The goal would be to make the guidebook widely available and publically accessible for free.

Throughout this project any planned expenses will be discussed with the faculty advisors prior to making the expenditure. All expenditures will be documented and justified to ensure that the awarded grant funds will be expended in a timely and efficient manner. Michigan Tech's Office of Research and Sponsored Programs will manage and oversee the accounting and expenditures to be fully compliant with federal regulations.

## Partnerships

This project will not be possible without partnerships. Results from a thermodynamic model are only as good as its inputs and execution. The complexity and high learning curve of 2D and 3D thermodynamic modeling is further complicated by the complex network of interconnected shafts and galleries. Without a consulting partnership with an experienced modeler like Zhen Liu, the results can lead to an investment that fails to deliver expected results. The Keweenaw Research Center has been keeping building occupants comfortable since 2010 with an active minewater geothermal heating and cooling system, its abundance of operational data will be invaluable for testing and validating technical and financial analysis tools developed. The partnership with the KRC is essential for the testing and validation of developed analysis tools from this project. The database of component costs will be validated by partnering with Progressive AE, a firm with expertise in small-scale alternative energy design. Partnerships with Main Street Calumet, a community revitalization organization in an historic mining community, will help the project team understand and validate the political sustainability consideration sections of the guidebook. A partnership with Calumet-Laurium-Keweenaw Schools, a K-12 school district in an historic mining region where the school building is located less than 100 feet from a flooded mineshaft, can present many opportunities for education about sustainability and minewater geothermal energy. These partners have agreed to serve on an advisory board for the proposed project. After key milestones are met the project team will meet with the advisory board for feedback. Moreover, the advisory board will formally evaluate the primary outputs from the proposed project (Guide and table top models). See the Appendix for letters of support from the CLK Schools, Progressive AE, and Main Street Calumet.

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## Appendix C: A Community Guide to Mine Water Geothermal Heating and Cooling

An illustration of a two-story house with a grey roof and white siding. The house has several windows with shutters and a central entrance. In the foreground, there is a green lawn and a driveway. Below the lawn, a cross-section of the ground is shown, revealing a geothermal system with orange and blue loops representing the heat exchange process.

# A COMMUNITY GUIDE TO MINE WATER GEOTHERMAL HEATING AND COOLING

Informing Communities about  
Geothermal Potential

2015

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This Guide was written by a group of undergraduate and graduate students at Michigan Technological University. It would not have been possible without the support, guidance, and contributions from faculty members at Michigan Tech and other professional experts. In particular, these include Jay Meldrum and Richelle Winkler who co-advised this project. Chris Green also provided considerable support and with regards to technical analysis and data collection. Michael Korb, of the Pennsylvania Department of Environmental Protection's Bureau of Abandoned Mine Reclamation, also provided comments and suggestions.



## 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).

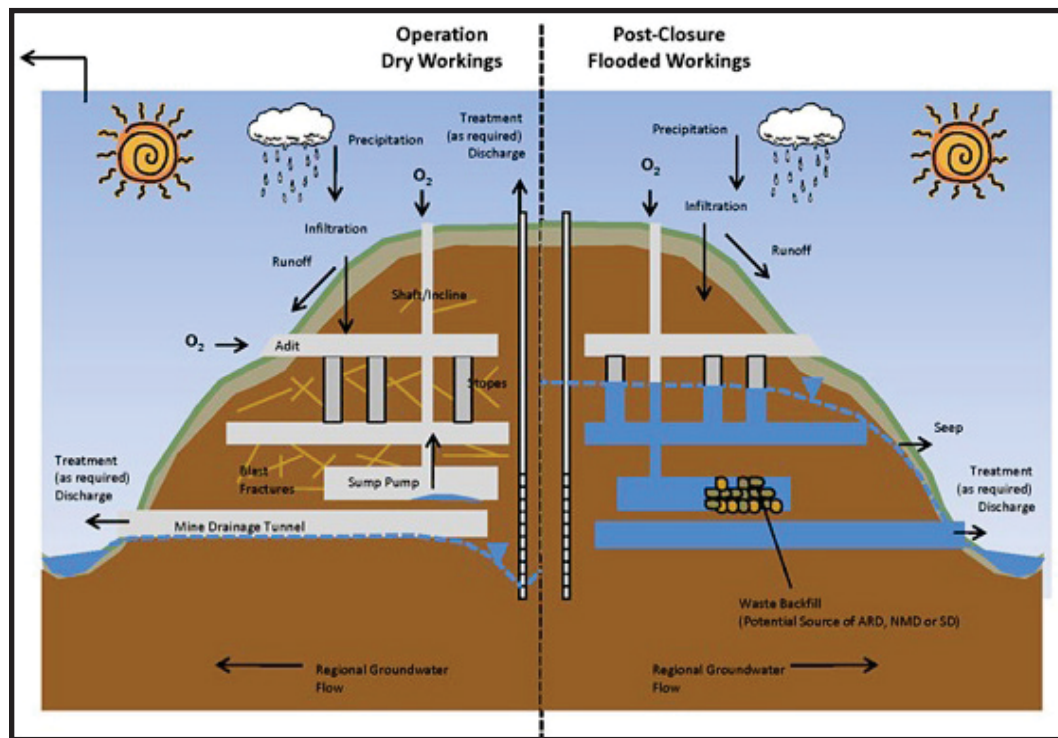


FIGURE 1. Water Management in active and closed mines [1].

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 flood underground mine required two boreholes and 2000 ft of pipe [14, 15].

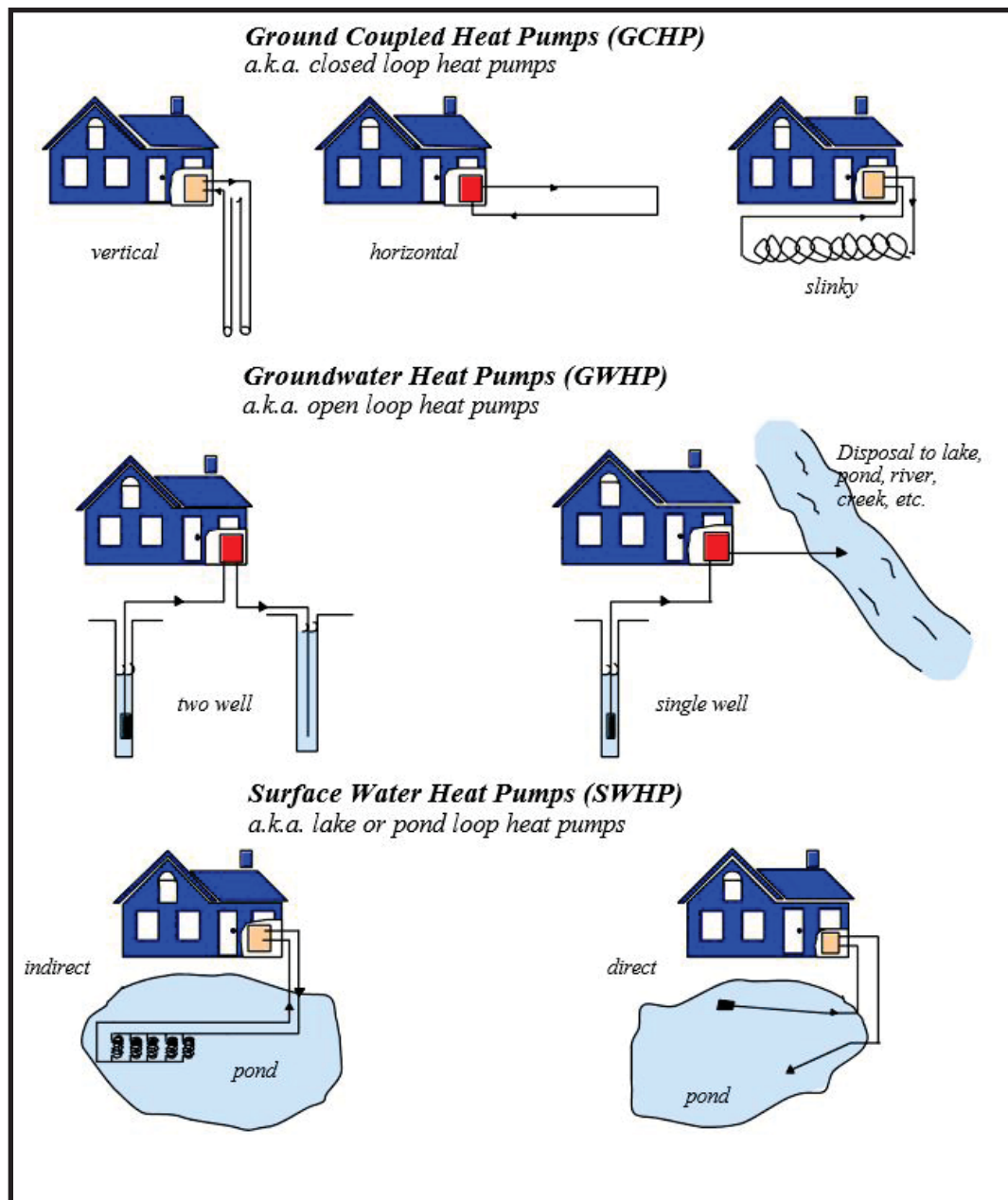
The dramatic reduction in drilling costs is possible due to the much larger thermal capacity of a flooded mine. By comparison, a geothermal heat pump system that exchanges heat with the ground in a vertical setup requires a 100 to 300 ft well to be drilled for every ton of heating/cooling; for a large system, that translate 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 requires 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.

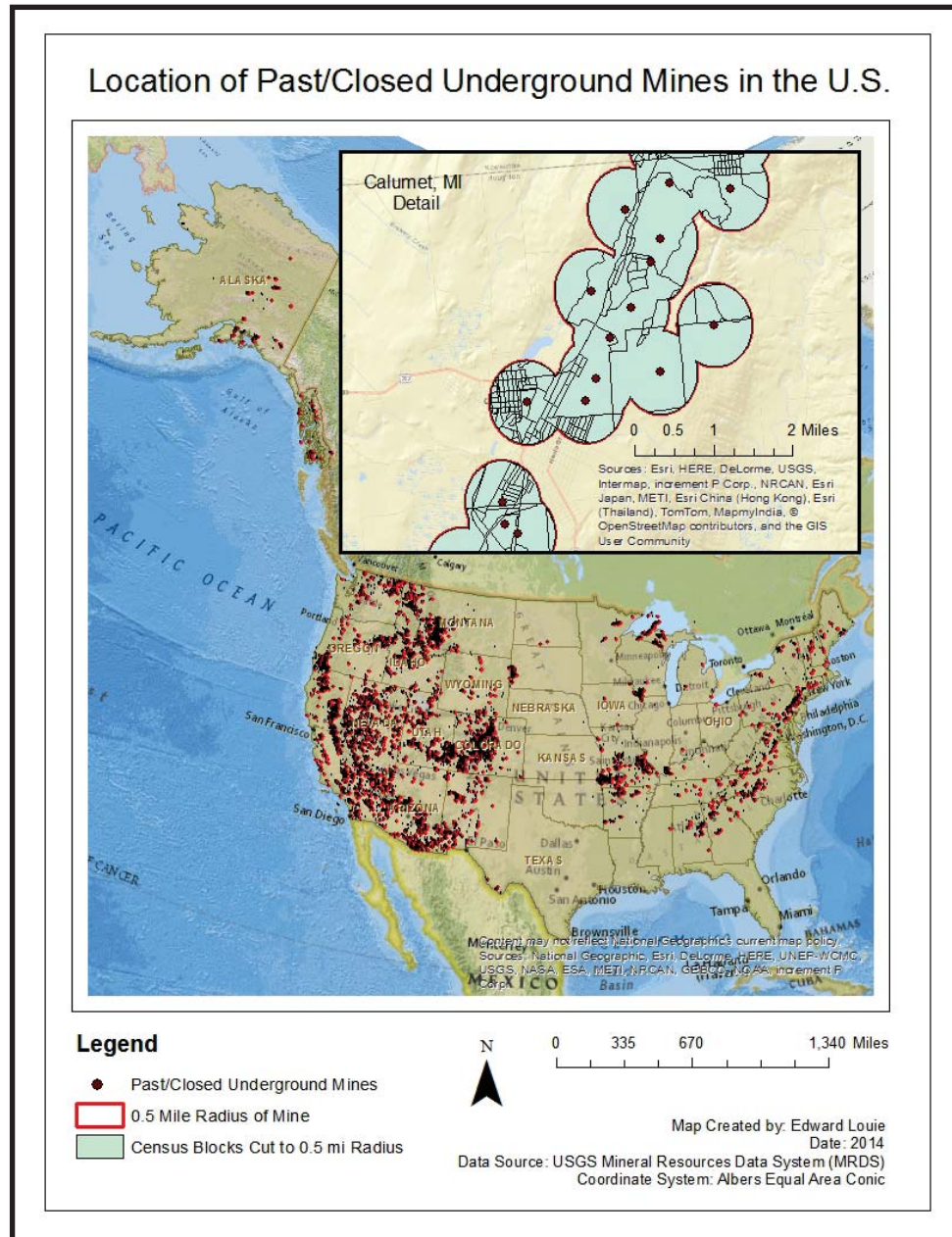
Steam boiler systems can be retrofitted with a heat pump hot water system; however, it is not recommended as heat pumps cannot concentrate heat enough to generate steam or hot water [18].

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.



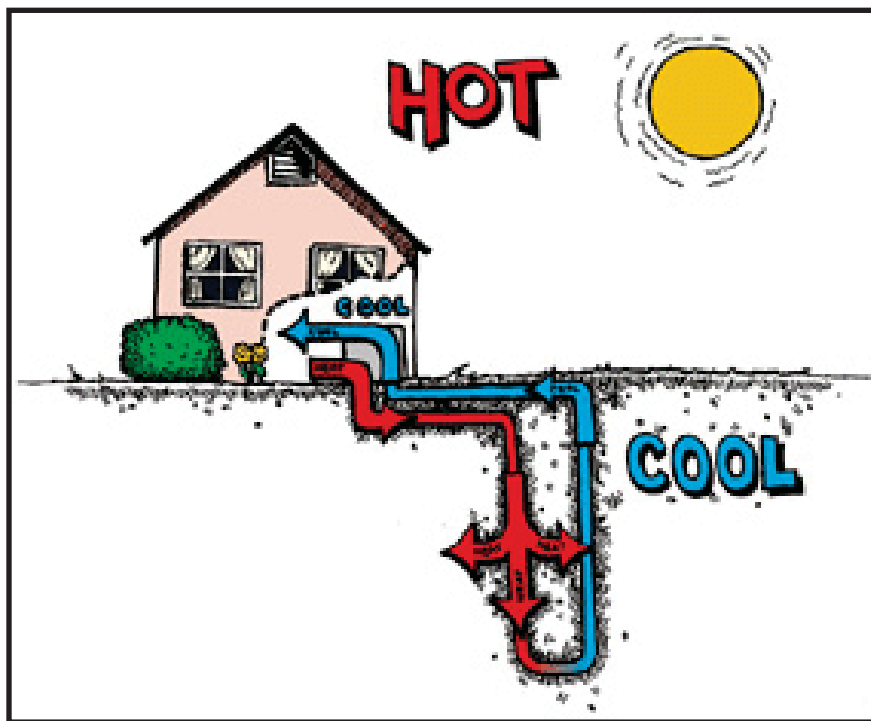
**FIGURE 4. Illustrated above is a U.S. Map of Closed/Past Underground Mines with a 0.5 mile Radius Buffer to Show Which Census Population Blocks are Within. Data Source: [7] and [9].**

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



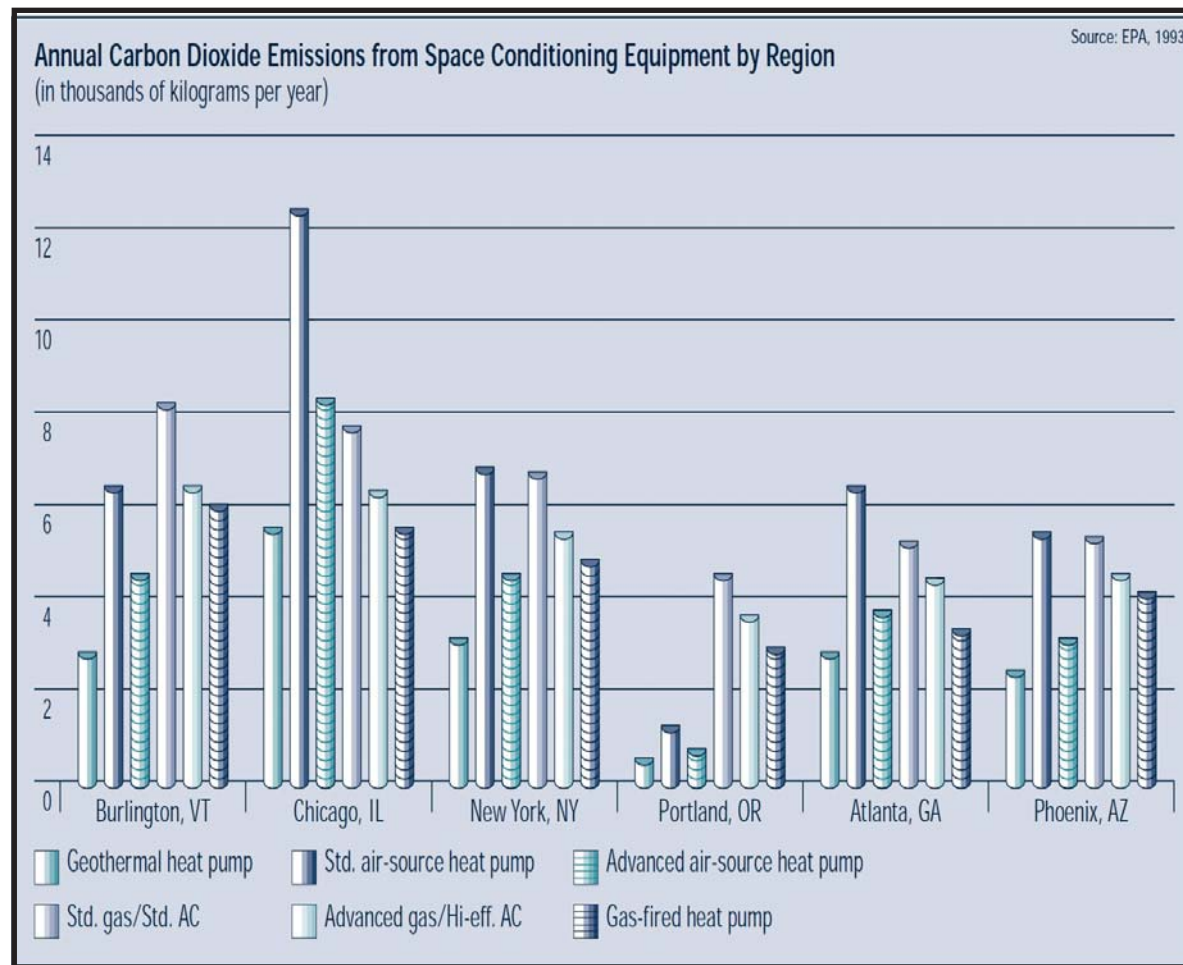
Energy is the power to do work derived from the utilization of resources to provide heat or work. Exergy is the maximum useful work possible from a resource.

