Mine Pool Geothermal: Opportunities in West Virginia

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Mine Pool Geothermal in West Virginia

Christine Risch

Director of Resource and Energy Economics, Center for Business and Economic Research

William Sheils, MBA

Research Associate, Center for Business and Economic Research

Marshall University

One John Marshall Dr.

Huntington, West Virginia 25701

Phone: (304) 696-5747

EXECUTIVE SUMMARY

This report is the second in a series of steps toward development of mine pool geothermal resources in West Virginia. The objective is to help West Virginia capitalize on this resource and enable energy savings and possible future economic development in the State's mining regions. Mine pools are passive, low-temperature geothermal resources that are energy saving opportunities for businesses and institutions located near the pools.

Underground mines often contain very large pools of water at very stable temperatures. This water, once transported to the surface, can transfer heat that can make heating and air conditioning more efficient. Water-source heat pumps are said to be the easiest and least expensive type of geothermal system to install because these projects do not require the extensive digging and trenching that ground-source projects do. In addition, water provides better heat transfer than earth and a large waterbody is an excellent heat sink.

Mine pool resources are considered to be quite versatile due to the wide range of possible end-users. Public buildings such as hospitals, commercial facilities, and universities with year-round and round-the-clock heating and cooling needs are considered ideal users, as are server farms and manufacturing processes with high cooling requirements.

Former coal-mining areas in Nova Scotia and Pennsylvania have been utilizing mine pool water for decades and are excellent sources of expertise for West Virginia. A large, flooded mine under the town of Springhill in Cumberland County, Nova Scotia has made that area a continental leader in use of the resource. Several manufacturing facilities and public buildings are already utilizing the mine water to heat and cool interior space, and the county has plans to create a geothermal district that will house a 100-acre business park.

Every facility surveyed for this study in North America reported a payback of five years or less for each investment. The closest system to West Virginia is in Scranton, Pennsylvania where Marywood University installed a geothermal cooling system for a 30,000 square-foot space as a retrofit to its existing system. The system cost $530,000 in 2010, but the resulting savings from cooling operations alone allowed the investment to be paid back in under three years.

Mine pool geothermal systems are typically installed as retrofits to existing facilities. However, in the future there may be opportunities to build new facilities near the mine pools to take advantage of the low-cost energy the resource provides. The energy efficiency features of this resource will become more important as energy costs rise.

The West Virginia Geological and Economic Survey (WVGES) is a key resource to understanding the mine pool resource in the State. The WVGES estimated the capacity of several dozen mine pools and this data shows that many pools in West Virginia are more than large enough to utilize this resource.

With input from the WVGES, pools located below population centers were selected as candidates for further engineering analysis. These pools are located in both northern and southern West Virginia. Mine pools located below existing businesses and facilities provide the best opportunities for development as no new infrastructure would be required. Schools and government agencies are excellent candidates because these institutions remain in place for decades and can reap multi-year benefits from energy savings.

Most of the places of interest identified in this study are K-12 schools and universities. Examples are Fairmont State University, which is located above or next to Bethlehem Mines No. 41, and Appalachian Bible College in Mt. Hope, located above the Cranberry Mine. Other public facilities above mine pools include the Mine Safety & Health Administration's Triadelphia office, the Northern Regional Correctional Facility in Moundsville, and the McDowell Federal Prison in Welch.

An engineering analysis is the next step to assess these resources in West Virginia. Some mine pool sites are more complex than others due to differences in age, size, and potentially competing use by public water systems. A study will need to evaluate geological information to assess how to approach and access the mine pool.

Water quality is an important aspect of development as many of the mine pools in northern West Virginia are in acid-producing coal seams, which will cause rapid sediment buildup and clog equipment. The southern West Virginia mine pools identified are generally in coal seams that do not have this issue.

Some mine pools are quite old and may not be good candidates for development as little to no records exist regarding the history of the mines. These include pools in mines above the towns of Glen Dale, McMechen, Mount Hope, and Oak Hill.

A parallel next step would be identification of an existing facility as an interested adopter that is able to retrofit a space conditioning system. This would also entail determining whether to implement an open vs. closed-loop system or whether the resource is best used for heating, cooling or both.

Globally, mine pool geothermal systems can be designed independent of reservoir size and have been observed with a range of water temperature of 43 to 82° F and mine depths from 50 to 700 m. Cooler water is expected for West Virginia's mine pools, which may mean that cooling is a more appropriate application than heating.

The cost of a mine pool geothermal system varies by configuration and the size of the building to be conditioned. Examples studied range from 8,100 to 151,000 ft^2 and the range of costs for U.S.-based projects was \$100,000 to \$530,000 (\$150,000 to \$750,000 in \$2021). Years to payback for these same facilities was reported between two and five years.

All the mine pool projects studied are located directly above the source. Additional pipeline and pumping costs would be incurred if a project were developed further away.

Next steps for West Virginia are to study systems in place in the United States and Canada, and to design an approach to assess some of the mine pools in the State. That assessment will incorporate geological data regarding pool size, depth, location relative to potential users, water quality, location in the mine relative to drainage, mine age, competing uses of the resource. Institutional and corporate knowledge of the pool will be very important. A simultaneous effort should be to identify interested users that are potential candidates to utilize a pool.

A mine pool geothermal project can save energy and lower energy costs, reduce associated emissions from avoided energy consumption, and provide a way to benefit from closed underground coal mines that are currently seen only as liabilities. Mine pool geothermal projects simultaneously promote energy efficiency and preserve mining history. These projects are potential ways to bring economic activity to former coal mining areas and contribute to a positive legacy for the coal industry.

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Introduction

Underground mines often contain very large pools of water at very stable temperatures. These mine pools are passive, low-temperature geothermal resources. This water, once transported to the surface, can transfer heat that can make heating and air conditioning more efficient. It has been said that "water from a mine is a terrible thing to waste."[1]

Conventional passive geothermal systems utilize the relative temperature of the ground to make heating and air conditioning more efficient. Both conventional and mine pool systems can provide substantial energy and cost savings, which is a benefit that alone is enough to merit consideration of this resource. Use of geothermal energy can also shrink a facility's carbon footprint by reducing emissions from displaced conventional energy sources.

There are multiple examples demonstrating the near-term value and return of installed mine pool geothermal systems in North America. These include several in Nova Scotia in Cumberland County and the former town of Springhill, and the towns of Scranton and Kingston in Pennsylvania. These systems vary in age, scale, function, and cost, but the common element shared by them is an observable energy savings compared to conventional systems. In Scranton, Pennsylvania an investment by Marywood University in a mine pool system below the school to cool a single building provided a payback of less than three years in terms of energy cost savings (Greenman-Pederson, Inc. n.d.).

This report is an initial step toward examining the mine pool geothermal resource in West Virginia as an opportunity to provide future energy savings for businesses and institutions. The objective for West Virginia is to begin an evaluation of the resource for possible development in key areas across the State.

Factors that have limited the exploitation of geothermal energy from mine pools include relatively low costs of conventional energy costs and incomplete information about the location and condition of underground mine workings (Watzlaf 2006). The dislike of the coal industry is likely another reason (Korb, Minepool Geothermal in Pennsylvania 2012). Also, because mining companies are required to treat mine water, mine water has always been considered a liability. This is an incomplete view as it does not consider the potential of mine water as an energy efficiency resource.

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[1] From a 2007 U.S. Department of Energy presentation titled "U.S. Mining Regions –The Saudi Arabia of Geothermal Energy" by Terry E. Ackman and George Watzlaf.

West Virginia's Mine Pool Resources

West Virginia's vast network of abandoned mines contain many mine pools that are viable sources of geothermal energy. Coal mining has taken place within most of West Virginia's 55 counties, but the most prominent areas of historical activity for deep mines lie within the state's south central, north central, and northern panhandle regions.

The *West Virginia Mine Pool Atlas* is a key report published by the WVDEP and the West Virginia Geological and Economic Survey's (WVGES) Coal Bed Mapping Program to evaluate the potential for abandoned underground coal mines to serve as sources of large volumes of groundwater (West Virginia Geological & Economic Survey 2012). The report:

- Evaluated coal seams with heavy underground mining to determine which parts of the seam are above, near, and below major drainage.
- Estimated maximum mine pool volume of each seam.
- Prepared maps of each major mine pool.

Originally, the Atlas was expected to reveal large sources of water supplies to support processes such as aquaculture, public supply, coal-to-liquid hydrocarbons, hydraulic fracturing water for gas wells, and power plant cooling. Use of mine pools to improve the efficiency of heating and cooling will not preclude these uses in the future, while the converse may not be true as those uses are consumptive and may deplete the water.