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 analysis 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 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

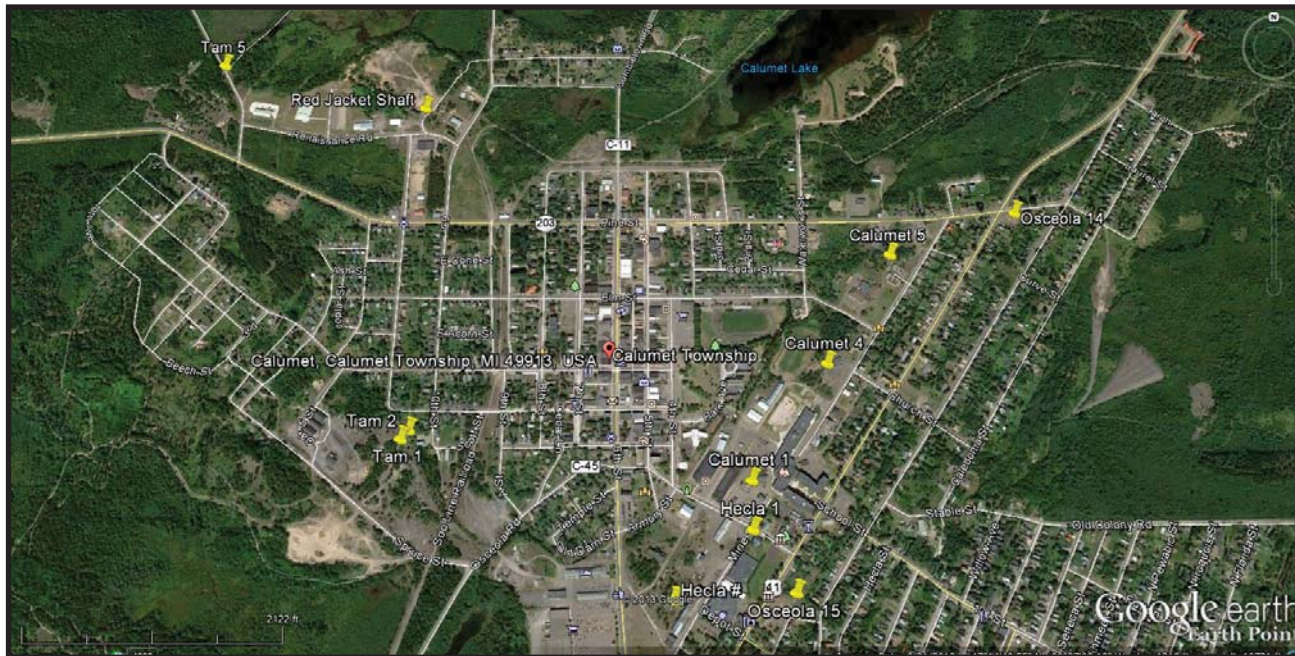


In Calumet, the location of several mine shafts was obtained from historic maps and local knowledge. The team visited shaft locations in person and took cell phone GPS readings. The GPS points were then overlaid onto a publicly available Google Map as shown in Figure 6.

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=z4tp4KtKUUVk.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.

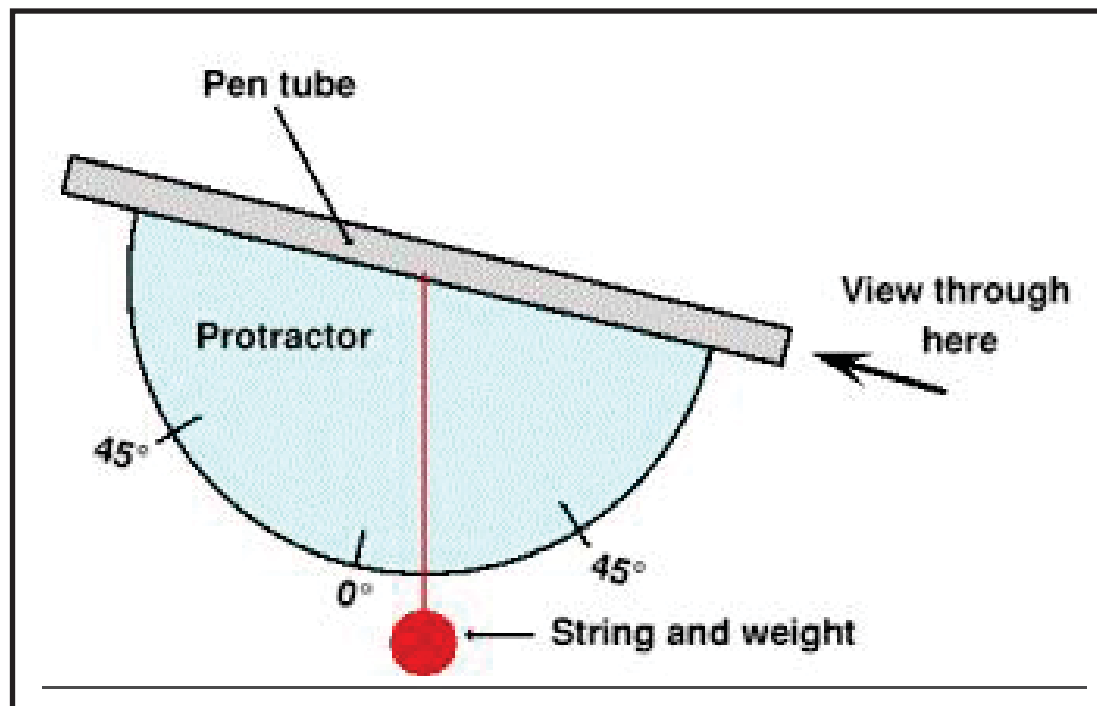


FIGURE 7. A DIY Inclinometer [25]

## 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.

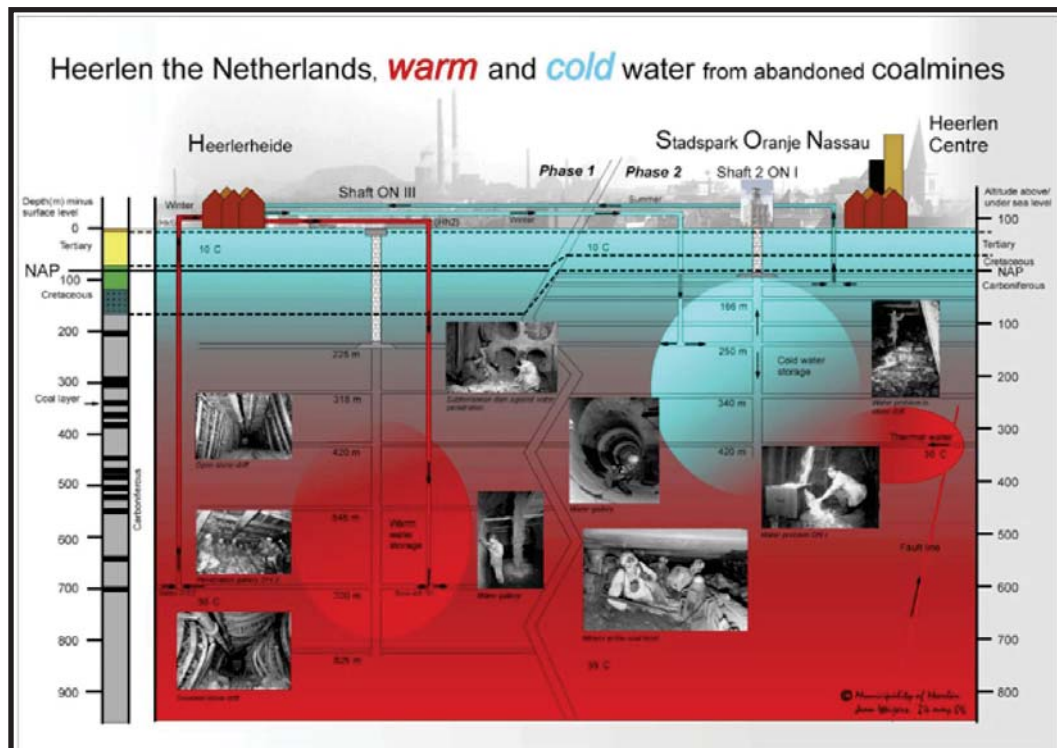


FIGURE 8. Schematic of the Heerlen mine water Geothermal System [27].



## 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](http://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 Surrrette 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.

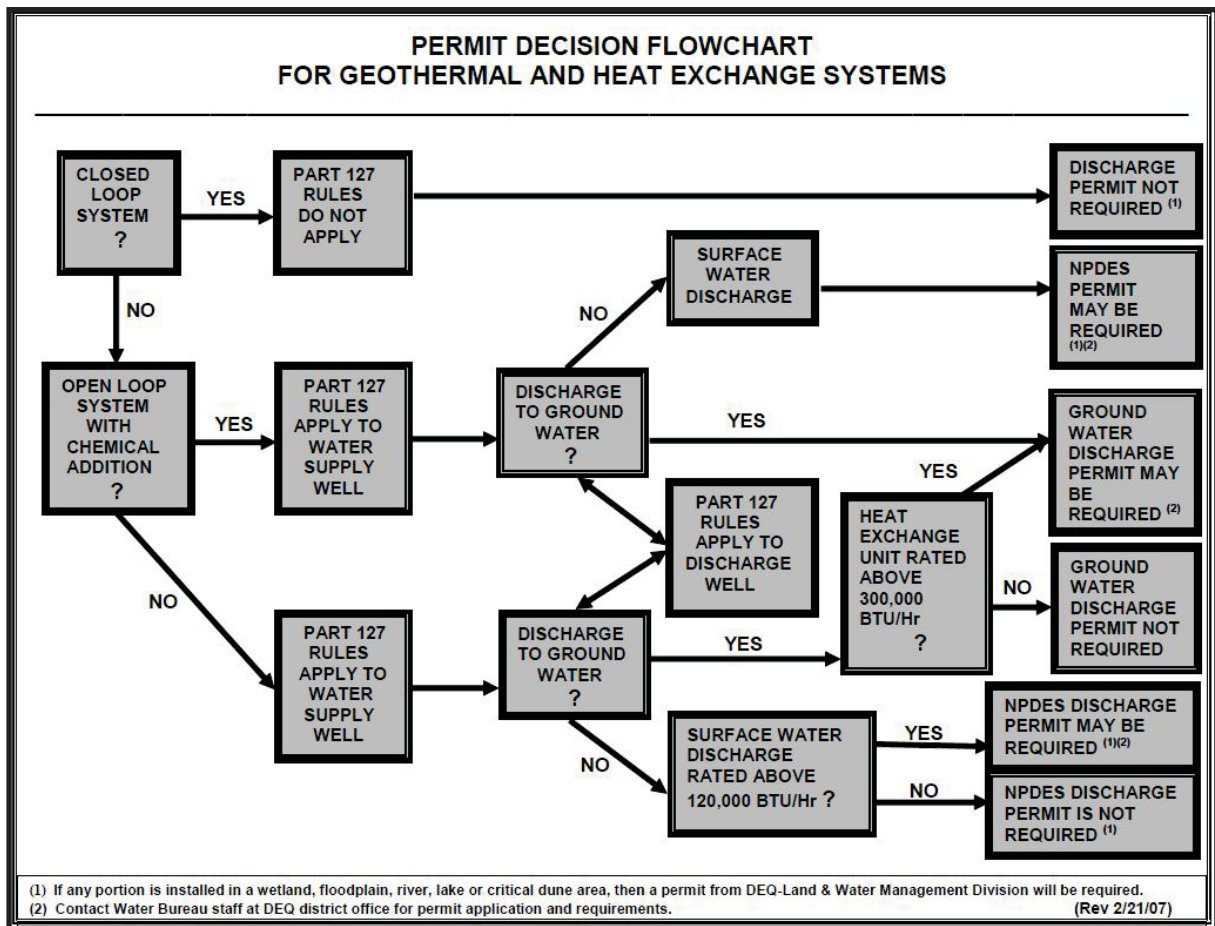
### WATER, LAND, HEAT, AND MINERAL REGULATIONS

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 CO2 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 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 The International Ground Source Heat Pump Association (IGSHPA) 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 IGSHPA 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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# Appendix

## APPENDIX A - EXAMPLES OF MINEWATER GEOTHERMAL SYSTEMS

Globally there are about 30 documented mine water geothermal systems in place. The information available for many of these systems is limited and incomplete as shown in Table 1. The lack of detailed published data is to be expected since building operators typically have no incentive to document and publish performance result or conduct economic and environmental comparisons. Installation firms also lack an incentive to conduct and publish studies if the client does not demand one.