Coal Seams

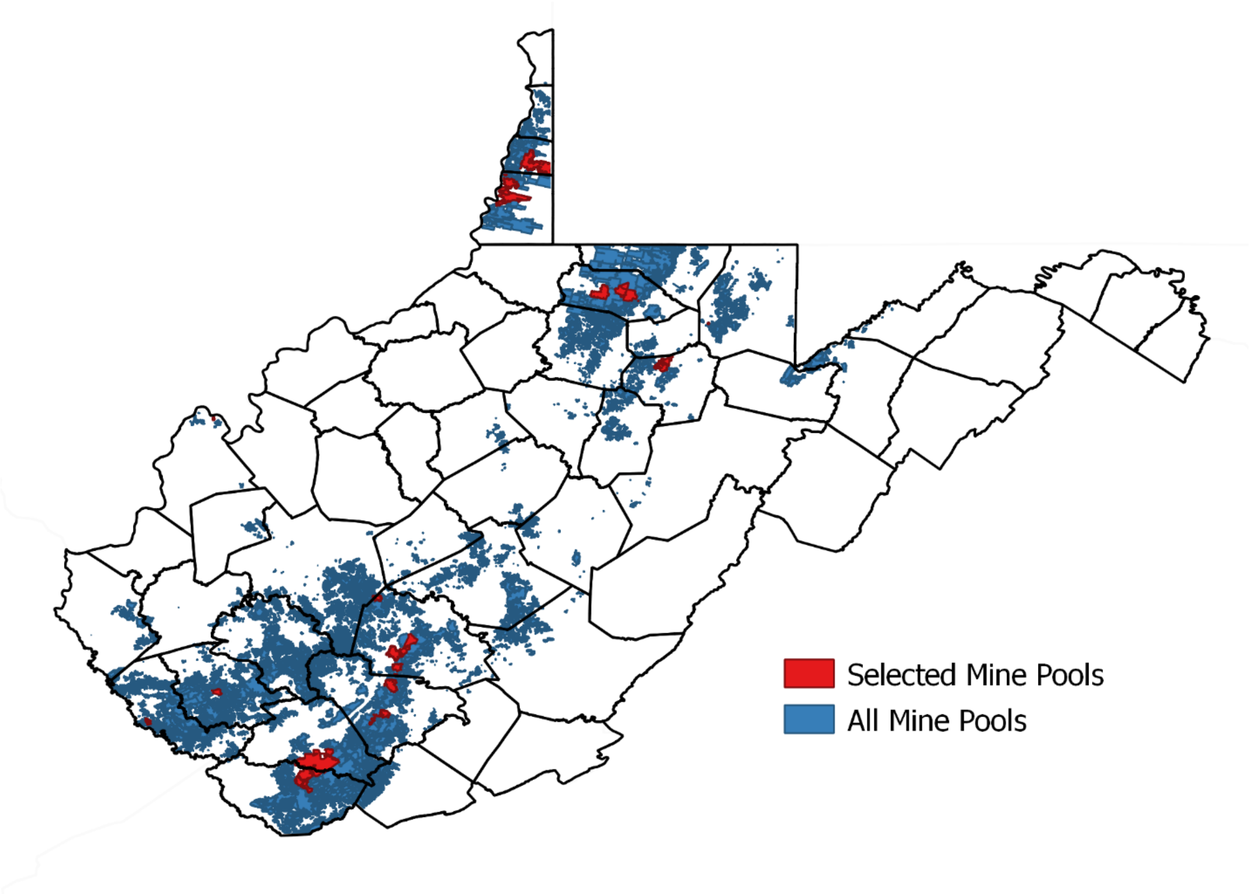
Among the collection of sources of mine pools the Pittsburgh coal seam, located within the Upper Pennsylvanian Monongahela Formation, may be the largest. The Pittsburgh seam is a 1,912 square-mile area comprised of western Pennsylvania and northern West Virginia that is estimated to have 1.36 trillion gallons of mine water stored underneath 5,000 square miles of land (Korb 2012). It is estimated that 30 percent of this water could be extracted from and returned to the seam without substantial long-term consequences from the resulting transfer of heat (Watzlaf 2006).

Within the Lower Pennsylvanian New River Formation, the Sewell and Beckley seams have the greatest potential for containing totally or partially flooded mine voids. Mines in the other coal beds tend to be small, are generally above drainage, and therefore contain limited potential for storing significant volumes of groundwater (West Virginia Geological & Economic Survey 2012).

In the southern portion of West Virginia, many mine pools are within the Pocahontas and Sewell coal seams. The seam runs diagonally from southwest to northeast, stretching as far south as McDowell County and as far north as Tucker County.

The following map depicts the location of all mine pools in West Virginia. The red pools were selected for initial further analysis as they are located below population centers with existing businesses and facilities that may be able to take advantage of the resource.

Map of West Virginia Mine Pools and Pools Selected for Further Analysis



Mine Pools Below Towns

By capacity alone, West Virginia houses enormous potential for geothermal energy applications. There are multiple mine pools in West Virginia, with the size of several pools larger than the resource in Cumberland County, Nova Scotia, a continental leader in utilization of this resource. The size of the mine pool beneath the former town of Springfield, Nova Scotia is approximately three billion gallons (Hickey 2021). In West Virginia, there about 20 mines under towns with storage capacity of more than one billion gallons and 12 of these mines have a capacity of more than three billion gallons (WVGES 2020). Mine pools below populated areas should be the first to be assessed as these are best positioned to be engineered to provide space conditioning for existing establishments.

The following table is a list of closed mines with pools that are located directly below towns and that are estimated to have storage capacity of more than 250 million gallons. Additional closed mines below towns, but with smaller pools, also exist. It is assumed that these larger pools would be the first to be evaluated via an engineering study. Four of these mines are still operating and may become resources in the future once mining is complete. More recently closed mines are also presumed to be better prospects due to access to engineering records.