Table 1. Documented Mine Water Geothermal Systems To Date

| Table 1. Documented Minewater Geothermal Systems To Date |             |   |                |  |                          |                          |                      |   |                        |                      |   |                          |                                |                |                            |  |
|--|-------------|---|----------------|--|--------------------------|--------------------------|----------------------|---|------------------------|----------------------|---|--------------------------|--------------------------------|----------------|----------------------------|--|
| Date   | Country     | Site Name   | System Purpose | Water Temp (F)                                   | Depth (ft)               | Pump Rate (GPM)          | Mine Type            | System Capacity   | Loop Type              | Number of Heat Pumps | Total Area Heated (ft2)                                   | Upfront Cost (\$)        | Annual Savings (\$)            | Payback period | Some Feasibility Analysis? | Literature   |
| 1979   | USA         | Radio Shack at Midway Shopping Center, Wilkes-Barre, PA               | Heat & Cool    | 56 F   | 95 ft                    | 89 gpm                   | Coal                 |   | Open, Single Well      | 1                    | 3197 ft2  |                          | 1000                           |                | No                         | (Moran, 1981) & (Schubert and McDaniel, 1982) & (Korb, 2012)   |
| 1981   | USA         | Kingston Recreation Center, Wilkes-Barre, PA                          | Heat and Cool  | 61 F   | 30 ft                    | 90 gpm                   | Coal                 |   | Open, Two Well         | 1                    | 17000 ft2   |                          | 6000 vs Gas                    |                | Yes, Water Chemistry       | (Schubert and McDaniel, 1982) & (Korb, 2012)   |
| 1980s  | USA         | First Hospital Wyoming Valley Nesbitt Memorial Health Center          | Heat and Cool  | 54 F   | 275 ft to 380 ft         | 125 gpm                  | Coal                 |   | Open, Three Well       |                      |   |                          |                                |                | Yes, Water Chemistry       | (Schubert and McDaniel, 1982) & (Korb, 2012)   |
| 1984   | Germany     | Nursing Homes in Essen-Heisingen, Germany                             | Heat           |  |                          |                          | Coal                 | 350 kW  |                        |                      |   |                          |                                |                | No                         | (Wieber and Pohl, 2008), (Hall, 2011)  |
| 1980s  | Canada      | Ropak Can-Am Ltd. Springhill, Nova Scotia, CA                         | Heat & Cool    | 64 F   | 460 ft                   | 63 gpm                   | Coal                 | 45 kW   | Open                   | 11                   | 16700   | 110,000                  | 160,000                        | <1 year        | Yes                        | (Jessop et al., 1995), (Jessop, 1995), (Mason, 2009), (CADET, 1992), (Michel, 2007), (Michel, 2008), (Martin, 2009), (Watzlaf and Ackman, 2006)      |
| 1994   | Germany     | School in Ehrenfriedersdorf, Sachsen                                  | Heat           |  |                          |                          | Tin                  | 1 School  |                        |                      |   |                          |                                |                | No                         | (Wieber and Pohl, 2008), (Hall, 2011)  |
| 1995   | USA         | Municipal Buiding in Park Hills, MO                                   | Heat & Cool    | 57 F   | 394 ft                   | 75 gpm                   | Lead                 | 112 kW  | Open, Two well         | 9                    | 8073 ft2  | 132,400                  | 4,800                          | 4.6            | No                         | (GeoExchange, 2002), (Ohio DNR, 2011), (Hall, 2011), (Watzlaf and Ackman, 2006)  |
| 1997   | Germany     | Mining Museum Visitor Center in Ehrenfriedersdorf, Sachsen, Germany   | Heat           |  |                          |                          | Tin                  | 82 kW, Museum   |                        |                      |   |                          |                                |                | No                         | (Wieber and Pohl, 2008)  |
| 1998   | Norway      | Wormshall Cavern, Concert and Banquet Hall in Hedmark County          |                |  | 1970 ft                  |                          | Copper, Zinc, Sulfur |   | Closed                 | 1                    |   |                          |                                |                | No                         | (Hall, 2011)   |
| 1999   | Scotland    | Housing Redevelopment Project in Shettleston                          | Heat           | 54-64F   | 328 ft                   |                          | Coal                 | 16 Houses, 65 kW  |                        | 2                    |   |                          | 60% saving                     |                | No                         | (John Gilbert Architects, 1997)  |
| 2000   | Scotland    | Housing Redevelopment Project in Lumphinnans                          | Heat           | 57 F   | 558 ft                   |                          | Coal                 | 18 Houses   |                        |                      |   |                          | 75% saving                     |                | No                         | (John Gilbert Architects, 2004)  |
| 2004   | Canada      | Dr. Carson and Marion Murray Community Centre Springhill, Nova Scotia | Heat & Cool    | 68 F   |                          |                          | Coal                 | 96 Tons   | Open Loop, Two Well    | 8                    | 390,000 ft2   |                          | 60% Saving, 100,000 to 135,000 | 5              | Yes                        | (Michel, 2007), (Michel, 2008), (Michel, 2009), (Mason, 2009), (McDiarmid, 2007), (Noble, 2012), (Kube Solution, 2004)                               |
| 2006   | Germany     | Zollverein Cube Building in Essen-Katernberg                          | Heat           | 86 F   | 3280 ft                  |                          | Coal                 | School of Design Building, 790 kW                       | Open Loop              |                      |   |                          |                                |                | No                         | (Thien, 2015), (Zanger-Sned Architects, 2008)  |
|  | USA         | John Wesley Church, Pennsylvania                                      | Heat and Cool  |  |                          | 75-100 gpm, free flowing | Coal                 |   |                        |                      | 2400 ft2 with an additional 40,000 ft2 of unused capacity |                          | 80% on Heating, 50% cooling    |                | No                         | (Burtner, Cairns, and Cash, 2009), (Ohio DNR, 2011), (PA Environment Digest, 2009)   |
| 2006   | Canada      | 36 Luxury Apartment Condos in Quebec                                  | Heat & Cool    | 56.6 F   | 0                        |                          |                      | 1 Church  | Open Loop              |                      |   | 80,891                   |                                | 50%            | No                         | (Raymond, Therrien, and Hassani, 2008)   |
|  | Germany     | Swimming Pool Heat and Supplemental District Heat in Shachsen         | Heat           |  |                          |                          | Uranium              | 1 swimming pool + 690 kW supplement to district heating | Open                   |                      |   | 6039                     |                                | 50%            | No                         | (Raymond, Therrien, and Hassani, 2008)   |
| 2007   |             |   |                | 54 F   | 472 ft                   | 528 gpm                  |                      |   | Closed                 |                      |   |                          |                                |                | No                         | (Matthas and Schreyer, 2007), (Hall, 2011)   |
| 2008   | Netherlands | Heerleen, Netherlands   | Heat & Cool    | 82 F Hot Well, 61 F Cold Well, 64-72 F Warm Well | 2300 ft, 820 ft, 1150 ft | 1057 gpm Hot, 2025 Cold  | Coal                 | 700 kW up until 2012                                    | Open                   | Many                 | 560,000 ft2 total in 2012, 5 million ft2 by 2015          | 57 Million Euro, Phase I | 70% Energy Savings             |                | Yes                        | (Op 't Veld and Demolin-Schneiders, 2007), (Op 'tVeld, Cauberg-Huygen, and Maastricht, 2008), (Santer, 2008), (Verhoeven et al., 2013), (VITO, 2012) |
| 2008   | UK          | Kensa Engineering Offices   | Heat           |  |                          |                          | Tin                  | 20 kW   | Closed Loop            |                      |   |                          |                                |                | No                         | (Preece and Younger, 2014), (Younger, 2013)  |
| 2009   | USA         | Marywood University   | Cool           | 55 F   | 340 ft                   |                          | Coal                 |   | Open Loop, Two Well    |                      |   | 130,000                  |                                |                | No                         | (Korb, 2012), (Hall, 2010), (Legere, 2014)   |
| 2009   | Russia      | District Heating System in Novosibirsk                                | Heat           | 55 F   | 164 to 500 ft            |                          | Coal                 | 10.9 MW   | Open Loop              | 3                    |   | 11 Million Euro          |                                |                | No                         | (UNFCCC, 2007)   |
| 2009   | Germany     | Castle Freudenstein, Freiberg   | Heat & Cool    | 50 F   | 200 ft                   | 57 gpm                   | Coal                 | 160-180 kW Heating, 120 kW Cooling                      | Open Loop, Single Well | 1                    |   |                          |                                |                | No                         | (Kranz and Dillenardt, 2010)   |
| 2010   | Spain       | University of Oviedo  | Heat and Cool  | 68-77 F  | 230 ft                   |                          | Coal                 | 3.7 MW  | Open Loop              |                      |   |                          | 75% Energy Savings             |                |                            | (Loredo et al., 2011), (HUNOSA, 2015), (HUNOSA, 2014), (Op 't Veld, 2012)  |
| 2010   | USA         | Keveeaw Research Center in Calumet, MI                                | Heat & Cool    | 53 F   | 300 ft                   | 75 gpm                   | Copper               | 129 kW  | Open Loop, Single Well | 14                   | 10,000 ft2  |                          |                                |                | No                         | (Osborne, Green, and Meldrum, 2013, Personal Communications)   |
| 2010   | Germany     | 4 Residential buildings in Auguste Victoria                           | Heat & Cool    |  | 560-2300 ft              |                          | Coal                 |   | Closed                 | 4                    |   |                          |                                |                | No                         | (Bracke and Bussmann, 2015), (Thien, 2015)   |
| 2011   | UK          | Coal Authority Office Buildings                                       | Heat           | 68 F   |                          | 24 gpm                   | Coal                 | 12 kW   |                        |                      |   |                          |                                |                | Yes, Water Chemistry       | (Banks, 2013), (Preece and Younger, 2014), (Younger, 2014)   |
| 2012   | Germany     | Small District Heating "Robert Muser" Project                         | Heat           | 68 F   | 1870 ft                  | 419 gpm                  | Coal                 | 4.5 MW  | Open Loop              | 11                   |   |                          |                                |                | No                         | (BINE, 2013), (Thien, 2015)  |
| 2013   | Germany     | Freiberg University of Mining and Technology                          |                | 64 F   | 750 ft                   | 247 gpm                  | Coal                 | 260 kW  |                        |                      |   |                          |                                |                | No                         | (Bracke and Bussmann, 2015)  |
| 2014   | Spain       | Mieres Hospital   | Heat & Cool    |  |                          |                          |                      |   |                        |                      |   |                          | 70% Energy Savings             |                | Yes                        | (HUNOSA, 2015), (HUNOSA, 2014)   |

## APPENDIX B - COMMUNITY PLANNING TOOLS

The following resources and websites may help your community through the participatory planning process.

### *A New Model: Participatory Planning for Sustainable Community Development*

This website is maintained by the Race, Poverty and the Environment journal. The link brings you to a page that outlines what participatory planning is and the various steps involved in the process. The website also has other resources regarding race, poverty and the environment.

<http://reimaginepe.org/node/920>

### *Community Tool Box*

The community tool box is an online resource center for those interested in social change. Among the resources on the site is the following link, which provides information on strategic planning and developing a vision statement.

<http://ctb.ku.edu/en/table-of-contents/structure/strategic-planning/vision-mission-statements/main>

### *Community Planning.net*

Another online clearinghouse of information related to community planning, this site has several guides and checklists available for download.

<http://www.communityplanning.net/useful/checklists.php>

### *Asset-based Development*

Traditionally, community development projects were developed by conducting needs assessments. These assessments focused on what communities were lacking and took a problem solving approach to community development. Increasingly, asset-based development is being used as a tool to develop community projects. This approach focuses on building on the strengths of a community. Instead of asking the question "what do we need" it asks "what do we have"? The aim of this approach is to develop a collaborative environment within a community.

Some elements of asset-based development are community asset mapping, community institutions reviews, infrastructure assessments, and community skills survey.

### *Community asset mapping*

This can be the development of a physical map that highlights important landmarks in a community. These landmarks can include schools, churches, hospitals, a popular restaurant, parks, etc. This tool can also be used to identify opportunities for growth.

The following are resources on community mapping:

#### *Equitable Development Toolkit: Community Mapping*

<http://www.policylink.info/EDTK/Mapping/>

#### *Strengthening Community Education: The Basis for Sustainable Renewal Mapping Community Assets Workbook*

[http://www.abcdinstitute.org/docs/Diane%20Dorfman-Mapping-Community-Assets-WorkBook\(1\)-1.pdf](http://www.abcdinstitute.org/docs/Diane%20Dorfman-Mapping-Community-Assets-WorkBook(1)-1.pdf)

#### *Center for Community Mapping*

<http://www.centerforcommunitymapping.org/>

#### *Community Resource Mapping: A Strategy for Promoting Successful Transition for Youth with Disabilities*

<http://www.ncset.org/publications/viewdesc.asp?id=939>

#### *Community Tool Box: Geographic Information Systems: Tools for Community Mapping*

<http://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/geographic-information-systems/main>

### *Community Institution Reviews*

This is a process a community can undertake to better understand the institutions that exist in a community, the services and resources they provide, and important contact information. Community institutions may include schools, food banks, churches, non-profits, etc.

### *Infrastructure Assessment*

This is a process a community would undertake to better understand their existing infrastructure. This would include looking at the conditions of sewage systems, roads and other transportation systems, parks, etc. This is also important to undertake as new development may impact existing infrastructure.

### *Community Skills Survey*

This is an assessment tool that could be conducted at the neighborhood level. This process would develop a map of an area indicating the skill sets of residents of the area. Skills may include plumbing, sewing, childcare, etc.

### *Oral Histories*

Oral history collects information about the past from observers and participants living during that time. It gathers data not available in written records about events, people, decisions, and processes. The following links offer suggestions on how to perform oral history interviews. Involving students and various community members in this process is highly recommended.

#### *ORAL HISTORY TECHNIQUES: How to Organize and Conduct Oral History Interviews from Indiana University*

[http://www.indiana.edu/~cshh/oral\\_history\\_techniques.pdf](http://www.indiana.edu/~cshh/oral_history_techniques.pdf)

#### *Step-by-Step Guide to Oral History by Judith Moyer*

[http://dohistory.org/on\\_your\\_own/toolkit/oralHistory.html](http://dohistory.org/on_your_own/toolkit/oralHistory.html)

#### *East Midlands Oral History Archive: Information Sheet #2; Conducting an oral history interview*

<http://www.le.ac.uk/emoha/training/no2.pdf>

#### *Grosse Pointe Historical Society: Sample Questions To Conduct An Oral History Interview*

<http://www.gphistorical.org/pdf-files/oralhistory.pdf>

#### *Guidelines for Oral History Interviews: The History Channel Student Workbook (adapted from Michael Gatto)*

<http://www.history.com/images/media/interactives/oralhistguidelines.pdf>

*Pennsylvania Historical and Museum Commission: Steps for Conducting An Oral History Interview*

[http://www.portal.state.pa.us/portal/server.pt/community/oral\\_history/4351/conducting\\_an\\_oral\\_history\\_interview/445230](http://www.portal.state.pa.us/portal/server.pt/community/oral_history/4351/conducting_an_oral_history_interview/445230)

*Community Development Indicators*

Although development indicators are unique to each community, it may be helpful to know that most indicators fall under four basic categories: sustainability, quality of life, performance evaluation and healthy communities. The links below offer examples of community development indicators as well as factors to consider while deciding which indicators are relevant for your community.

*American Planning Association: Community Indicators*

<http://www.seachangeop.org/sites/default/files/documents/2006%2009%20APA%20-%20Community%20Indicators.pdf>

*Community Tool Box: Community-Level Indicators: Some Examples*

<http://ctb.ku.edu/en/table-of-contents/evaluate/evaluate-communitarity-initiatives/examples-of-community-level-indicators/main>

*Sustainable Measures: Sustainable community indicator checklist*

<http://www.sustainablemeasures.com/node/94>

*Ownership Structures/funding resources*

As mentioned in the body of the guide book, there are a number of organizations that may exist that can help the planning team develop ownership models.

These include local community economic development corporation (CEDC), community development foundations (CDFs), small-business association (SBA), or a university extension offices. You can learn more about these resources by following the links below.

### *Community-wealth.org: Overview: Community Development Corporations (CDCs)*

This site includes a number of resources related to community-based economic development. This link will bring you to the site on Community Development Corporations. To find a CDC in your area, do an internet search on "Community Development Corporations" and your state/locality.

<http://community-wealth.org/strategies/panel/cdcs/index.html>

### *Charles Stewart Mott Foundation: Community Foundations*

Good overview of the basics of a community foundation: a non-profit organizations that use local resources to meet local needs. Also includes resources on community philanthropy.

<http://www.mott.org/FundingInterests/Issues/Community%20Foundations>

### *The Community Foundations National Standards Board*

Another site with overview information on Community Foundations. Includes a link to find local CFs.

<http://www.cfstandards.org/about-community-foundations>

### *US Small Business Administration: Local Assistance*

The SBA assists small businesses through loans, loan guarantees, contracts, counseling session and more. To find a local office, use the following link:

<https://www.sba.gov/tools/local-assistance>

### *Cooperative Extension Offices*

Your local cooperative extension office may provide economic development assistance.

### *Northwest Cooperative Development Center*

A nonprofit organization located in Portland, OR that supports cooperatives in Oregon, Washington, Idaho and Hawaii. You can also learn about co-ops from their site.

<http://nwcdc.coop/>

### *The University of Wisconsin Center for Cooperatives*

Comprehensive resource center on all aspect of co-ops, from planning to managing and everything inbetween.

<http://www.uwcc.wisc.edu/>

### *Cooperative Network*

Information and resources on co-op in Wisconsin and Minnesota.

<http://www.cooperativenetwork.coop/>

### *USDA: Rural Business-Cooperative Service*

Offering programs and services to support business development in rural areas.

<http://www.rd.usda.gov/about-rd/agencies/rural-business-cooperative-service>

### *Community Development Block Grant Program - CDBG*

"The CDBG program works to ensure decent affordable housing, to provide services to the most vulnerable in our communities, and to create jobs through the expansion and retention of businesses. CDBG is an important tool for helping local governments tackle serious challenges facing their communities. The CDBG program has made a difference in the lives of millions of people and their communities across the Nation."

[http://portal.hud.gov/hudportal/HUD?src=/program\\_offices/comm\\_planning/communitydevelopment/programs](http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopment/programs)

### *Socially Conscious Banking*

As an alternative to the conventional model of banks working with big businesses to offer conventional products, a new idea is taking root that focuses on community-based businesses, responsible consumers and environmental commitment. Learn more about a model from the West Coast here:

Beneficial State Bank

<http://onepacificcoastbank.com/history.aspx>

### *Social Financing*

There is a growing movement to address social issues through a business perspective. This approach is known as "social financing", "social enterprises", or "social entrepreneurship". More information on this emerging financing model can be found below:

### *Center for Social Innovation: Community Bond*

A Community Bond is an alternative funding mechanism for non-profits.

<http://communitybonds.ca/community-bond/>

*AP Social Financing: Social Finance 101*

A summary of the various terms and definitions found in the field of social financing.

<http://apsocialfinance.com/social-finance-101/>

*AP Social Financing: Social Financing Resources*

<http://apsocialfinance.com/>

## APPENDIX C - EDUCATION OPPORTUNITIES

### *Adventures with Iggy*

[http://www.igshpa.okstate.edu/publication/edu\\_outreach.htm](http://www.igshpa.okstate.edu/publication/edu_outreach.htm)

### *United States Department of Energy*

United States Department of Energy Office of Energy Efficiency and Renewable Energy has created a document outlining definitions and facts about geothermal energy and provide instructions for five different in-class activities for students in grade 5 through 8. This document also contains links for further educational resources.

[http://www1.eere.energy.gov/education/pdfs/geothermal\\_energy.pdf](http://www1.eere.energy.gov/education/pdfs/geothermal_energy.pdf)

The Department of Energy (DOE) has an Energy Education and Workforce Development website designed to educate people of all ages about energy efficiency and renewable energy. It contains K-12 lesson plans and activities as well as clean energy jobs and career planning.

<http://www1.eere.energy.gov/education/lessonplans/>

### *Oral histories*

Oral history collects information about the past from observers and participants living during that time. It gathers data not available in written records about events, people, decisions, and processes. The following links offer suggestions on how to perform oral history interviews. Involving students and various community members in this process is highly recommended.

[http://www.indiana.edu/~cshm/oral\\_history\\_techniques.pdf](http://www.indiana.edu/~cshm/oral_history_techniques.pdf)

[http://dohistory.org/on\\_your\\_own/toolkit/oralHistory.html](http://dohistory.org/on_your_own/toolkit/oralHistory.html)

<http://www.le.ac.uk/emoha/training/no2.pdf>

<http://www.gphistorical.org/pdf-files/oralhistory.pdf>

<http://www.history.com/images/media/interactives/oralhistguidelines.pdf>

[http://www.portal.state.pa.us/portal/server.pt/community/oral\\_history/4351/conducting\\_an\\_oral\\_history\\_interview/445230](http://www.portal.state.pa.us/portal/server.pt/community/oral_history/4351/conducting_an_oral_history_interview/445230)

*National Environmental Education Week*

National Environmental Education Week (EE Week) is the nation's largest celebration of environmental education. It is held each spring around the time as Earth Day and inspires environmental learning and stewardship among K-12 students. Although this website does not specifically address minewater geothermal, it does offer inspiring ideas for activities and educational opportunities that are generally informative and beneficial and can be adapted to fit your needs.

<http://www.eeweek.org/ee-week>

## APPENDIX D: LOW-COST/DIY STRATEGIES FOR ASSESSING WATER QUALITY

Water quality data can be difficult to ascertain due to the depth and conditions of the shafts. In addition, on the shelf equipment designed to survey and sample such environments can be too expensive, complicated, or suboptimal for the task at hand. As a result the authors of this guidebook have devised some low-cost instruments for surveying and obtaining water samples from mine shafts using commonly accessible equipment. The following table of instruments and instructions on when and how to use each one has been developed as a starting point for you to modify for your situations. While this guidebook contains a number of creative solutions/strategies on how to obtain water quality data from depth, they are by no means the only or necessarily the best solutions. The planning team should make it a goal to brainstorm better ways to collect the desired water quality data and share success stories with the public at large.

### *Temperature at depth*

A fishing reel with a line counter can be used to measure the depth.