Towns Above Closed Mines With Mine Pools > 250 Million Gallons

Town	Mine(s)	Storage Gallons	Coal Seam	Year Closed
Beckley	Cranberry	2.5 billion	Sewell	<1980s
Bethlehem	Shoemaker	12.9 billion	Pittsburgh	Still operating
Blacksville	Blacksville No. 1	430 million	Pittsburgh	Still operating
Fairmont	Bethlehem #41	7.9 billion	Pittsburgh	1980s to 2000s
Fairview	Loveridge	27 billion	Pittsburgh	Still operating
Farmington	Bethlehem #44 and #8	8.2 and 4 billion	Pittsburgh	<1980s
Glen Dale	Glendale	1 billion	Pittsburgh	<1950s
Grant Town	Federal No. 1	18.9 billion	Pittsburgh	Still operating
Mannington	Joanne	8 billion	Pittsburgh	1980s to 2000s
McMechen	Hitchman	3.4 billion	Pittsburgh	<1950s
Moundsville	Alexander, Panama, Parrs Run	5.8, 0.8, and 0.9 billion	Pittsburgh	<1980s
Mount Hope	Sun	1.7 billion	Sewell	<1950s
Oak Hill	Lochgelly, Oakwood, Whipple	2.1, 2.8 and 1.4 billion	Sewell	<1980s
Sophia	Keystone No. 4, Lillybrook	500 and 900 million	Pocahontas 3 & Pocahontas 6	1980s to 2000s
Welch	Pinnacle, Shannon Branch, Poca No. 4	15.9, 5.9,1.4, and 0.6 billion	Pocahontas 3 & Pocahontas 4	1980s to 2000s
Triadelphia	Valley Camp #3	12.1 billion	Pittsburgh	1980s to 2000s
Williamson	Jade Energy	300 million	Lower Powellton	1980s to 2000s

Source of storage gallons and seam: West Virginia Geological and Economic Survey, 2020.

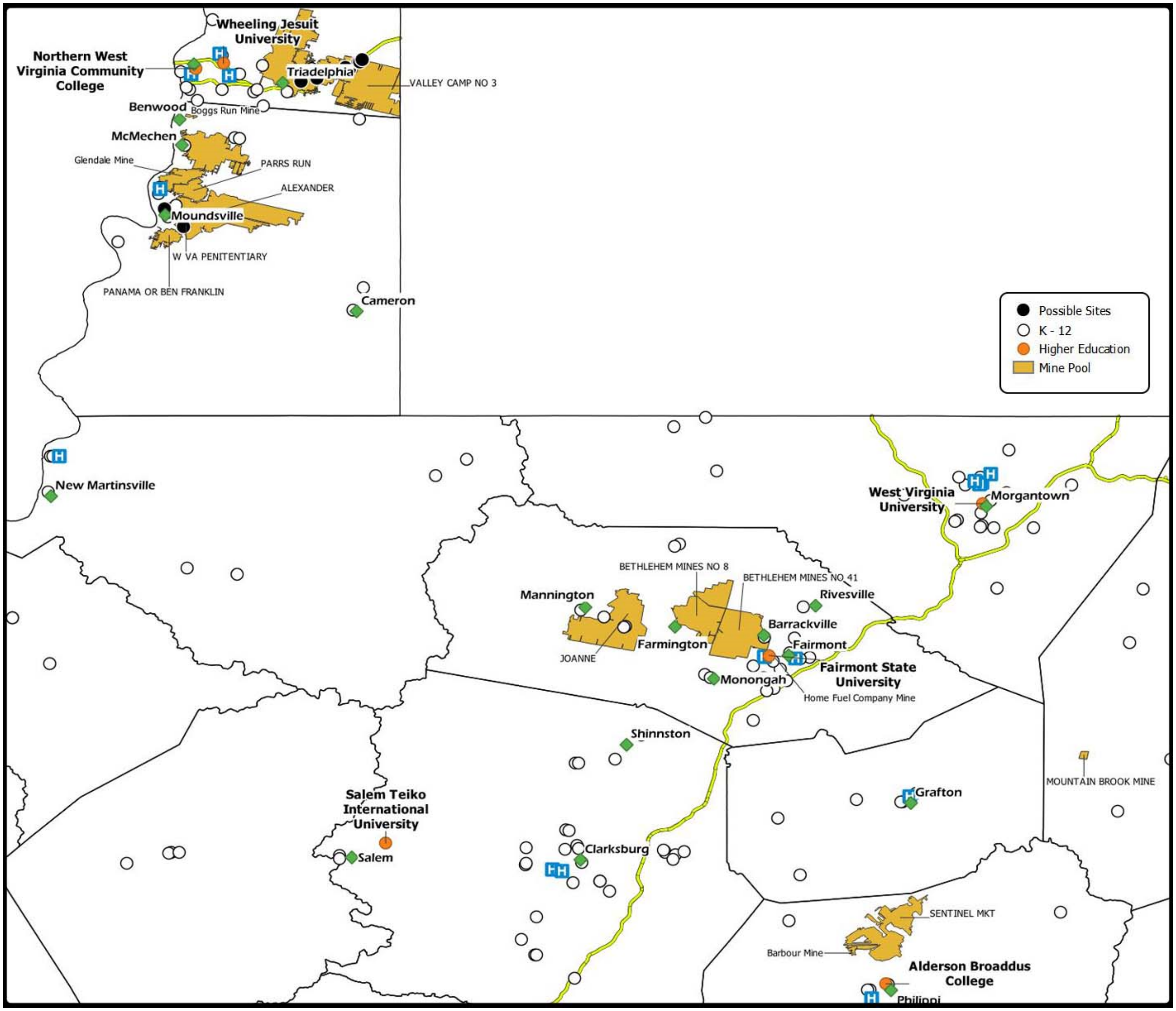
These mines have options for utilization of their mine pools based on economic activity within the towns above them. Most of the places of interest are K-12 schools and universities, including Fairmont State University and Appalachian Bible College in Beckley. Other public facilities include the Mine Safety & Health Administration’s (MSHA) Triadelphia office and the Northern Regional Correctional Facility in Moundsville.

In the following maps, K-12 schools and universities are marked to show proximity to mines with mines pools. Other possible sites marked and are establishments with large climate-controlled spaces like malls, general merchandise stores, hotels, manufacturers, and public buildings. The collection of public buildings includes the Northern Regional Correctional Facility in Moundsville and the McDowell Federal Prison in Welch.

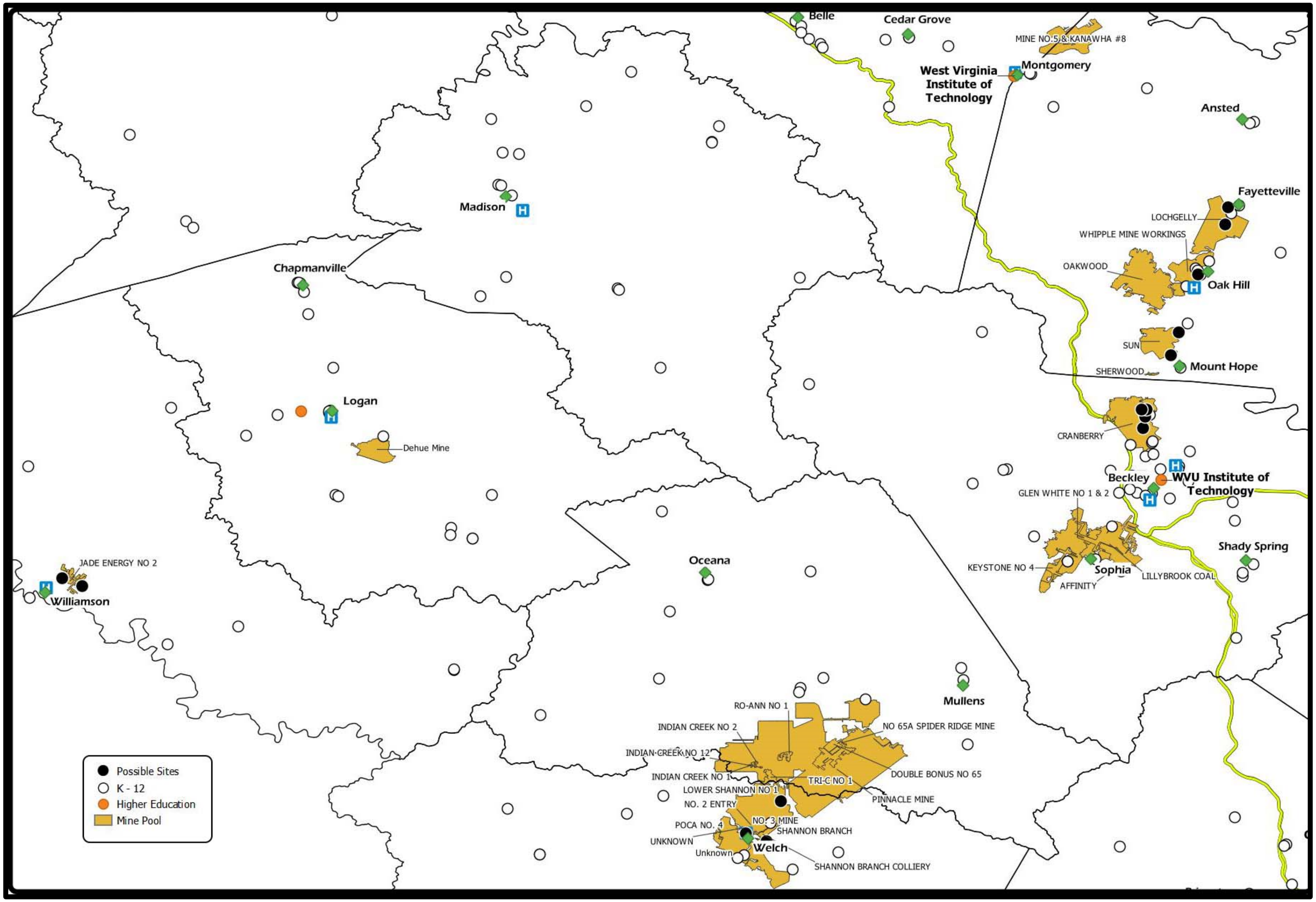
For example, in Northern West Virginia the Valley Camp No. 3 mine near Triadelphia is located beneath three manufacturers, a shopping mall, general merchandise stores, a high school, two hotels, and a MSHA office. In Southern West Virginia near Beckley the Cranberry Mine is located beneath two schools, a mall, a hotel, and the Appalachian Bible College. The Sun mine near Mount Hope is beneath a National Military Recruiting Center and the JW and Hazel Ruby Welcome Center for the Summit Bechtel Boy Scout Reserve.