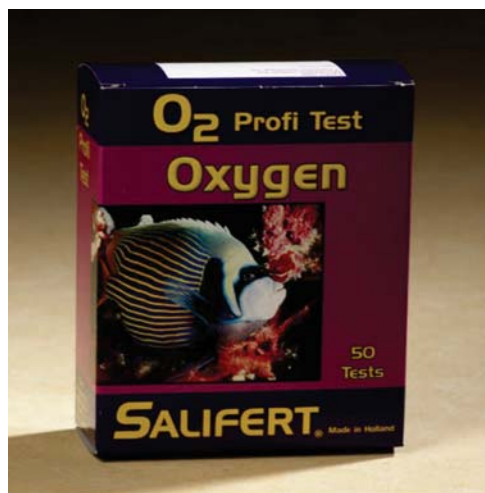


*Submersible Thermometer*

\$370

*Dissolved Oxygen*

\$20 Test kit

*pH*

\$4 Test Kit

*Hydrogen Sulfide*

\$45 Test Kit



## *Water Hardness*

\$5 Test Kit



## *Angles*



## APPENDIX E - MINE SHAFT ASSESSMENT WORKSHEET

| NAME OF MINESHAFT              | DESCRIPTION  |
|--------------------------------|--|
| Date and time of the survey    |  |
| Names of people on team        |  |
| Equipment check list           | 1. Phone <input type="checkbox"/> 2. Hiking boots <input type="checkbox"/> 3. Work gloves <input type="checkbox"/> 4. Hard Hat <input type="checkbox"/> 5. Shock cord and or rope <input type="checkbox"/><br>6. Flashlight <input type="checkbox"/> 7. Note pad <input type="checkbox"/> 8. Camera <input type="checkbox"/> 9. Map or GPS <input type="checkbox"/> 10. Tape measure <input type="checkbox"/> 11. Inclinator <input type="checkbox"/><br>12. Fishing rod <input type="checkbox"/> 13. Towels <input type="checkbox"/> 14. Marks <input type="checkbox"/> |
| Date of the weather condition  |  |
| Incline of mineshaft           |  |
| Accessibility to the mineshaft |  |
| Debris in the mineshaft        |  |
| Record measurements            |  |
| Miscellaneous                  |  |
| Survey time ending             |  |

ILL 4. Spreadsheet for taking field notes and data (a copy enhancement from the AEE team)

## APPENDIX F WATER CHEMISTRY

### *Water Chemistry*

Analysis of the mine water chemistry is important if an open loop system is to be considered.

Some of the water quality data described in this section requires access to a local certified water lab. The closest water quality lab can be located via searching the internet with your state and the term “certified water laboratory”, almost always your state’s department of public health or department of environmental protection/quality will have a list of certified water analysis laboratories to contact. The lab will or can provide two containers typically a 16 ounce plastic bottle and a 4oz. sterile plastic container and a tablet that contains preservatives and a chlorine inhibitor for the 4oz bottle. The water in the larger container will be used to test for everything but bacteria. Samples must be brought to the lab within 24 hours if bacteria or nitrate/nitrite testing is to be conducted [1]. Thus it is also important to time the water sampling on a weekday during a time when the lab is open.

A complete batch of water quality tests from a certified lab can costs hundreds of dollars and the turnaround time for the results is usually a week’s time. Some water quality parameters that the lab will report can be determined quicker yourself. The pH is one such parameter, pH test strip can be found at pet stores (aquarium supplies) and the pool supply section of some department stores. They are inexpensive and give instant results. Simply dip the test strips in the water and watch the color change. Compare the color change to the chart that is provided from the pH testing kit. Additional ideas and resources on low cost water quality testing equipment can be found in Appendix D: Low-Cost/DIY Strategies for Assessing Water Quality.

Obtaining a surface sample of minewater is easy if it is visible and near the surface however more often than not, specialized equipment is needed to retrieve a sample. A Kemmerer sampler is likely the best tool for collecting a water sample at varying depths in a vertical mine shaft. Like a temperature logger, a Kemmerer sampler is quite expensive, usually in the hundreds of dollars.

However unlike a temperature logger, there may not be an easy to make homemade alternative to purchasing one. As a result it is best to evaluate the condition of the mine shafts prior, to determine whether a Kemmerer sampler is a viable option for obtaining water samples since sliding the sampler down the side of a mineshaft will stir up debris and give a nonrepresentative water 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, as shown in Figure 1.



*Figure 1. A Kemmerer sampler after it has been triggered by the messenger. [2]*

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. The following video [3] by the California Environmental Protection Agency demonstrates how to use a Kemmerer device.

The feasibility of using the water in the mine shaft for an open loop geothermal setup can be assessed by analyzing the chemical characteristics of the water. These water chemistry analysis can determine characteristic such as the acidity and hardness of the water. Some of these characteristics can be measured directly while others are determined indirectly through proxy indicators.

Relevant water chemistry characteristics include measures of pH, salinity, hardness, dissolved gas, and suspended solids. Recommended maximums or range values will be provided. If the test results indicate values in excess or outside the range, corrosion resistant materials may be required to reliably operate an open loop geothermal setup. Alternatively a close loop system setup would be chosen.

In some communities the mine water is already being used in some way such as drinking water. In these cases, it is important to prevent changes to the mine water chemistry which would impact these other uses.

Obtaining a measure of the water conditions prior to installing a system is important for tracking any changes. More details about each of these water characteristics and its implications on costs and system configuration are described below.

### *PH*

PH is a scale that measures the acidity or alkalinity of water. The scale runs from 0 to 14, where 7 is considered neutral (neither acidic nor alkaline). The pH of the water affects how corrosive the mine water is and whether an open loop system is possible. Water that is acidic (pH of 6 or less) will corrode metal surfaces and so will corrode the inside of a pump or heat exchanger more quickly than alkaline water. If the water is highly acidic (less than 4), the community needs to decide whether the extra capital cost for more corrosion-resistant materials for pumps and heat exchangers is worth the avoided costs of frequent maintenance or decide to installed a closed loop system in order to protect lower-cost pumps and heat exchangers that are not equipped with corrosion resistant parts [4]. The rate corrosion is greatly multiplied when aggressive ions such as chloride and/or iron are present in the water in concert with a low pH [5].

### *Salinity*

Salinity is a measure of the saltiness of a solution. The salt in mine water comes from water dissolving certain minerals in the bedrock of the shaft. Saltwater corrodes metals much faster than freshwater. Corrosion is a process that happens when dissolved salts - electrically charged atoms or groups of atoms - speed up electron transfers between themselves and metals. These electron transfers weaken metals however some metals are more resistant to these effects than others.

Careful selection of materials can go a long way to mitigating corrosion problems. Using elements made out of high grade stainless steel, bronze or titanium will increase corrosion resistance. Salinity can be measured in terms of parts per million (ppm), milligrams per liter (mg/l) or grams per liter (g/l) or by its electrical conductivity measured in millisiemens per centimeter ( $\mu\text{S}/\text{cm}$ ). A salinity higher than 30  $\mu\text{S}/\text{cm}$  (15 ppm or 15 mg/l) warrants parts designed to operate in saltwater conditions (seawater has a salinity of 50,000  $\mu\text{S}/\text{cm}$ ) or a closed system with pipes that will last in saltwater conditions [6].

Titanium for example experiences almost no corrosion at even saturated levels of various chloride solutions [7]. The mine water in Heerlen, the Netherlands has a very high chloride concentration of 18,800 mg/l [8]. The titanium heat exchangers installed in 2008 are still operating problem free today [8].

### Hardness

Hard water is water that has high mineral content. Some people may be familiar with the effects of hard water when it causes build-up on shower walls, faucets, and spots on the car after washing. Mine water can gain hardness as it contacts and dissolves calcium and magnesium contained in the bedrock of mine shaft. Hard water can form deposits called “scale” that can clog the pipes, pump, and heat exchanger of an open loop geothermal system. Water hardness is quantified in milligrams per liter (mg/l), parts per million (ppm), or grains per gallon (grains/gal). Table 1 is a chart for hardness classification. If the mine water is hard or very hard, a closed system is recommended to prevent costly recurring maintenance and breakdowns.

*Table 1: Hardness scales [9]*

| <b>Classification</b> | <b>Level<br/>(mg/l or ppm)</b> | <b>Level<br/>(grains/gal)</b> |
|-----------------------|--------------------------------|-------------------------------|
| Soft                  | 0-17.1                         | 0-1                           |
| Slightly Hard         | 17.1-60                        | 1-3.5                         |
| Moderately Hard       | 60-120                         | 3.5-7.0                       |
| Hard                  | 120-180                        | 7.0-10.5                      |
| Very Hard             | 180 & over                     | 10.5 & over                   |

The amount of calcium and magnesium that can be dissolved in the water is also dependent on the pH and temperature. Warmer and more acidic waters can dissolve more minerals and therefore can have higher hardness [10]. The hardness of the water can be very different from location to location and at different depths thus it is necessary to take specific measurements [11].

### Dissolved Gases

Dissolved gas is the combination of gas and water. The carbonation found in beverages like soda is an example of a dissolved gas. Dissolved gases are usually measured in either mg/l or ppm. The four dissolved gases frequently found in mine water are: carbon dioxide, methane, hydrogen sulphide, and oxygen. The most disconcerting dissolved gases are oxygen and hydrogen sulphide as they can contribute to corrosion. It is important to measure dissolved gas levels because sometimes the mine water has no dissolved oxygen to start, but the installation of an open mine water geothermal system could introduce dissolved oxygen into the mine water. In this scenario, problems like corrosion or the formation of biological growth of algae can occur.

### *Suspended Solids*

Suspended solids are small solid particles that are mixed throughout the water and do not readily sink to the bottom. Most minewater contains a high degree of suspended solids. These suspended solids come from many sources, including dust and debris left over from mining, chemical reactions that cause mineral precipitation, and biological growth.

Suspended solids can clog pumps and coat heat exchangers with a film that can reduce performance. The amount of suspended solids in the water can be stated in two ways: turbidity and total suspended solids (TSS). Turbidity is a quick but less accurate measure of suspended solids. It estimates the amount of suspended solids by the amount of light scattered by suspended particles. Turbidity is measured in units of Nephelometric Turbidity Units (NTU) [12]. TSS measures all suspended solids in the water by mass with units of mg/l.

The composition of the suspended solids can also be analyzed. The characterization of the suspended solids is as important as the amount of suspended solids. Traditional well pumps can handle a small amount of suspended solids especially if they are not abrasive in nature.

Mine water often contains high levels of abrasive suspended solids. Suspended coal dust is highly abrasive and will quickly wear out a traditional submersible well pump. If this is found in high concentrations, an open loop system may still be viable if the pump is carefully selected. A submersible drainage or slurry pump designed for sewage or mining applications should be selected instead of a well water pump. The added cost of these pumps could warrant moving to a closed loop system configuration [13] [14].

A water quality lab will conduct tests which will measure the above water chemistry characteristics directly and indirectly. The water quality report from the lab may be difficult to interpret. Table 2 contains the parameters and terms frequently found in a typical report and explains the meaning and significance of different values that are relevant for developing a mine water geothermal system. Ranges or maximum recommended values are included for parameters that can impact the longevity of an open loop system.

The table also explains how the values contribute to pH, salinity, hardness, and suspended solids described above. For a direct example of how to interpret water quality test results, Appendix F includes a report for samples collected from mine shafts in Calumet, MI.

*Table 2: Description of Common Parameters Found in a Water Quality Lab Test Result With Value Ranges Relevant to Mine Water Geothermal*

### *Heat Pump Setups*

#### Parameters

#### Descriptions

1

#### Carbonate & Bicarbonate Alkalinity

Carbonate and bicarbonate anions contribute to alkalinity meaning they have the ability to neutralize acid. This would not have an effect on the system.

2

#### Chloride

Chloride is sometimes found in concert with sodium, the combination is commonly known as table salt. The presence of chloride in even low concentrations (10s of ppm) accelerates a condition called pitting corrosion to many metals including steels, stainless steels, aluminum, and aluminum alloys when in constant contact with the water. Bronze and titanium are metals that are highly resistant to saltwater corrosion.

3

#### Conductivity

Conductivity in water is due to the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity is measured in micromhos per centimeter ( $\mu\text{mhos/cm}$ ) or microsiemens per centimeter ( $\mu\text{s/cm}$ ). A closed system should be considered if the mine water has a conductivity of thousands of  $\mu\text{s/cm}$  or more as this indicates very high levels of dissolved solids which can react with metals [15].

4

#### Hardness

Hardness is very important because it indicates how much dissolved calcium and magnesium is in the water. The hardness of water is measured in three different types of units: grains per gallon (gpg), milligrams per liter (mg/L), or parts per million (ppm) [9]

The hardness classification of the water from soft to very hard in different units of measure is shown in Table 1. If the hardness is above 120 mg/l, a closed loop system is recommended to prevent clogging.

## 5 pH

A closed system or materials which are especially corrosion resistant is recommended if the pH is less than 4 to ensure longevity of the system.

## 6 Sulfate

The presence of sulfates alone should not have an effect on a mine water geothermal system; however, sulfates are often linked and found in concert with salts such as calcium and metals such as iron which have negative effects on equipment and the environment. At times these compounds can be at critical conditions inside mines such that if, for example, a small amount of oxygen were to be introduced, undesirable chemical reactions could occur. Many ore deposits, especially gold and coal mines, contain high amounts of sulfate even after mining [16].

Under the right conditions, especially if oxygen is available, oxidation and reduction chemical reactions that can result in sulfur gas releases, metal precipitation, and scaling deposits. These reactions can happen naturally as water fills the mine after closure, resulting in environmental liabilities such as acid mine drainage [17].

If a mine site is not experiencing such reactions, but the water is found to contain high levels of sulfate (1,000s of mg/l), great care should be taken to ensure that a mine water geothermal system does not introduce oxygen into the mine water which can trigger undesirable reactions [18]. Sulfates present in the water in even small concentrations can give off a rotten egg smell.

## 7 Iron

Iron is frequently sourced from iron sulfide (aka pyrite) which is the most common sulfide mineral and commonly found in coal and gold mines. As a result, it is common to find iron in mine water. Pyrite forms oxidizing reactions in the presence of oxygen and water; these reactions have a tendency to lower the pH of the water and form iron solids called iron(III) hydroxide [19].

Iron in low concentrations should not pose a problem however iron in concentrations of 1,000s of mg/l will likely be in concert with low pH and visible iron precipitates. These precipitate contribute to water hardness and can clog pipes, corrode heat exchangers and pumps [20] [21].

8

#### Manganese

The presence of manganese occurs in nature occasionally, and is usually accompanied by iron but in much lower concentrations. Manganese is typically found in higher concentrations with acidic water. It does not typically precipitate into a solid unless high amounts of dissolved oxygen is available nor does it cause reactions which affect pH. The presence of manganese should not affect a mine water geothermal system [22] [23].

9

#### Potassium

Potassium is commonly found in small concentrations in water, it is part of the standard batch of tests conducted at a water quality lab because occasionally it may be high enough to pose a problem for drinking water. In a mine water geothermal system, the level of potassium is not a problem. It does not affect the pH or precipitate into a solid because itself is not water soluble. [24] [25].

10

#### Sodium

Sodium is commonly found in all waters. In mine water, it is often accompanied by high levels of chloride however it can also be found in the form of sodium sulfite and sodium nitrate. High sodium alone will not cause problems with a mine water geothermal system, it is neither corrosive nor easily precipitated. [26]

Note: Historical records may indicate other unique minerals/chemicals that may justify additional water quality tests at specific locations. A good resource for additional information about the above water quality parameters and water quality indicators can be found at the "National Ground Water Association [27]"

*CASE STUDY, Assessment of the Calumet No. 3 Mine Water*

Two water samples were collected from a mine shaft named Calumet #3 in Calumet, MI for water quality tests to determine the feasibility of an open loop geothermal system. The results are shown below in Figure 2.

Comparing the results with the information above, the water quality report shows that the mine water in Calumet No. 3 has a hardness scale in the “moderately” hard range, not high enough to be a cause of concern. The chloride, sulfate and conductivity results are low enough coupled with a neutral pH to suggest that no special materials will be needed. The trace metals concentrations are not high enough to pose a problem in a mine water geothermal system.

Note that the iron and manganese values in this report are in micrograms per liter (ug/l) rather than milligram per liter (mg/l). The iron concentration is 9.5 mg/l which is low and will not be a concern. Because the water will not be consumed for drinking the bacteria count in coliforms and E. coli are not a concern. These bacteria are not the ones which will cause any chemical reactions in the water. In summary, this water quality test report shows no barriers to the option of an open loop geothermal heat pump system.

Figure 2. Water Quality Report Of Sample Collected From Calumet No. 3

## APPENDIX F

**ANALYTICAL REPORT**

Client: MTU/KRC

WWA Job #: 54372

**Project:**

Date Received: 10/11/2014

Date Reported: 10/27/2014

**Sample Results**

| Sample No. / ID / Description / Matrix             | Result | Flags | Units      | Date       | Method           | MDL  | MQL  |
|--|--------|-------|------------|------------|------------------|------|------|
| <b>54372-001 / Calumet #3 / Drain Pipe / Water</b> |        |       |            |            |                  |      |      |
| <b>General Chemistry Parameters</b>                |        |       |            |            |                  |      |      |
| Alkalinity (t)                                     | 120    |       | mg/L       | 10/15/2014 | 310.2            | 50   | 100  |
| Chloride   | 10 J   |       | mg/L       | 10/21/2014 | 4500-Cl- E       | 7    | 20   |
| Conductivity                                       | 240    |       | umho/cm    | 10/22/2014 | 2510B            | 1    | 2    |
| Hardness   | 100    |       | mg/L       | 10/23/2014 | 2340B            | 0.1  | 0.7  |
| pH   | 7.1    |       | pH Units   | 10/14/2014 | 4500H+ B         | 0.10 | 0.20 |
| Sulfate  | 16     |       | mg/L       | 10/17/2014 | 4500-SO4- E      | 3.0  | 6.0  |
| Total Dissolved Solids                             | 210    |       | mg/L       | 10/15/2014 | 2540C            | 10   | 10   |
| <b>Trace Metals - Total</b>                        |        |       |            |            |                  |      |      |
| Iron (t)   | 9500   |       | ug/L       | 10/23/2014 | 200.7            | 10   | 20   |
| Manganese (t)                                      | 96 Q   |       | ug/L       | 10/23/2014 | 200.7            | 0.50 | 2.0  |
| Potassium (t)                                      | 4.5    |       | mg/L       | 10/23/2014 | 200.7            | 0.10 | 0.40 |
| Sodium (t)   | 7.6    |       | mg/L       | 10/23/2014 | 200.7            | 0.50 | 1.0  |
| <b>54372-002 / Calumet #3 / Water</b>              |        |       |            |            |                  |      |      |
| <b>General Chemistry Parameters</b>                |        |       |            |            |                  |      |      |
| Coliforms  | 140    |       | MPN/100 mL | 10/11/2014 | Modified Colitag | 1    | 1    |
| E. coli  | ND     |       | MPN/100 mL | 10/11/2014 | Modified Colitag | 1    | 1    |

ND = Not Detected, MDL = Method Detection Limit, MQL = Method Quantitation Limit,  
ppm = mg/l (liquid) or mg/kg (solid), ppb = ug/l (liquid) or ug/kg (solid)

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## APPENDIX G: FUNDING SOURCES


Federally the IRS, DOE, and USDA are the main branches which offer financial assistance for geothermal systems. In addition to the tax, grant, and loan incentives described in Appendix B1, one should check the DOE's Geothermal Technologies Office for updates on new incentives. Federal funding frequently waxes and wanes with changing political climate for example in the 1970s and 80s a series of Federal risk reduction policies were implemented through the Program Research and Development Announcement program (PRDA), User Coupled Confirmation Drilling Program (UCDP), and Program Opportunities Notice (PON). Additional grants are available for specific joint scenarios, for example the DOE's Technical Assistance Grant Program is available for projects which involve superfund site remediation.