Additional data are available on mine pools located within one mile of a town (WVGES 2020). Developing these pools would likely require longer pipelines to access the resource.

Map of Northern West Virginia Mines with Mine Pools Below Towns



Map of Southern West Virginia Mine Pools Below Towns



Features of Mine Pool Geothermal Systems

Geothermal heat pumps have greater efficiency than air-source heat pumps when the source/sink temperature (the mine pool) is closer to desired space conditions than outdoor air temperatures. As described by the primary geothermal trade association in the U.S., as it gets colder outside air source heat pumps lose efficiency while geothermal heat pumps continue high efficiency because it's hard to extract heat from outside air as it gets colder. Geothermal heat pumps are not subject to drastic temperature fluctuations, because they're coupled to the temperature in the shallow earth, which ranges between about 45 and 75 degrees in the US (Geothermal Rising 2021).

Water-source heat pumps are said to be the easiest and least expensive type of geothermal system to install. This is because water-source geothermal projects do not require the extensive digging and trenching that is needed for burying loop pipelines needed for ground-source projects. In addition, water provides better heat transfer than earth and a large waterbody provides an excellent heat sink (Korb 2018).

Open vs. Closed-Loop

In an open-loop system thermally spent water is reinjected into the mine pool after circulating through the user facility. In a closed-loop system, mine water is not collected but merely heats or cools water, or another heat transfer fluid, circulated from the surface. A key advantage of an open-loop system is that it is scalable, while a primary disadvantage is dealing with the presence of dissolved metals and contaminants that can clog equipment. Conversely, a primary advantage of closed-loop systems is control of the quality of the fluid, with a key disadvantage being less scalability as well as slightly lower overall efficiency (Banks 2017).

Type of System (Heating vs. Cooling)

Geothermal systems can be designed to heat, cool, or both heat and cool depending on facility need. The type of system deployed can be determined based on analysis of the seasonal heating and cooling load of a facility.

Energy Savings

While each geothermal system is different, observation of systems in place produces expected energy savings that are considerable. A study by engineers at Tetra Tech found that compared to conventional air-source heat pumps and natural gas systems, geothermal heating/cooling systems “can save 40 to 65 percent in heating costs, 30 percent in cooling costs, and 15 percent for hot water costs.” Furthermore, these systems generate a “55 to 70 percent” reduction in a typical facility’s carbon footprint (Korb, Leadership Opportunity:

Pennsylvania Should Make Mine Water Geothermal A Key Part Of Its Clean Energy Transformation 2018).

The National Energy Technology Laboratory (NETL) released a similar study of flooded underground coal mines. It found that such systems could reduce annual heating costs by up to 70 percent over standard oil and gas systems, and cooling costs by up to 50 percent over standard air conditioning (National Energy Technology Laboratory 2007).

The Cumberland Energy Authority in Nova Scotia is a leader in promotion of mine pool geothermal resources. The Authority conducted a recent study evaluating the energy savings for facilities that are using its mine pool resource. Compared to median consumption for comparable benchmark facilities, energy savings ranged from 11.9 to 43.6% (EfficiencyOne Services 2017).

Costs

The cost of a mine pool geothermal system varies by configuration. Demand for geothermal energy is a function of the space of a building to be conditioned. Examples studied range from 8,100 to 151,000 ft^2. The range of costs for U.S.-based projects identified in this study is $100,000 to $530,000 ($150,000 to $750,000 in current prices). Years to payback for these same facilities was reported between two and five years.

This payback range matches that of an analysis by Dalhousie University in Canada using a model produced by the Canadian Geothermal Energy Association. That analysis indicated that a capital investment of $500,000 for a simple geothermal heating system can be repaid in energy cost savings in 5 years, and that a combined geothermal heating and cooling system could be repaid in approximately 5.3 years (Dalhousie University 2015).

It should be noted that all the mine pool projects studied are located directly above the source. If a project were developed further away additional pipeline and pumping costs would be incurred.

Information on the costs of conventional geothermal systems can be useful for generating expectations for the cost of a mine pool geothermal system. Maintenance costs for geothermal heat pump systems are said to be significantly less than standard heating and cooling systems (Watzlaf 2006).

Use of underground mine water in geothermal heat pumps could be extremely cost effective, particularly at existing mine water treatment sites where the mine water is already being pumped and treated (NETL 2007). This possibility should be considered when evaluating which mine pools to test for development.

Opportunities to Use Mine Pool Geothermal

There are multiple opportunities to utilize West Virginia's mine pool resources at compatible facilities located above the pools. Geothermal systems can be installed as retrofits to existing HVAC systems, making the resource applicable to existing facilities and institutions.

Compatible Facilities

Facilities that are good matches for these systems are primarily those with space conditioning needs that can take advantage of the consistent, low temperature of the mine pool water. The resource is considered to have "attractive versatility" due to the wide range of end-users (Breede 2015).

Public buildings such as hospitals, commercial facilities, and universities with year-round and round-the-clock heating and cooling needs are considered ideal users (Korb 2018). Computer applications and manufacturing processes are also good potential matches (Korb, Minepool Geothermal in Pennsylvania 2012). Industries with high cooling requirements like server farms may be especially well suited to use the resource (WVGES 2020).

In manufacturing, use of mine pool geothermal is best suited for processes that do not have high temperature needs. A study prepared for the Cumberland Energy Authority states that industries that use a significant amount of heat below 100°C may have the best opportunity to take advantage of the resource. The food, beverage, dairy, rubber product, plastic product, greenhouses, and sugar processing facilities are thought to be good candidates as these industries have a suitable portion of heating needs between 0^0C and 100^0C (EfficiencyOne Services 2017).

Other researchers have reached similar conclusions. Per the 2015 "Management Without Borders" study by Dalhousie University the following industries are particularly suited to exploit the benefits of mine pool geothermal.

- Agriculture/Aquaculture - due to cost effective control of temperature regulation
- Data centers - as ambient cold water is a very good cooling resource and as cooling costs are one of largest costs for data centers.
- Warehouses/large production floors – due to space conditioning needs.

Examples of Mine Pool Geothermal Systems in North America

Mine pool geothermal systems currently operate in several places in North America and Europe. The following list includes five facilities in the United States, two in Canada, and three in Europe. One of the U.S. facilities is no longer operating.

Pennsylvania and Virginia

The **Kingston Community Recreation Center in Kingston, PA** operates one the nation's oldest continuously operating mine pool geothermal systems. The system has been a model for engineers to observe.

- Began using a mine pool geothermal system in 1981.
- Built with a grant from the U.S. Department of Interior.
- 17,000 ft^2 facility.
- System includes an open loop for mine water and two closed loops for clean water with a heat exchanger in between.
- Estimated annual heating bill of $8,000, compared to approximately $14,000 for natural gas, $24,000 for electric resistance, and $40,000 for fuel oil.
- The production well was replaced once and the pumps three or four times in 30 years.

Marywood University in Scranton, PA has operated a mine pool geothermal cooling system for its Center for Architectural Studies since 2010. The building is a renovated gymnasium that is now the design studios for the University's School of Architecture.

- Radiant cooling in the form of chilled beams cooled by the mine pool provide all cooling for the building and replaced a traditional HVAC system.
- Mine pool depth of 340 feet
- Water temperature of approximately 59° F
- Facility footprint of 30,000 ft^2
- 2,000 feet of pipe needed
- Up-front investment of $530,000
- Resulting energy savings allowed the project to be repaid in under three years.

This system was paid for in part by a 2009 grant from the Pennsylvania Department of Environmental Protection (Korb 2012). The system developed under the grant has been incorporated into Marywood University's overall campus sustainability effort and the facility has received LEED Gold Certification from the US Green Building Council. Other sustainable features of the building include a green roof, daylight harvesting and rainwater harvesting (Greenman-Pederson, Inc. n.d.).

In Pittsburgh, the **John Wesley A.M.E. Zion Church** briefly operated a mine pool geothermal system before the church stopped being used. In 2006, the PADEP installed piping to prevent flooding of the church by water draining from an 1800s-era abandoned mine under the city. In 2008, grant funds were provided to construct a geothermal circuit to capture the energy from the mine drainage to heat and cool the church, and to provide for heating and cooling to a potential development next door. The project operated for about a year until the church stopped being used due to some restoration needs (Korb 2012).

A proposed **Geothermal Heating District for Johnstown, PA** has been under evaluation for about a decade. The Greater Johnstown Watershed Association and the Pennsylvania Environmental Council received grants to study this mine pool project as a potential geothermal heating district to reduce heating and cooling costs for facilities in Johnstown (Korb 2018). The assessment began in 2011 and was completed in 2015 with a finding that while the project was technically viable it was not economically feasible because there was no potential for cost-savings for a specific targeted user. It was found that it would be more cost-effective to integrate the use of geothermal into the new building than to retrofit the existing systems (Pennsylvania Environmental Council n.d.).

In 2016 the Johnstown project was mentioned as part of reclamation project within the Abandoned Mine Lands (AML) program. The project was to be a combined acid mine drainage (AMD) treatment and mine pool geothermal pilot project (Office of Surface Mining Reclamation and Enforcement 2017).