Funding sources are often organization specific for example a cooperative-run utility district heating system could apply for funding through the National Rural Utilities Finance Corporation and National Cooperative Services Corporations.

While federal funding experiences boom bust cycles, state, local and utility level incentives are often much more stable albeit being unevenly spread. Due to proactive environmental and energy policy by many states have implemented Renewable Portfolio Standard (RPS), state tax incentives, loans and grants targeting specific and/or multiple organizational sectors. A matrix of which current state/local and utility incentives are applicable to each organizational sector can be found in Appendix B2. Most projects take advantage of government sponsored loans because it is often difficult to obtain a private loan or support from venture capitalist due to the perceived high risk and long payback periods of low-grade geothermal projects (Bloomquist, 2004).

In addition to financial incentives, policy can further enhance the incentive to promote clean energy. For example, two states, Maryland and New Hampshire, have made GHPs a qualifying technology for Renewable Energy Credits (REC's) under the State's Renewable Portfolio Standard (RPS) mandate. This provides Utilities an additional incentive to promote the use of GHPs and receive environmental credits for the avoided thermal load (GEO-NII, 2013).

Many states have a policy setup where the utility's profits are not dependent on the amount of energy sales, this policy is formally called decoupled. Where this is the case, the utilities may offer or can be persuaded to offer on-bill financing implemented either in the form of a tariff-based system or an on-bill loan. On-bill financing uses energy utility bills as the vehicle or repayment of loans. Currently five states Oregon, California, New York, Massachusetts, and Hawaii have state requirements for utilities to offer on-bill financing (C2ES.com, 2014).



According to data compiled by the Center for Climate and Energy Solutions, 9 additional states have on-bill financing offered by one or more utilities. In addition four other states are in the process of setting up on-bill financing policy. On-bill financing has gained rapid popularity with good reports of high utilization due to it being a zero or subsidized interest loan. On-bill financing if implemented in tariff-based is not considered a loan which allows organizations which are prohibited from assuming new debts to fund a system.

PACE financing is another innovative scalable and sustainable financing strategy which has been set up by many states. The capital is typically obtained by local or state governments issuing bonds to investors and then using the money to provide loans to consumers and businesses to fund energy efficiency retrofits. The loans are repaid over the assigned period (typically 15 or 20 years) via property taxes. The advantage of PACE financing is that the loan is attached to the property rather than the homeowner so if the property is sold before the loan is paid off, the new owner continues making payments.

In both on-bill and PACE financing, the loan terms is generally setup such that the financial savings from the energy efficiency retrofits is greater or equal to the monthly payment or increase in property tax thus homeowners and businesses are not paying more than they would be prior to the upgrades.

*Federal:**Table 5. Federal Incentives for Geothermal Heat Pumps*

| Incentive Program Description                                 | Residential | Multi-Family | Commercial | Industrial | Manufacturing | Agricultural | Native Corporation | Schools | Non-Profit | Utility | Municipal Utility | Rural Electric Cooperative | State Government | Local Government | Tribal Government | Non-Federal |
|---|-------------|--------------|------------|------------|---------------|--------------|--------------------|---------|------------|---------|-------------------|----------------------------|------------------|------------------|-------------------|-------------|
| Investment Tax Credit (ITC)                                   |             |              | X          | X          |               | X            |                    |         |            | X       |                   |                            |                  |                  |                   |             |
| Modified Accelerated Cost-Recovery System (MACRS)             |             |              | X          | X          |               | X            |                    |         |            |         |                   |                            |                  |                  |                   |             |
| USDA - Rural Energy for America Program (REAP) Grants         |             |              | X          |            |               | X            |                    | X       |            | X       |                   | X                          | X                | X                | X                 |             |
| USDA - REAP Loan Guarantees                                   |             |              | X          |            |               | X            |                    |         |            |         |                   |                            |                  |                  |                   |             |
| Renewable Energy Production Incentive (REPI) (Certain States) |             |              |            |            |               |              | X                  |         |            |         | X                 | X                          | X                | X                | X                 |             |

*The Rural Energy for America Program (REAP)*

The Rural Energy for America Program (REAP) provides financial assistance to agricultural producers and rural small businesses in rural America to purchase, install, and construct renewable energy systems; make energy efficiency improvements to non-residential buildings and facilities; use renewable technologies that reduce energy consumption; and participate in energy audits and renewable energy development assistance.

*The REAP program is comprised of the following components:*

The Renewable Energy System and Energy Efficiency Improvement Guaranteed Loan and Grant Program provides financial assistance to agricultural producers and rural small businesses to purchase, install, and construct renewable energy systems; make energy efficiency improvements; use renewable technologies that reduce energy consumption; and participate in energy audits, renewable energy development assistance, and feasibility studies. Read more

The Energy Audit and Renewable Energy Development Assistance Grant Program provides grant assistance to entities that will assist agriculture producers and small rural businesses by conducting energy audits and providing information on renewable energy development assistance. Read more: [http://www.rurdev.usda.gov/BCP\\_Reap.html](http://www.rurdev.usda.gov/BCP_Reap.html)

Table 6. State and Local Incentives for Geothermal Heat Pumps

| State & Local Incentives | Incentive Program Description  | Residential      | Multi-Family | Commercial | Industrial | Manufacturing | Agricultural | Native Corporation | Schools | Non-Profit | Utility | Municipal Utility | Rural Electric Cooperative | State Government | Local Government | Tribal Government | Non-Federal | Construction | Installer Contractor |
|--------------------------|--|------------------|--------------|------------|------------|---------------|--------------|--------------------|---------|------------|---------|-------------------|----------------------------|------------------|------------------|-------------------|-------------|--------------|----------------------|
|                          |  | Eligible Sectors |              |            |            |               |              |                    |         |            |         |                   |                            |                  |                  |                   |             |              |                      |
| Alabama                  | Local Government Energy Loan Program   |                  |              |            |            |               |              | X                  |         |            |         |                   |                            | X                |                  |                   |             |              |                      |
| Alaska                   | Renewable Energy Grant Program   |                  |              | X          |            |               |              |                    |         | X          |         |                   |                            | X                | X                |                   |             |              |                      |
| Arizona                  | Energy Equipment Property Tax Exemption  | X                |              | X          | X          |               |              |                    |         |            |         |                   |                            |                  |                  |                   |             |              |                      |
| Arizona                  | Renewable Energy Business Tax Incentives   |                  |              | X          | X          |               |              |                    |         |            |         |                   |                            |                  |                  |                   |             |              |                      |
| Arizona                  | Town of Buckeye - Green Building Incentive   | X                |              |            |            |               |              |                    |         |            |         |                   |                            |                  |                  |                   |             |              |                      |
| California               | Burbank Water & Power - Green Building Incentive Program                             |                  | X            | X          |            |               |              |                    | X       |            |         |                   |                            |                  |                  |                   |             |              |                      |
| California               | California Enterprise Development Authority (Figtree PACE) - Statewide PACE Program  | X                |              | X          |            |               |              |                    |         |            |         |                   |                            |                  |                  |                   |             |              |                      |
| California               | CaliforniaFIRST  |                  | X            | X          | X          |               | X            |                    |         |            |         |                   |                            |                  |                  |                   |             |              |                      |
| California               | City of Santa Monica - Expedited Permitting for Green Buildings                      | X                |              | X          |            |               |              |                    |         |            |         |                   |                            |                  |                  |                   |             |              |                      |
| California               | County of San Bernardino - Green Building Incentive                                  | X                |              | X          |            |               |              |                    |         |            |         |                   |                            |                  |                  |                   | X           | X            |                      |
| California               | Sonoma County - Energy Independence Program  | X                | X            | X          | X          |               |              |                    |         |            |         |                   |                            |                  |                  |                   |             |              |                      |
| California               | Western Riverside Council of Governments - Home Energy Renovation Opportunity (HERO) | X                |              |            |            |               |              |                    |         |            |         |                   |                            |                  |                  |                   |             |              |                      |
| California               | Western Riverside Council of Governments - Large Commercial                          |                  |              | X          |            |               |              |                    |         |            |         |                   |                            |                  |                  |                   |             |              |                      |

### Utility:

Table 7. Utility Incentives for Geothermal Heat Pumps

| Utility Incentives | Incentive Program Description  | Residential      | Multi-Family | Commercial | Industrial | Manufacturing | Agricultural | Native Corporation | Schools | Non-Profit | Utility | Installer Contractor | Municipal Utility | Rural Electric Cooperative | State Government | Local Government | Tribal Government | Non-Federal | Construction | Installer Contractor |
|--------------------|--|------------------|--------------|------------|------------|---------------|--------------|--------------------|---------|------------|---------|----------------------|-------------------|----------------------------|------------------|------------------|-------------------|-------------|--------------|----------------------|
|                    |  | Eligible Sectors |              |            |            |               |              |                    |         |            |         |                      |                   |                            |                  |                  |                   |             |              |                      |
| Alabama            | Central Alabama Electric Cooperative - Residential Energy Efficiency Rebate      | X                |              |            |            |               |              |                    |         |            |         |                      |                   |                            |                  |                  |                   |             |              |                      |
| Alabama            | South Alabama Electric Cooperative - Residential Energy Efficiency Loan          | X                |              |            |            |               |              |                    |         |            |         |                      |                   |                            |                  |                  |                   |             |              |                      |
| Alabama            | TVA Partner Utilities - Energy Right Heat Pump Program                           | X                |              |            |            |               |              |                    |         | X          | X       |                      |                   |                            |                  |                  |                   |             |              |                      |
| Arizona            | UES - Renewable Energy Credit Purchase Program                                   | X                |              | X          |            |               |              |                    |         |            |         |                      |                   |                            |                  |                  |                   |             |              |                      |
| Arkansas           | AEP SWEPCO - Commercial and Industrial Energy Efficiency Rebate Programs         |                  | X            | X          |            |               |              | X                  | X       |            |         |                      |                   | X                          | X                | X                |                   |             |              |                      |
| Arkansas           | First Electric Cooperative - Home Improvement Loans                              | X                |              |            |            |               |              |                    |         |            |         |                      |                   |                            |                  |                  |                   |             |              |                      |
| California         | Lassen Municipal Utility District - Residential Energy Efficiency Rebate Program | X                |              |            |            |               |              |                    |         |            |         |                      |                   |                            |                  |                  |                   |             |              |                      |
| California         | Pacific Power - FunAnswer Express  |                  | X            | X          |            | X             |              |                    | X       |            |         |                      |                   | X                          | X                | X                |                   |             |              |                      |
| California         | Plumas-Sierra REC - Residential Energy Efficiency Rebate Program                 | X                |              |            |            |               |              |                    |         |            |         |                      |                   |                            |                  |                  |                   |             |              |                      |
| California         | Redding Electric - Earth Advantage Rebate Program                                | X                | X            |            |            |               |              |                    |         |            |         |                      |                   |                            |                  |                  |                   |             |              |                      |

## Appendix D: EPA P3 Phase I Project Report Summary

# EPA P3 Phase I Project Report Summary

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## **Executive Summary**

**Date of Project Report:** March 12, 2015

**EPA Agreement Number:** SU83569201

**Project Title:** Developing a Guide for Harnessing Low-grade Geothermal Energy from  
Minewater for Heating and Cooling Buildings

**Faculty Advisor(s), Departments and Institutions:**

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Note: All team members are students at Michigan Technological University

Project Period: 8/15/2014 – 8/14/2015

**Description and Objective of Research:**

Energy used for heating and cooling contributes directly and indirectly to pollutants, which contribute to climate change and acid rain. In former mining communities, heating and cooling costs are high for a number of reasons. Additionally, the loss of active mining often represents an economic and leadership glut in former mining communities. In many of these former mining communities, the inactive mines are seen as a nuisance or potential risk. This project aims to change that legacy by educating communities about the potential to reuse these mines as a source of geothermal heating and cooling.

Despite these challenges, inactive, flooded mines offer an opportunity, or silver lining, in that they can be used to provide low-cost geothermal heating and cooling. Thousands of mines across the U.S. are each filled with millions to billions of gallons of water. The water is insulated and heated by the earth. These flooded mines represent an enormous geothermal reservoir and a great potential for heat exchange. Despite this opportunity, most people do not perceive the ground beneath their feet as possessing any useful energy. As a result less than 0.001% of the earth's low-grade geothermal is currently utilized (Murphy, 2012). Most people never think of tapping into flooded mines for geothermal energy or even know where to start.

Using mine water for geothermal heating and cooling has been proven to be technically feasible and economically viable. Globally there are approximately 20 geothermal heat pump

systems operating on mine water (Preeene, 2013 and author's literature search). While the technology exists to utilize minewater, there are very few active projects. With so few systems in existence communities who have considered mine water geothermal can be hesitant to take significant steps to explore it. Without a central repository of how to approach this type of projects, low adoption will remain an issues. Low adoption also creates a perceived risk barrier, leading communities to believe that if it is not commonly done, there must be something that makes it not possible.

To minimize the perceived risks, the objective of this P3 project is to create a guidebook and educational materials that former underground mining communities can use to evaluate their flooded mines for use in geothermal heat pump systems. A process that would provide a significantly more efficient way to heat and cool buildings.

### **Summary of Findings:**

Based on our review of existing systems, literature, and our interactions within the community of Calumet, MI, we believe that mine water geothermal has the potential to reduce carbon emissions and help to deal with acid mine drainage (Planet); to promote economic development in places with low income and high unemployment (Prosperity); and to improve people's ability to meet their basic needs to stay warm and comfortable while celebrating local culture and heritage (People). However, former mining communities need knowledge, guidance, and resources in order to seriously consider and to be able to take advantage of the water in their mines for geothermal energy.

While our overall goal is to provide a guidebook for mining communities to understand the potential of this resource, to evaluate the technical feasibility in their own community, and to develop empowering social networks, skills, and resources to promote sustainable redevelopment more broadly, our specific objectives include:

- 1) Determining the need for the guidebook on a national scale
- 2) Creating a process which allows communities to understand mine water geothermal collectively
- 3) Providing an everyday understanding of low-grade geothermal energy
- 4) Providing a calculator for communities to estimate the capital costs and payback period

### **Results from Objective One: *Determining the need for the guidebook on a national scale***

Our work with the community of Calumet, MI indicated a local need for a guidebook to minewater geothermal heating and cooling. To assess the national relevance of this project, we conducted a literature review, reached out to national organizations that work on abandoned mine issues, and utilized geographic information system (GIS) demographic information. It was clear from our literature review that there is enormous potential for these projects (Ackman and Watzlaf, 2007; Korb 2012; Ohio DNR, 2011). Our national partners have also communicated with us that they work with over 100 communities across the US that could benefit from this project (see attached letters of support). In our GIS analysis, the team combined population Census 2010 data with the USGS dataset on the location of past underground mines. **Our research found that at the absolute minimum there are 768,000 Americans that live within a half mile of such a great renewable resource. From this we determined that a guidebook is needed nationally.** Such a tool could help inform mining communities across the U.S. about

the opportunity of using mine water for geothermal heating and cooling. Moreover, the guidebook provides clear instructions on what a community can do to determine the feasibility of a system.

Results from Objective Two: *Creating a process which allows communities to understand mine water geothermal collectively*

Perceived risk is a hurdle in adoption of any new technology. Collaborative problem solving can help overcome this hurdle.. As a result, participatory planning theory is an integral part of the guidebook. The guidebook gives instructions, and inspiration, through examples of existing systems to help communities explore the feasibility of using their flooded mines for geothermal heat pump systems. The process involves using the knowledge, expertise, and material resources available within the community. The process of collecting and evaluating data will also build community leadership, engagement, and pride. **As a result of this objective, our guidebook emphasizes a participatory process for collecting and interpreting data relevant to the feasibility of a system.**

Results from Objective Three: *Providing an everyday understanding of low-grade geothermal energy*

The guidebook overcomes the barrier to understanding low-grade geothermal energy and heat pumps by explaining them in simple terms, and connecting them to common experiences. Building on the idea that interactive learning is the best learning (Pérez-Sabater et al., 2011), the Phase I project also included the development of a working physical model depicting an example setup of a mine water geothermal system as a travelling showpiece. As a result of this objective, the P3 team has developed instructions for building a sample model for educating the public, business owners, and policy makers on the “how to” of mine water geothermal systems.

Results from Objective Four: *Providing a calculator for communities to estimate the capital costs and payback period*

An additional barrier to widespread adoption of geothermal heat pump systems is their perceived expense. Indeed, the drilling and excavation needed for traditional geothermal heat pump systems contributes significantly to the increase in cost compared to alternative HVAC solutions (Kavanaugh, Gilbreath, and Kilpatrick, 1995). By tapping into the thermal reservoir of flooded mines, the number of wells needed is significantly reduced, dramatically reducing the costs of drilling and excavation (Idem. and author’s case comparisons, Korb, 2012). To help communities analyze their payback time, a spreadsheet calculator was developed for capital costs and payback period analysis.

**Conclusions:**

Overall, the research conducted under Phase I suggests that the exploration and development of mine water geothermal systems has the potential to help reverse the economic, environmental, and social challenges former mining communities face. Reduced heating and cooling costs can help make business expansion financially feasible and inviting for new businesses. This can in turn lower unemployment and emigration rates. With increased liquid funds, individuals, businesses, and the community can invest in further development.

Community pride may increase with the mines recast as an environmental “good” that promotes sustainability a source of low cost heating and cooling, rather than an environmental “bad” that communities must accept or deal with. In fact, entire community identities and outside images may be transformed from “dirty old mining town” to “progressive and sustainable community.” Communities can be proud to be heating and cooling using the most energy efficient means available today and be proud of their role in reducing pollution to the environment and mitigating climate change.

### **Proposed Phase II Objectives and Strategies:**

The key aims for Phase II are to:

- 1- Evaluate the Community Guide to Mine water Geothermal in additional case communities and revise it accordingly.
- 2- Develop and distribute a grade 7-9 curriculum around low-grade geothermal and opportunities for using mine water for geothermal energy.
- 3- Utilize existing networks to publish and distribute the guidebook

The Phase I edition of the guidebook was written based on the team’s work in Calumet, MI and our literature review. For our Phase II project, we will evaluate and revise the guidebook by working with national partners to test the Guide in multiple contexts. We will also develop educational modules and utilize our existing networks to publicize our guidebook.

In order to evaluate and refine the guidebook, the team has been working with our partners to identify additional case communities where we will work in depth for over one year-one in a Pennsylvania coal-mining region, another in a western hard rock mining region.

This process will be iterative and will include working with our partners (see letters attached), learning about the communities and traveling to the communities. The team will conduct community workshops to introduce the guidebook and its assessment procedure. The team will also conduct follow-up activities to gauge the success of workshops/guidebook. This information will inform revisions and help us better understand how to publicize it. We will also continue to develop a network of interested parties and share information within this network. Our goal for these partnerships is both to further refine the guidebook and to begin to develop a method of best practices for sharing the resources.

Our second objective aims to develop and distribute a grades 7-9 curriculum around low-grade geothermal, heat pumps, and cultural legacies of mining and change. We will work with the Michigan Tech Center for Science & Environmental Outreach to develop this curriculum. With the Center, we will host a curriculum development institute and work with 15 local teachers to develop web-based educational modules. The curricular modules will integrate with Next Generation Science standards. They will be publicized and distributed utilizing our existing networks, as an appendix to the Guidebook, and in presentations at national meetings.

Finally, we will attend national conferences related to mine reclamation that attract community organizations to publicize our guidebook and related curriculum. These conferences include the Pennsylvania Abandoned Mine Conference in June 2015, and at the National Association of Abandoned Mine Land Programs annual conference in 2015 and in 2016.

### **Publications/Presentations:**

A draft of the guidebook titled *A Community Guide to Mine Water Geothermal Heating and Cooling* is available by request.

Louie, E., Macleod, E., Masterton, A., Michaelson, M., Slagle, N., Occhietti, D. (October 2014). *Exploring the Social Feasibility of Minewater Geothermal in Calumet*. Presentation at the 8<sup>th</sup> Annual D80 Conference, Michigan Technological University, Houghton, MI.

Meldrum, J., Winkler, R. (November 2014). *Using Mine Water for Geothermal Energy in the Keweenaw*. Presentation Green Lecture Series, Michigan Tech University, Houghton, MI.

Slagle, N., Warsko, K. (December 2014). *A Community Guide to Minewater Geothermal Heating and Cooling: Draft Review Meeting*. Presentation to the community advisory board, Calumet, MI.

*Exploring Minewater Geothermal for Communities*: Public presentation to the community of Calumet, MI. April 2015.

Winkler, R. (June 2014). *Exploring the Social Feasibility of Minewater Geothermal in Calumet*. Presentation to The Bluffs Senior Living Community. Houghton, MI.

Winkler, R. (June 2014). *Exploring the Social Feasibility of Minewater Geothermal in Calumet*. Presentation to the Rotary Club of Houghton, MI.

### **Supplemental Keywords:**

geothermal, community development, community identity, minewater, mine water, geoexchange, heat pump, low grade geothermal, mine reclamation.

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## Body of Report

### A. Summary of Phase I Results

#### Background and Problem Definition

##### *People*

Settlements near areas of mining are often a direct result of the mining. Since mining is an inherently unsustainable activity, these towns often suffer economically and socially once the mine closes (Freudenburg and Wilson 2002, Humphrey et al. 1993). Mines are often located in remote areas where energy must be transported or transmitted a long distance contributing to high costs. The combination of unemployment, high poverty, and high energy costs makes many of these areas among the most depressed regions in America. Despite the immense capital invested to create underground mines, after closure they are primarily seen as an environmental burden and a health/accident risk. The sustainable reuse of flooded mines for geothermal energy would provide value back to former mining communities in terms of environmental benefits and, a low-cost source of heating/cooling, a potential source of economic development, a way to celebrate local cultural and place identities.

Culturally, reusing the mines represents a transition from unsustainable to sustainable, a connection between the past, present, and future, as well as a source of hope and pride. Cultural ties, sense of place, and community identity are important components of quality of life and community development (Flora and Flora 2013). Mine water geothermal provides an opportunity to celebrate the cultural legacy of mining and reinforce community identity, while at the same time promoting environmental sustainability. By associating the mining past with something positive for the future, rather than the more typical environmental degradation and contamination associated with mining histories, mine water geothermal offers opportunities for developing a strong and positive sense of place that may attract tourists, in-migrants, and reduce young adult out-migration (Manzo and Perkins 2006). It provides an opportunity to “recast” community place identity as progressive, forward-thinking, and sustainable rather than as an “old mining town.”

People around the world would experience health benefits from shifting toward geothermal sources of heating/cooling. As research and demonstration sites have shown, geothermal results in energy savings that translates to reduced air and water pollution from coal power (EPA, 1993). Carbon dioxide, sulfur dioxide, nitrogen oxides, particulate matter, and mercury are pollutants predominantly from coal combustion (EIA, 2014a). Sulfur dioxide and nitrogen oxide exposure leads to increased asthma symptoms (Burt et al., 2013). Fine particulate matter commonly increases respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing. It can also lead to premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, and decreased lung function (Burt et al., 2013). The health and environmental impacts of air and water pollution are not confined to the area in which it is produced; they can be transported by winds and in rivers and impact society as a whole (The National Academy of Science, 2009), .

### ***Prosperity***

Reduced heating and cooling costs, via mine water geothermal, can help make business expansion financially feasible and inviting for new businesses. This can in turn lower unemployment and emigration rates. With increased liquid funds, individuals, businesses, and the community can invest in further development. The Ropak facility in Nova Scotia, Canada is an example of such cascading economic benefits.

The mine water geothermal system in the Ropak facility in Nova Scotia, Canada had a capital cost of \$110,000 but resulted in an annual savings of \$160,000 per year, a 60 percent reduction over the equivalent oil-fired furnace system (Mason, 2009, IEA, 1992, Jessop, 1995). The economic advantage is further enhanced when the abated cost of dehumidification are taken into account (Jessop, 1995). Since Ropak's success outside investors entered Springhill and the industrial park attracted more businesses looking to benefit from geothermal energy, which has increased economic prosperity in the local community. In addition to the industrial park, Springhill's NHL sized ice rink and community center installed mine water geothermal and became the largest facility to do so in Canada. Heating and cooling with geothermal has saved the complex \$70,000/year in energy costs and \$45,000 in annual maintenance costs (Gorman, 2013). Today, over a dozen local businesses either have access to or choose to use geothermal energy in Springhill (Thompson, 2013).

Similar examples exist in the U.S. The mine water geothermal system installed at the John Wesley AME Zion Church in Pittsburg, PA cost \$80,000 but reduced heating costs by 80% and cooling cost by 50% (Ohio DNR, 2011). The system in Park Hills, MO cost \$132,400 but saves \$30,844 annually (Ohio DNR, 2011; Koufos, 2011).

Although geothermal heat pumps have higher upfront costs they are frequently the most cost effective means to heat and cool buildings. As a result the payback period of a traditional geothermal system is typically between 6 and 20 years depending on capital costs, energy prices and energy price increases (Self, 2013). However, due to the capital savings and increased operational efficiency from warmer temperatures than the surrounding ground, mine water geothermal systems can be expected to have shorter payback periods. Published payback periods can be as short as less than a year in the case of Ropak to 4.6 years for Park Hills, MI (Jessop, 1995; Ohio DNR, 2011).

### ***Planet***

Electricity use represents a significant source of pollution especially in areas where power from coal constitutes a large part of the electricity mix (EIA, 2015, Sieminski, 2013). In the U.S. coal power plants are the leading source of carbon dioxide, sulfur dioxide, and mercury emissions and a significant contributor to nitrogen oxides and particulate matter pollution (Union of Concerned Scientist, 2011). Even though the U.S. is transitioning to shale sourced natural gas for power generation, careful lifecycle analysis suggests CO<sub>2</sub> reductions of 50% (Fulton, 2011). While impressive, it cannot preclude efforts to reduce energy demand since the cleanest kW is the one that does not need to be generated. Changing one's heating and cooling system presents significant savings potential since heating and cooling accounts for nearly half of the energy consumed in households (EIA, 2014b) and the highest energy cost component in commercial buildings (27%) (DOE, 2012).

Geothermal heat pump has been identified by the DOE as the most energy efficient system for heating and cooling a building (DOE, 1998). The DOE has determined that a traditional geothermal system will result in a 63% reduction in electricity usage compared to electric heat (DOE, 1998). The water in flooded mine shafts can be slightly or significantly warmer than the surrounding ground due to thermal convections bringing higher temperatures from deep parts of the mine to the surface. Since the efficiency of heat pumps increase when the temperature difference between the source and the destination is reduced (Meggers, 2010), utilizing mine water which is warmer than the surrounding ground can result in further efficiency gains.

Mine water geothermal systems can also dramatically reduce land disturbances compared to traditional geothermal systems. This is best evidenced by the comparison between the system at Ball State University and Marywood University. At Ball State University 3,600 wells each 400 to 500 ft deep were drilled to create the geothermal exchange interface for their closed loop heat pump system (Ball State University, 2012). This closed loop system also required 10 miles of pipe (Korb, 2012). In contrast, at Marywood University, a similar sized geothermal heat pump system utilizing a flood underground mine required two boreholes and 2000 ft of pipe (Marywood University, 2010). This dramatic reduction in erosion and land disturbance is possible due to the much larger thermal capacity of a flooded mine. Furthermore unlike natural gas and oil, mine water geothermal systems gracefully lend to collaboration with other renewable energy projects such as wind and solar which do not release emissions during operation.

### ***Relevance and significance to developing or developed world***

According to the [World Coal Association \(2009\)](#) 95% of China's coal mines are underground mines, in India that figure is 64%, in the U.S. 40%, and the UK 28%. Statistics from coal alone clearly shows that there has been and will be many closed underground mines. Minerals including gold, silver, iron, copper, zinc, nickel, tin and lead as well as gems like diamonds are all typically extracted using underground mines. Almost all of these mines will fill with surface and groundwater when active mining closes. Thus, knowledge on how to reuse these man made cavities filled with water productively will be of great benefit to communities around the world. Inevitably people will continue to live near mines after they close. There is ample evidence from a number of communities and facilities that have used flooded mine shafts in geothermal heat pump systems with great success to suggest that this form of reuse should be examined by many more communities and facilities. The goal for our project is to create resources that will be helpful for a diverse array of communities both nationally and internationally. In the U.S. alone, our team found, by combining Census 2010 data with the USGS dataset on mines in GIS, that at the absolute minimum there are 768,000 Americans that live within a half mile of a past underground mine (Census, 2014, USGS, 2005).

### ***Implementation as an Educational Tool***

Our team's P3 project has served as an educational tool in multiple dimensions- for students engaged in the project, for community partners engaged in the project, and most importantly we seek to provide educational opportunities for the general public.

One of the barriers to geothermal energy and especially mine water geothermal implementation is a lack of education on the subject. When people hear the term geothermal

many instinctively think of Yellowstone, Old Faithful Geyser, and hot springs. But most don't think of the mines or their backyard as possessing viable geothermal potential. These perceptions, combined with a perception that geothermal systems are not affordable (Holladay, 2013), are two social barriers this project seeks to overcome.

We are creating resources that will help communities to understand, visualize, and realistically evaluate potential opportunities for tapping into the mine water in their local area for geothermal energy. We aim to elucidate connections between mine water geothermal and its potential to benefit social, economic, and environmental facets such as air and water pollution reduction and climate change mitigation through improving efficiency and energy savings. We encourage community organizations and leaders to inspire the community to come together to explore the possibility of mine water geothermal energy. This process requires communities to exercise leadership, democratic decision-making, and to build personnel and knowledge networks. This leadership network is key to generating community interest and spreading the idea of mine water geothermal.

### **Purpose, Objectives, Scope**

Our team is working to provide resources for former mining communities to understand potential opportunities associated with using water in flooded mines in geothermal heat pump systems for heating and cooling buildings. We seek to provide tools for communities to self-evaluate the social, economic, and technical feasibility of tapping into the mine water for geothermal energy. Our key objectives are:

- 1- to spread knowledge about mine water geothermal possibilities
- 2- to empower disadvantaged communities to gain knowledge and skills and to mobilize resources and work toward self-determination
- 3- to motivate communities and provide realistic, accessible avenues through which people can work together to evaluate and potential implement mine water geothermal systems

We have created a *Community Guide to Mine water Geothermal*; a calculator tool which helps communities to estimate installation costs, potential cost savings, and payback period for installing a mine water geothermal system in their own communities under multiple contexts; and a working table-top model that illustrates how a mine water geothermal system works. Throughout the project, we take a community participatory approach aimed at empowering local communities and fostering community-based leadership.

It is our goal that developing and distributing these resources will result in more municipalities and individuals exploring the possibility of utilizing mine water geothermal and ultimately increased adoption. Based upon our research, we believe that adopting mine water geothermal could contribute to reduced air pollution, reduced CO<sub>2</sub> emissions, improved potential for community economic development, and opportunities for celebrating community cultural identities. Moreover, because our approach focuses on community empowerment, we believe there is good potential for community development and positive social outcomes even in cases where communities who explore the potential of mine water geothermal using our Guidebook but decide against implementing a system. The process we share focuses on building various “community capitals” (including building social networks (social capital); building knowledge, skills and

leadership (human capital); and investigating opportunities for political, economic, and built capitals), which together contribute to sustainable community development (Flora and Flora 2013).

The Guidebook's scope encompasses social, economic and environmental understanding and assessment in a range of range of mining situations. The current draft of the Guidebook reflects these aspects based on research with the community of Calumet, MI and published literature from existing mine water geothermal system around the world.

## **Data, Findings, Outputs/Outcome**

### *Specific Anticipated Analysis and Accomplishments*

All the tasks proposed in the original phase I proposal were either completed, found to be unnecessary for the objective, or completed by other research literature and cited in the guidebook. In place of any tasks found to be unnecessary for the objective, one or more relevant tasks took its place. The table summarizes these anticipated components our work related to these components is described in detail below.

| <b>Task</b>                                       |                     |               |
|---|---------------------|---------------|
| Assessing National Population Proximal to Mine    | Originally Proposed | Completed     |
| Maximum Sustainable Heat from Mine                | Originally Proposed | Not Completed |
| Building Energy Demand                            | Originally Proposed | Modified      |
| Water & Mine Characteristics Assessment           | Originally Proposed | Completed     |
| Capital Cost and Payback Period Spreadsheet       | Originally Proposed | Completed     |
| Carbon Savings Spreadsheet                        | Originally Proposed | Modified      |
| Navigating and Generating Socio-Political Support | Originally Proposed | Completed     |
| Table Top Model                                   | Originally Proposed | Completed     |
| Contact Existing Mine Water Geothermal Systems    | Originally Proposed | Completed     |
| Legal Concerns                                    | Originally Proposed | Completed     |
| Financial Methods Decision Matrix                 | Originally Proposed | Modified      |
| Ownership Methods Decision Matrix                 | Originally Proposed | Modified      |
| Energy Utility Rate Comparison                    | Addition            | Completed     |

One of the project's tasks was to understand the national population that could benefit from this guidebook. The 2010 U.S. Population Census contains the most detail national survey of where people live in the U.S. This spatial data is available at various resolutions with the most detail being the block level data. The USGS has a national dataset, called the Mineral Resources Data System, on the location of past and present surface and underground mines. From this dataset, past/inactive underground mines were selected. The data actually records the location of not only the mine but the mine shafts as well in some instances though the data is incomplete. The two data sets were overlapped in ESRI ArcMap. A reasonable maximum distance to pump mine water from an existing shaft to a building is a half-mile. Combining the data with this parameter it was found that 768,000 Americans in 370,000 homes live within a half mile of a mine/mine shaft. These values represent a minimum number since the database of past mines and mine shafts is incomplete. Additionally underground mines extend horizontally, sometimes for

miles, thus buildings greater than a half-mile from an existing shaft may be able to drill a short distance to intersect with a flooded mine shaft.

Another task was to develop a tool or model for determining the maximum sustainable amount of heat that can be extracted from a mine shaft. This was found to be unnecessary since flooded mines contain millions to billions of gallons of water. The amount of thermal energy contained dwarfs the amount that buildings would need. Additionally, a local induced thermal disturbance caused by heat extraction will be attuned through thermal convective mixing through the interconnected mineshafts vertically and horizontally. In traditional geothermal sites, Murphy (2012) argues that the recharge rate of geothermal heat is rather slow and inadequate to keep up with point source extraction rates however that the heat reservoir is enormous so much so that it will take hundreds of thousands of years to deplete. The team found that it would take 165,000 years to fully deplete the thermal reservoir of a traditional geothermal site based on the equations and constants by Murphy (2012). Even in conditions where geothermal is not truly sustainable, it is sustainable for the time horizons relevant to society. Through computer modeling, Madiseh et al. (2012) estimates that every kilometer of underground mine tunnel can produce about 150 kW of heat sustainably.

Another task was develop a way to collect energy usage/demand of the buildings around a mine shaft. Research in Calumet, MI found this task to be rudimentary. The more challenging task not identified in the original proposal is determining the energy specifically by the heating and cooling system. A method found to be a good estimate 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 cooking, by subtracting July's natural gas usage from the other months, 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 the other month's electric bills will result in an estimate of the energy used for heating.

This method of estimation is a little trickier 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' energy bills. The remaining is an estimate of the energy used for air conditioning.

Another task in the original proposal was to develop a list of products and procedures that can be used to assess relevant water and mine characteristics. For assessing the mine characteristics the guidebook directs readers to conduct oral histories and research mine company documents prior to conducting physical assessments. This pre-survey is invaluable for determining where to survey, what sorts of prior permissions are necessary, and the level of hazard and safety to exercise. The research established that it is vital know the vertical and horizontal distance which the water will need to be pumped and piped. To determine the horizontal pipe path distance it is most efficient to record the GPS location of the mineshafts and layout the horizontal pipe path in Google Earth/Map to buildings of interest. The location of the mine shafts can be made public so members of the community can use Google Earth/Map to layout the pipe path to their building of interest. The angle of incline to a mine shaft is also important for calculating the true vertical distance a pump must be able to lift.

The water characteristics were divided into two sections one which is relevant regardless of the geothermal heat pump setup (open loop or closed loop) and another section which is relevant to open loop systems only. In all systems the temperature, temperature gradient, and distance to the water are important design parameters. For open loop geothermal systems, it is important to analyze the water to ensure it will not quickly damage the pump and heat exchanger or clog the piping. To make this determination the pH, salinity, hardness, dissolved oxygen and suspended solids level of the water needs to be assessed. These components are assessed directly and/or indirectly. The guidebook provides instructions on how to obtain a water sample and understand a water quality assessment report. Additionally recommended maximums are given for when the water is to be considered unsuitable to be used in an open loop system. The guidebook and the appendix detail some creative methods for obtaining water and mine characteristics data using low-cost and/or DIY solutions.

Another task in the original proposal was a spreadsheet to calculate the economics of a mine water geothermal system. The created spreadsheet takes the depth to the mine water, angle of the shaft, temperature of the water, horizontal pipe length, and the size of the current heating system to calculate an estimate of the capital cost to install geothermal heat pump which exchanges its heat with mine water. To calculate payback period the spreadsheet takes the cost of electricity, cost of the current heating fuel (natural gas, propane, electricity), and number of months of heating.

A carbon savings calculator was to be included in this spreadsheet in the original proposal; this was not included since the EPA has already conducted a detailed study on the CO<sub>2</sub> savings of geothermal heat pumps. Geothermal heat pumps exchanging heat with mine water will yield similar if not better results if the water is warmer than the surrounding ground due to convection bring heat from deep in the mines to the surface.

Guidance on how to navigate and generate socio-political support and interest from the community was a task in the original proposal. Through research and observation on the methods Main Street Calumet generates socio-political support, a process called The Participatory Planning for Sustainable Community Development (PPSCD) in research literatures was selected as the recommended model for navigating and generating socio-political support.

Poor public understanding of heat pumps in general especially geothermal heat pumps has been identified as a cause of low adoption. To aid public understanding, table top models of different geothermal heat pump configurations were proposed. Instead of multiple table top models, one operational table top model was constructed which allows the public to touch warm water generated by a heat pump concentrating heat from a water reservoir.

Contacting existing mine water geothermal systems for more information on their system was a task in the original proposal. Indeed, some more information was obtained. However, more importantly, the contacts, were extremely interested in the guidebook. The contacts expanded the number of external reviewers of the guidebook. Additionally, more information on the existing geothermal systems was found to be less important than how they contributed to other aspects of the community. For example in Nova Scotia Canada, mine water geothermal systems helped increase jobs and business growth. In Herleen the Netherlands, a district system configuration was proven to be feasible but discussions are currently taking place on how to make the system a billable utility.

The lack of established legal precedent surrounding heat extraction from mine water was an area of research in the original proposal. Despite research, not a lot of new insight could be found. The overarching conclusion regarding the legal precedent is that there should be no problem. The legal section, discusses why certain existing legal precedent would not be applicable to a mine water geothermal setup.

A financial and ownership method decision matrix was originally proposed. It was determined that it would be more helpful to simply provide communities with examples of different ownership structures and allow communities to decide on how to decide on which ownership structure is right for them. Similarly communities were less concerned about a financial decision matrix as they were with knowing what financial sources and setup options are available.

An unanticipated easy first check a community can do to determine whether a mine water geothermal system is economically feasible in their community comes from evaluating the cost of alternative heating fuels available versus the cost of electricity. Modern geothermal heat pumps have coefficients of performance (COPs) greater than 3.3, as a result, if the cost of electricity is less than 3.3 times that of natural gas, the cost of operating geothermal heat pump will be less than heating with natural gas. Even with the present low natural gas prices and high electricity prices, analyzing the state average residential natural gas and electric prices for September 2014 revealed that geothermal heat pumps are still the most cost effective option in 44 states.

### ***Overall Key Outcomes***

Phase I has achieved four key outcomes: (1) contributed to the interdisciplinary education around possibilities of mine water geothermal for eight undergraduate and four graduate students; (2) begun national partnerships and spurred interest in working with communities toward mine water geothermal projects; (3) strengthened campus-community partnerships between Michigan Tech University and Calumet, MI (a high poverty former mining community) empowering community members and spreading knowledge about potential of mine water geothermal; and (4) produced a set of educational materials that will continue to be used to help individuals and community organizations to understand the potential of mine water geothermal and to begin to evaluate its applicability in multiple environmental, social, and economic contexts.

The project has provided opportunity to develop an interdisciplinary education among our team, which then also serves as a model for other teams and projects seeking to successfully combine social, engineering, and communication knowledge and research to make real world impacts. The project brings together a team of student researchers with expertise in energy policy, anthropology, scientific and technical communication, and chemical, mechanical, civil and environmental engineering. The team is co-supervised by two faculty members who each bring different skills and perspectives: a sociologist specializing in community development and a mechanical engineer specializing in alternative energy. We teach each other new knowledge as we work together and we have come to appreciate the unique contributions we all can make. Not only have we all learned about the possibilities of mine water geothermal (something most of us had never before considered), but we have also learned to work together as a productive interdisciplinary team. We'll carry these teamwork skills with us throughout our careers.

This project has also led us to develop working relationships with experts in geothermal energy development, mine reclamation, and community organizations locally, regionally, and nationally that have motivated increasing investigation into minewater geothermal possibilities. We have developed relationships with heat pump engineers at Mitsubishi who have visited our team at Michigan Tech, led a workshop for us about heat pump system designs, and continue to consult. We are also partnering with the Eastern Pennsylvania Coalition for Abandoned Mine Reclamation to learn more about mine reclamation in that region and to share our developing expertise on possibilities associated with minewater geothermal. Our work has already inspired this group to work more closely with communities in their region who might want to explore this possibility. And finally, our partnership with the Office of Surface Mining (OSM) Volunteer In Service To America (VISTA) program has introduced this organization to the idea of mine water geothermal and has considerable potential for exploring these possibilities further.

The team is based upon a partnership with community members and community leaders in Calumet, Michigan. We follow principles of community engaged scholarship to involve the community in the entire research and communication process. In fact, we came to this project because community members expressed interest in exploring the possibility of minewater geothermal and reached out to the university for help. So, the collaboration with the Calumet community throughout the project has also helped the community learn about geothermal energy, heat pumps, and the opportunities and challenges associated with reusing flooded mine shafts. The relationship has also been productive in that it has provided a critical source of community-based impact on the development of our resources so that they may better fit the needs of the key audience. We have worked closely with a community advisory board we created to oversee this project to design, edit, and revise our materials. We have a large public presentation in Calumet scheduled for April 6, 2015. At that presentation we will provide a summary of mine water geothermal possibilities, an overview of our Guidebook, and set up stations where our students and the audience can together interact with various tools including the tabletop model we created, the economic analysis calculator, and a web-based map that measures distances to mine shafts in their own community.

Finally, the Guidebook and associated resources will be made available to the general public. If awarded a Phase 2 award we'll be able to make much better progress in refining and distributing these materials. But regardless, the results of the Phase I award will be available.

## **Discussion, Conclusions, Recommendations**

Former mining communities are among the most depressed areas in America due to a combination of social, economic, and environmental challenges that create a disadvantaged context within which hundreds of thousands of individuals live and make their livings. Socially, mine water geothermal has the potential to increase community pride by recasting the mine as a sustainable resource of heat capable of providing low cost heating and cooling for the community rather than valueless or a burden. Furthermore, communities can be proud to be heating and cooling using the most energy efficient means available today and be proud of their role in reducing pollution to the environment and mitigating climate change.

Economically, the capital cost of a mine water geothermal heat pump systems can cost 33 percent less than a traditional geothermal systems due to reduced drilling and excavation

requirements. Operational costs of a mine water geothermal system can also be less than a traditional geothermal heat pump system if the mine water is a higher temperature than the surrounding ground. The higher temperatures reduce the amount of electric energy needed by the heat pump to concentrate the heat. The water in the mines in Calumet, MI was found to have a temperature of 53 F whereas the surrounding ground temperature is 45 F. The potential economic benefits of heating and cooling with mine water can have cascading effects as evidenced by the community of Nova Scotia, Canada.

Environmentally, mine water geothermal systems can have dramatically less land disturbances than traditional geothermal systems. This is best evidenced by the comparison between the system at Ball State University and Marywood University, 3,600 wells versus 2. When it comes to emissions, geothermal thermal heat pumps to have the lowest CO<sub>2</sub> emissions of any heating and cooling system due to its efficient use of electricity (EPA, 1993). Since mine water geothermal system can be more efficient than traditional geothermal systems if the mine water is warmer than the surrounding ground, they can potentially produce even less emissions.

Lastly, the usefulness of all energy is not equal. It is environmentally beneficial to conserve the most versatile energy resources for high value needs. Electricity is an incredibly versatile energy resource with thousands of uses it would be a waste to use it directly to heat buildings. On the other hand low temperature geothermal energy is not very versatile, however there is a plentiful supply of it. Each mine contains millions to billions of gallons of water insulated by the earth from the seasonal temperature variations. Using a heat pump, this vast supply of low-grade energy can be harnessed to heat and cool buildings, a task that does not require high quality energy. Mine water geothermal can help save high quality energy for use in more productive purposes.

### **Assurance that research misconduct has not occurred during the reporting period**

The collaborative nature of the research and writing of the guidebook means team members are reading and checking each other's work. Facts are checked to their source, and missing citations are brought to attention. In addition, the guidebook has been reviewed by faculty and external personnel. This system of checks provides assurance that research misconduct has not occurred at any point during the project.

### **Publications/Presentations of Phase I work**

Getting the word out about the idea of reusing flooded mines in geothermal heat pumps is a key part of this project's goals. The team has presented work from this project in multiple locations in our local community, including: to the Rotary club, to a senior living community, to our community advisory board in Calumet, to the Green Lecture Series sponsored by Michigan Tech University with community-campus audience, to an audience of approximately 100 conference attendees at the 8<sup>th</sup> Annual D80 Conference hosted by Michigan Tech. Our largest presentation (beyond the Sustainable Design Expo) is a public workshop/presentation scheduled for April 6, 2015 as discussed above.

Based on our Phase I work, we have published a complete draft of *A Community Guide to Mine Water Geothermal Heating and Cooling*. The Guide is currently available by request for

former mining communities to learn about reusing the flooded mine in geothermal heat pump systems and how to assess the feasibility of such systems.

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## Appendix E: EPA P3 Phase II Grant Proposal

# EPA P3 Phase II Grant Proposal

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### *Proposal for Phase II*

#### **P3 Phase II Project Description**

##### ***Novelty and Evaluation***

The key objectives for Phase II are to:

- 1- Evaluate the Community Guide to Minewater Geothermal in additional case communities and revise it accordingly.
- 2- Develop and distribute a 7-9th grade curriculum around low-grade geothermal and opportunities for using mine water for geothermal energy.
- 3- Utilize existing networks to publish and distribute the guidebook

The Phase I edition of the guidebook reflects the opportunities and challenges found at our local partner community, Calumet, MI, and through our literature review on national and international minewater geothermal projects. Our Phase II project will focus on continued refinement of the guidebook, development of training and educational modules, and networking with local and national partners to present, publish and distribute the guidebook.

These goals will be accomplished through working with identified local and national experts and established networks. In Phase II, the team will travel to communities and locations identified through our national networks to present and workshop the guidebook. The aim of these workshops will be to introduce interested parties to the ideas and methods laid out in the guidebook and allow the MTU student team to gather feedback to continue to refine the guidebook. These workshop experiences will ultimately led to development of training modules for community leaders interested in applying the guidebook in their local areas. These modules will include workshop materials, ideas, and experiences from our work with our partners. They will be integrated into the Phase II version of the guidebook as additional resources for community leader to adopt for their own use. Our training modules will be developed with our partners at EPCAMR and OSMRE/VISTA (DOI/VISTA). Letters of support from the Executive Director of EPCAMR, the OSMRE/VISTA and DOI/VISTA Program Officer are attached as supporting documents.

Phase II will also include the development of educational and training modules on the topics of minewater geothermal, heat pump systems, and civic engagement. Educational modules will be developed with our local partners, the Michigan Tech Center for Science and Environmental Outreach and the Keweenaw Research Institute. The educational modules will be geared towards grade 7-9 STEM and social science educators, and will be developed to address

the Next Generation Science Standards. The need for these training modules was identified through our Phase I work. These modules will bridge the identified knowledge gap from Phase I (community understanding and awareness).

Another important part of Phase II project is continued interdisciplinary work through the service-learning course at Michigan Tech. This course will be taught by a continuing member of our project team, and will be advertised to attract students in a variety of disciplines and academic levels. Students will be asked to commit at least three semesters to the course to ensure project continuity and reinforce the, learn, act, reflect elements of service-learning course work.

The final element of our Phase II project will be presenting our P3 work at various national conferences and through various media. Working with our partner at the Pennsylvania Department of Environmental Protection, we have identified several mine reclamation themed conferences to attend. These conferences include the Pennsylvania Abandoned Mine conference and National Association of Abandoned Mine Land Programs annual conference. We will also be developing press releases for newsletters of interested groups. These activities will ensure that our project reaches the widest possible audience.

As our project is focused on the dissemination of the information contained in our guidebook, evaluation of the success of our project will focus on the development of our local and national networks. Evaluation methods will include; surveys conducted at our workshops, compilation of our press coverage, and development of a network to share best practices related to minewater geothermal projects. The aim of these methods is to evaluate the usefulness of our guidebook and related educational/training materials. Additionally, development of a process to share best practices will ensure the long-term sustainability of the project.

### ***Overall Sustainability of Proposed Project***

In Phase I, our aim was to create a guidebook to help interested communities evaluate the potential for mine water geothermal systems. Our work in Phase I clearly indicated that the implementation of minewater geothermal projects has the potential for positive impacts in the three areas of sustainability; people, prosperity and planet. In order for our Phase I work to have the largest and most sustained impact, we need to work with national networks to disseminate the information we compiled in Phase I. We will accomplish this through several outreach activities in Phase II. All of these activities will be done in conjunction with established national organizations. Our project partners have over 85 years of combined experience working with former mining communities. We will utilize that expertise to accomplish our goals for Phase II.

The overall aim of the Phase II project work will be widespread dissemination of the information contained in our guidebook. Through this work, we will further develop our guidebook and related educational modules to best suit a national audience. Working with national partners will help ensure the long-term success of this project. The potential for mine water geothermal systems to reduce air and water pollution through reduced electricity consumption and construction impacts; contribute to economic savings and community revitalization has been demonstrated through our literature and case study examples from Phase I. The missing piece of the puzzle has been accessible information for communities interested in pursuing mine water geothermal projects. Phase II work will focus on the creation of modules that will present the information in the guidebook through a variety of media. These modules will be focused on “training the trainer” and will be designed and implemented with our

local and national partners. Our Phase II work also includes the development of educational modules that will be accessible electronically for a variety of audiences. These modules will be developed with local collaborators and will be designed to spread awareness and understanding of the topics related to mine water geothermal, heat pumps, and civic engagement.

### ***Educational and Teamwork Aspects of the Proposal***

There are two major educational aspects to our proposal. The first is the interdisciplinary coursework component. The second is the educational modules that will be products of this course work. The course will continue to be interdisciplinary and include students in various departments and academic levels at MTU. The course itself will be non-traditional, including field work components and a 3 semester commitment. Michigan Tech is primarily an engineering school, and often times technical education lacks the social dimension. This course will allow engineering students to gather first-hand knowledge of how to work through a project in conjunction with communities. Additionally, it will allow students in non-technical fields to gain experience working with technical experts. These experiences will help create more robust graduates. The fieldwork component of this project will include working with actual community and national partners which will help students develop leadership skills.

The second educational aspect of our proposal is the educational modules we will be developing. The need for these modules were identified in our Phase I work as we struggled to identify existing educational materials related to and mine water geothermal and heat pumps. These modules will be developed collaboratively with local school teachers and will be geared towards school districts in former mining regions. The modules will be focused on grades 7-9 STEM and social sciences courses and will integrate with Next Generation Science Standards. The modules will be available electronically on the Tech Alive [website](#) and will be accessible to the public. This element of the project will provide educational benefits to local and national teachers and their students and our project team. Dissemination of the modules will be conducted through our local and national networks.

The teamwork aspects of our proposal include teamwork within our project group and teamwork with our partners. Our current project team includes students with backgrounds in civil and environmental engineering, mechanical engineering, anthropology, chemical engineering, scientific and technical communication, and community development. Students are also in various stages of their academic career including freshmen, juniors, seniors and graduate. While the specific mix of backgrounds within the project team may change, it will continue to be interdisciplinary and include all academic levels. In addition, development of the educational modules will include students in other courses (such as computer science). This interdisciplinary work may be new for many of the students, but is an important element of real-world work. Students will also need to develop and maintain working relationships with our project partners. These partners include former mining communities; state and federal environmental agencies; and regional and national coalitions and societies. Working with our partners will include virtual communications and field work. These interactions will help students' professional development.

### **Quality Assurance Statement**

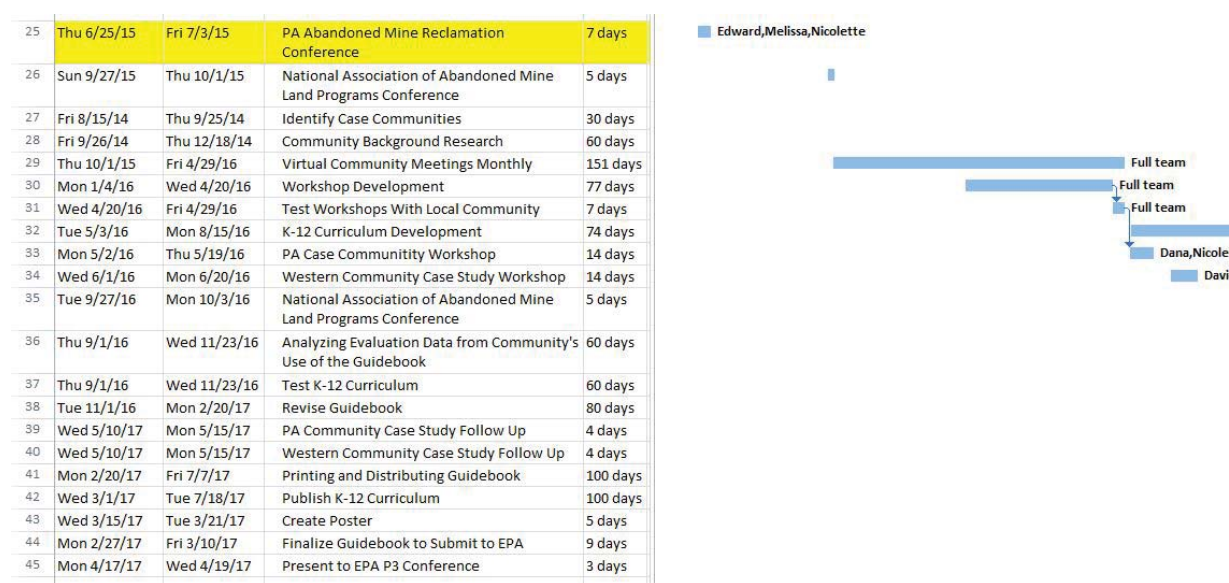
Human subject surveys and interviews will be conducted with the oversight of the institution's IRB. All researchers who will be conducting interviews or surveys will receive

training on the procedures and precautions surrounding this kind of research method. This training will be provided by the Collaborative Institutional Training Initiative (CITI). The names of those interviewed or surveyed will not be released in any published documents. All geospatial (ArcMap, Google Earth) modeling will be conducted with a write up of the data sources and data processing procedures such that the results can be repeated by a third party.

The Phase I edition of the guidebook has been reviewed by qualified people in Calumet, MI, a former copper mining community, and industry experts as detailed in the partnership section below. The Keweenaw Research Center, nearby, has an operational mine water geothermal system, staff familiar with the system has reviewed the Phase I edition of the guidebook. The phase II edition of the guidebook will be subjected to similar quality assurance reviews. The communities that the team partners with to test and expand the guidebook will also be reviewing the guidebook and its additions. Protocols for working with communities and the plans for data analysis will be reviewed by faculty and partners.

## Project Schedule

Below is a timeline showing significant steps, milestones, and the personnel assigned to each task in Phase II project.



## Workshops and Educational module development

The fall/spring 2015/2016 academic year will focus on developing and planning the community and teacher workshops; and preparing students for summer field work. The summer of 2016 will focus on implementation of the workshops and gather feedback on our guidebook and workshop modules. Continuing team members; Edward, Melissa, Nicolette, David, Dana, and Krista are candidates for conducting this research. Workshops and field data collection at each case community will be conducted by teams of two students. Each team will have a member with expertise in engineering and a member with expertise in social science research. Part of the Phase II grant funds will be used to fund students hourly during the summer to conduct this research. Workshops will be held at each case community and open to all interested community members and partnered organization leaders. Locations will likely be in Eastern PA

and the Rocky Mountains mining regions. Our second objective for the 2015/16 academic year is to develop 7-9th grade curriculum around low-grade geothermal, heat pumps, and cultural legacies of mining and change. We will work with the Michigan Tech Center for Science & Environmental Outreach to develop this curriculum. With the Center, we will host a curriculum development institute and work with 15 local teachers to develop educational modules. These modules will also be distributed utilizing our existing networks. These learning modules will focus on incorporation into the next generation science standards and be geared for STEM and social sciences classes.

The fall/spring 2016/17 academic year will focus on reflecting and analyzing the fieldwork experiences from Summer 2016; integrating lessons learned into the workshop modules; gathering feedback on the educational modules; and creating *A Community Guide to Minewater Geothermal Heating and Cooling 2.0*.

### ***Local and national outreach***

In addition to the community workshops that will be held in conjunction with our partners, we will also disseminate our P3 Project work through attendance at national conferences. Potential conferences have been identified by our partners and include the Pennsylvania *Abandoned Mine Lands (AML)* conference in June 2016, the NAAPL conference, and the SME conference in September of 2016.

### ***Course description***

The course related to the implementation of this project will be an interdisciplinary service-learning focused course. The Phase II course and project work will be taught, lead, and monitored by a PhD candidate (Edward and Nicolette are candidates). The course will require a three semester commitment for interested students to help insure project continuity and reinforce the, learn, act and reflect components of service-learning courses. This arrangement will be overseen by the faculty PI, Dr. Winkler.

Similar to Phase I, the progress towards a refined, relevant guidebook will be assessed by our partners described below. These partners are members of a former underground mining communities and/or have a mine water geothermal system installed already. The project's success will be measured by the feedback these reviewers give.

### **Partnerships**

Our partners consist of local and national networks of organizations and individuals. For Phase I, our partners were primarily local organizations and individuals. Without the support of the following groups and individuals, our Phase I project would not have been possible: Main Street Calumet, Keweenaw National Historical Park, Calumet Electronics, and Calumet-Laurium-Keweenaw School system; our community advisory board of Elmore Reese, Tom Tikkanen, Bob Langseth, David Geisler, Lorri Oikarinen, John Rosemurgy, Darryl Pierce, and Brian Taivalkoski. Within the Michigan Tech community; Jay Meldrum and Chris Green from the Keweenaw Research Center; and other faculty and staff at MTU.

Our partners for Phase II include; Michael Korb of the Pennsylvania Department of Environmental Protection Bureau of Abandoned Mine Reclamation and the author of "Minepool Geothermal In Pennsylvania". He has been acting as an outside reviewer of our guidebook, and

has encouraged us to participate in a number of conferences and has helped identify communities to partner with to test the guidebook. T. Allan Comp of the Office of Surface Mining Reclamation and Enforcement and the larger OSMRE/VISTA and DOI/VISTA network he represents. Through Michael Korb, we have also been in contact with a larger network of PA-based environmental organizations, including the EPCAMR. Robert Hughes, the executive director of that coalition has also agreed to partner with us for Phase II. Joan Chadde from the Michigan Tech Center for Science & Environmental Outreach will assist us in development of the educational modules.

### **EPA Human Subjects Research Statement, HSRS**

All researchers involved with interviews and surveys with the public have received IRB human subject training. Phase I of the project received exempt status from the IRB. The Phase II project tasks are in line to received exempt status as well.

## Appendix F: Permissions to use copyrighted materials

The professional report to Calumet, MI titled “Exploring the Social Feasibility of Minewater Geothermal in Calumet” in Appendix A, contains images and figures not created by the authors. Below are the permissions letters authorizing the use of the images and figures and an explanation as to why certain images and figures do not have or need a permission letter. All other images, figures, and tables not specified below are copyrighted by the authors.

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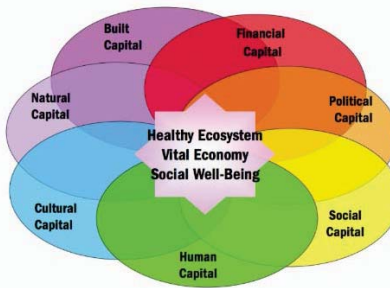
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Date: 4/26/2015

Dear Dr. Flora and Dr. Flora,

I am completing a masters report at Michigan Tech University which contains a collection of professional reports which I was an author or co-author to in the appendices. One of the professional reports, titled "[Exploring the Social Feasibility of Minewater Geothermal in Calumet](#)" contains a figure illustrating the community capitals framework. The figure or the concept of the figure originated from your book *Rural Communities*. I would like to ask your permission to reprint the following figure in my masters project report and retroactively ask for your permission to use the following figure in the aforementioned report.



The figure above was obtained through Ohio State University's [website](#) which featured it to advertise the 2014 Community Capitals Framework Institute conference on November 5-7, 2014.

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If these arrangements meet with your approval, please sign this letter where indicated below and return it to me as an attachment in an email. Thank you very much.

Sincerely,  
Edward Louie

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

Dr. Cornelia Flora and Dr. Jan Flora

Signature: \_\_\_\_\_

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Date: 4/26/2015

Dear Mike Forgrave,

I am completing a masters report at Michigan Tech University which contains a collection of professional reports which I was an author or co-author to in the appendices. One of the professional reports, titled "[Exploring the Social Feasibility of Minewater Geothermal in Calumet](#)" contains a picture of a capped mineshaft in Calumet. That picture, on page 12, came from your website. I am sorry neither I nor anyone else involved with the document at the time took the effort to contact you and ask you for permission before using and publishing that report to the public. I would like to retroactively ask you for your permission to use that image in the aforementioned report and for permission to reprint the image in my masters report which contains that report. The image came from the [Calumet No. 3](#) page of your website [coppercountryexplorer.com](http://coppercountryexplorer.com)



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If these arrangements meet with your approval, please sign this letter where indicated below and return it to me as an attachment in an email. Thank you very much.

Sincerely,  
Edward Louie

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

Mike Forgrave,

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

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Joan LaRoche  
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Date: 4/26/2015

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Dear Elmore Reese and Joan LaRoche,

I am completing a masters report at Michigan Tech University which contains a collection of professional reports which I was an author or co-author to in the appendices. One of the professional reports, titled "[Exploring the Social Feasibility of Minewater Geothermal in Calumet](#)" contains a picture take from your website. I am sorry neither I nor anyone else involved with the document at the time took the effort to contact you and ask you for permission before using and publishing that report to the public. I would like to retroactively ask you for your permission to use the image below in the aforementioned report and for permission to reprint the image in my masters report which contains that report. Here is the link to the image:

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If these arrangements meet with your approval, please sign this letter where indicated below and return it to me as an attachment in an email. Thank you very much.

Sincerely,  
Edward Louie

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

Elmore Reese and/or Joan LaRoche

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

The EPA P3 Phase I Grant Proposal in Appendix B contains no material which would warrant needing a permission letter.

The guidebook in Appendix C Community Guide to Mine Water Geothermal Heating and Cooling contains the following copyrighted figures, in which permission letters were obtained, shown below. All other images, figures, and tables not specified below are copyrighted by the author.

- Figure 1. See Permission letter below
- Figure 2. See Permission letter below
- Figure 3. See Permission letter below
- Figure 4. Permission letter not needed, author generated map in GIS using federal government data.
- Figure 5. Permission letter not needed, figure is sourced from the federal EPA.
- Figure 6. Permission letter not needed. The use and attributions fits within the Google's print permission and attribution guidelines.
- Figure 7. See Permission letter below
- Figure 8. See Permission letter below
- Figure 9. Permission letter not needed, figure is sourced from the Michigan DEQ.
- Appendix F, Figure 1. See the permission letter below

## Figure 1 Permission Letter

Edward Louie  
Academic Office Building 209  
Michigan Tech University  
1400 Townsend Dr.  
Houghton, MI 49931  
Email: [eplouie@mtu.edu](mailto:eplouie@mtu.edu)  
Cell: 503-961-3652

Date: 3/31/2015

Mr. Gilles Tremblay and Ms. Charlene Hogan  
[gtrembla@nrcan.gc.ca](mailto:gtrembla@nrcan.gc.ca)  
[chogan@nrcan.gc.ca](mailto:chogan@nrcan.gc.ca)

Dear Mr. Gilles Tremblay and Ms. Charlene Hogan,

I am completing a masters project report at Michigan Tech University entitled “Writing a Community Guidebook for Evaluating Low-grade Geothermal Energy from Flooded Underground Mines for Heating and Cooling Buildings.” I would like your permission to reprint in my masters project report the following image:

The International Network for Acid Prevention (INAP). (2012). Global Acid Rock Drainage (GARD) Guide.

The excerpt to be reproduced is: [Figure 4-4: Sources and Pathways of ARD, NMD, and SD in Underground Workings during Operation and Closure](#)

The requested permission extends to any future revision and editions of my project report, including non-exclusive world rights in all languages, and to the prospective publication of my project report by the Michigan Tech Library database. The Michigan Tech Library database may produce and sell copies of my project report on demand and may make my project report for free internet download at my request. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own [or your company/organization owns] the copyright to the above described material.

If these arrangements meet with your approval, please sign this letter where indicated below and return it to me as an attachment in an email. Thank you very much.

Sincerely,

Edward Louie

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

Gilles Tremblay and Charlene Hogan

Date: \_\_\_\_\_

Figure 2 Permission Letter

Edward Louie  
Academic Office Building 209  
Michigan Tech University  
1400 Townsend Dr.  
Houghton, MI 49931  
Email: [eplouie@mtu.edu](mailto:eplouie@mtu.edu)  
Cell: 503-961-3652

Date: 3/31/2015

Kevin Rafferty, P.E.  
PO Box 1935  
Klamath Falls, OR 97601  
Email: [tripower@bmi.net](mailto:tripower@bmi.net)  
Phone: 541-783-3324

Dear Mr. Kevin Rafferty,

I am completing a masters project report at Michigan Tech University entitled "Writing a Community Guidebook for Evaluating Low-grade Geothermal Energy from Flooded Underground Mines for Heating and Cooling Buildings." I would like your permission to reprint in my masters project report the following figure:

Rafferty, K. (2001). *An information survival kit for the prospective geothermal heat pump owner*. Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, OR.

The excerpt to be reproduced is: [Figure 1](#) on Page 2.

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If these arrangements meet with your approval, please sign this letter where indicated below and return it to me as an attachment in an email. Thank you very much.

Sincerely,

Edward Louie

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

International Ground Source Heat Pump Association

Kevin Rafferty, P.E.

Date: \_\_\_\_\_

Figure 3 Permission Letter

Edward Louie  
Academic Office Building 209  
Michigan Tech University  
1400 Townsend Dr.  
Houghton, MI 49931  
Email: [eplouie@mtu.edu](mailto:eplouie@mtu.edu)  
Cell: 503-961-3652

Date: 3/31/2015

International Ground Source Heat Pump Association (IGSHPA)  
1201 S Innovation Way, Suite 400  
Stillwater, OK 74074  
Email: [igshpa@okstate.edu](mailto:igshpa@okstate.edu)  
Phone: 405-744-5175

Dear International Ground Source Heat Pump Association (IGSHPA),

I am completing a masters project report at Michigan Tech University entitled “Writing a Community Guidebook for Evaluating Low-grade Geothermal Energy from Flooded Underground Mines for Heating and Cooling Buildings.” I would like your permission to reprint in my masters project report the following illustration:

International Ground Source Heat Pump Association (IGSHPA). (2013). What is a ground source heat pump? Available from: <http://www.igshpa.okstate.edu/geothermal/>

The excerpt to be reproduced is: [geothermal.gif](#)

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If these arrangements meet with your approval, please sign this letter where indicated below and return it to me as an attachment in an email. Thank you very much.

Sincerely,

Edward Louie

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

International Ground Source Heat Pump Association

By: \_\_\_\_\_

Title: \_\_\_\_\_

Date: \_\_\_\_\_

## Figure 7 Permission Letter

Edward Louie  
Academic Office Building 209  
Michigan Tech University  
1400 Townsend Dr.  
Houghton, MI 49931  
Email: [eplouie@mtu.edu](mailto:eplouie@mtu.edu)  
Cell: 503-961-3652

Date: 3/31/2015

David Robinson  
Email: [david@geography-site.co.uk](mailto:david@geography-site.co.uk)

Dear Mr. David Robinson,

I am completing a masters project report at Michigan Tech University entitled "Writing a Community Guidebook for Evaluating Low-grade Geothermal Energy from Flooded Underground Mines for Heating and Cooling Buildings." I would like your permission to reprint in my masters project report the following figure:

Robinson, D. (2006). River Gradient. In *The Geography Site*. Available from: <http://www.geography-site.co.uk/pages/skills/fieldwork/fluvial/grad.html>

The excerpt to be reproduced is the [diagram of the clinometer](#).

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If these arrangements meet with your approval, please sign this letter where indicated below and return it to me as an attachment in an email. Thank you very much.

Sincerely,

Edward Louie

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

The Geography Site

David Robinson

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

## Figure 8 Permission Letter

Edward Louie  
Academic Office Building 209  
Michigan Tech University  
1400 Townsend Dr.  
Houghton, MI 49931  
Email: [eplouie@mtu.edu](mailto:eplouie@mtu.edu)  
Cell: 503-961-3652

Date: 3/31/2015

Peter Op 't Veld  
Email: [p.optveld@huygen.net](mailto:p.optveld@huygen.net)

Dear Peter Op 't Veld,

I am completing a masters project report at Michigan Tech University entitled "Writing a Community Guidebook for Evaluating Low-grade Geothermal Energy from Flooded Underground Mines for Heating and Cooling Buildings." I would like your permission to reprint in my masters project report the following figure:

Op 't Veld, Peter. (2008). REMINING LOWEX Redevelopment of European Mining Areas into Sustainable Communities by Integrating Supply and Demand Side based on Low Exergy Principles. In FP6 Concerto II. Available from: [http://www.energy-in-minds.de/PDF/Other\\_documents/REMINING\\_general%20presentation.pdf](http://www.energy-in-minds.de/PDF/Other_documents/REMINING_general%20presentation.pdf)

The excerpt to be reproduced is the image on slide 14 which diagrams the mine water geothermal system in Heerlen.

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If these arrangements meet with your approval, please sign this letter where indicated below and return it to me as an attachment in an email. Thank you very much.

Sincerely,

Edward Louie

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

Peter Op 't Veld

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

Appendix F, Figure 1 Permission Letter

Edward Louie  
Academic Office Building 209  
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1400 Townsend Dr.  
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Email: [eplouie@mtu.edu](mailto:eplouie@mtu.edu)  
Cell: 503-961-3652

Date: 3/31/2015

Brian R. Murphy  
Department of Fish and Wildlife Conservation (0321)  
442 Latham Hall 220  
Ag Quad Lane  
Blacksburg, VA 24061  
Email: [murphybr@vt.edu](mailto:murphybr@vt.edu)  
Phone: 540-231-6959

Dear Dr. Brian R. Murphy,

I am completing a masters project report at Michigan Tech University entitled “Writing a Community Guidebook for Evaluating Low-grade Geothermal Energy from Flooded Underground Mines for Heating and Cooling Buildings.” I would like your permission to reprint in my masters project report the following image to showcase a Kemmerer sampler:

Murphy, B. R., Willis, D. W. (1996). Fisheries Techniques 2nd edition. Published by American Fisheries Society. Companion visuals in [American Fisheries Society Education Section](#), Chapter 4, Additional figures.

The excerpt to be reproduced is this [image](#) of a Kemmerer sampler.

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If these arrangements meet with your approval, please sign this letter where indicated below and return it to me as an attachment in an email. Thank you very much.

Sincerely,

Edward Louie

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

Brian R. Murphy

Signature: \_\_\_\_\_  
Date: \_\_\_\_\_

The EPA P3 Phase I Project Report Summary in Appendix D contains no material which would warrant needing a permission letter.

The EPA P3 Phase II Grant Proposal in Appendix E contains no material which would warrant needing a permission letter.