A possible project using mine water from **the former Upper Banner Mine near Wise, Virginia** is under evaluation by the Virginia Department of Mines, Minerals and Energy. The "Project Oasis" studied the feasibility of using water in flooded underground mines to cool data centers. This work identified three sites with opportunities to utilize 51° F mine water or underground space that provides a consistent 55° F temperature (OnPoint Development Strategies 2020). Currently, the team is looking to conduct a small-scale test of the resource and extract 25 to 30 million gallons per day out of the 700 million gallons estimated total size of the resource (Clear 2021). The analysis estimates that annual savings would be over $1 million annually, in reduced electric costs and municipal water purchases, in spite of larger capital costs compared to a conventional mechanical cooling system.

Nova Scotia, Canada

Several businesses and organizations in Cumberland County in Nova Scotia, particularly in the former town of Springhill, have experienced success with mine pool geothermal systems thanks to the area's abundance of mine pools, remnants of an economy once dependent on coal. More than 25 geothermal wells have been drilled in Springhill since 1987, and many of them remain operational (Pinchin Ltd. 2020).

The Cumberland Energy Authority collected detailed information for 13 of these wells in a report titled "Researching the Geothermal Potential of the Former Springhill Mine." The report provides data on the range of mine depths, water temperatures, pH measurements, conductivity levels, and the impact of water quality on pump replacement needs. The potential of the Springhill resources has been described as “nearly unlimited with an open loop system” (Dalhousie University 2015). As several of West Virginia’s mine pools are of a similar size, or larger, this is striking opportunity.

Mine depths for the Springhill, Nova Scotia wells ranged from approximately 32 to 740 feet, water temperature from 44 to 59° F, pH from 6.7 to 7.8, and conductivity from 1,153 to 5,594 microSiemens, measured in µS/cm. Combination geothermal systems in the Springhill area have been most commonly implemented in areas where mine water is between 54 and 57° F, indicating that this temperature range is suitable for both heating and cooling. The deepest known coal seam in Springhill is estimated to contain between 1.15 and 1.47 billion gallons of water, a volume sufficient to supply the town’s needs (MacAskill 2015).

BWAY Packing (formerly Ropak) in Springhill, Nova Scotia is a flexible packaging products manufacturing facility.

- Uses the mine pool to heat and cool 151,000 ft^2 of interior space
- Supply well is 140 m deep and pumps mine water at 240 L/min (63 gpm)
- Contains 11 heat pumps
- Mine water temperature of 64.4° F; outlet temperatures of 55.4° (winter) and 68° (summer)
- Water is returned to the mine 30 m below the surface
- Capital cost for the heat pump system was about 20% higher than estimated for a conventional oil system
- Estimated COP[2] (coefficient of performance) for the system was 3.6
- Company estimated $160,000 in annual savings over conventional oil system
- Payback period estimated at less than one year using 1989 energy costs
- Benchmark energy consumption 27.7% less than median reference facility

The **Dr. Carson & Marion Murray Community Centre** is a multi-use facility comprised of an ice rink (55%), multi-purpose area/conference area (40%), and offices (5%).

- Total conditioned floor area of the facility is approximately 75,000 ft^2
- The center’s energy use intensity (EUI) is approximately 15.3 equivalent kilowatt hours per ft^2 (ekWh/ft2), 43.6% better than the median.

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[2] The coefficient of performance (COP) is the amount of heat generated divided by the amount of energy needed to operate heat pump. The smaller the difference in temperature between the heat source and the heat sink (required temperature of the space to be heated), the greater the COP of the system.

Missouri and Michigan

The **Michigan Tech Keweenaw Research Center in Houghton, MI** operates a mine pool geothermal system in one building on its campus. The system is a tribute to the area's history, and both celebrates its mining heritage and promotes environmental progress (Michigan Tech Keweenaw Research Center 2015).

- Mine water stays around 53 to 55° F year-round
- Heats and cools a 11,000 ft^2 building
- Pipe the mine water up from 300 feet below the surface
- Closed-loop system with water mixed with glycol to avoid freezing
- Runs via 18 heat pumps throughout the center's main building.
- Cost of project was $100,000
- Payback estimated from three and five years

The City of Park Hills, MO has a mine pool geothermal system that is used to heat and cool one of its municipal buildings.

- Uses water from abandoned lead mines to heat/cool a 8,073 ft^2 two-story building
- Supply well is 120 m deep and pumps 57.2° F water at 74 gpm
- Contains 9 heat pumps, 113 kW capacity
- Water is returned to the mine via a return well (open-loop system)
- Cost an estimated 20% more than conventional system composed of rooftop air conditioners and natural gas heating system ($132,400 vs. $110,200).
- Annual savings of roughly $4,800/30% in 1996
- Payback period of 4.6 years using energy costs from 1996

Examples in Europe and the U.K.

There are many examples of mine pool geothermal projects in Europe, with most concentrated in Germany. Norway, Russia, and Scotland also utilize the resource. A comparative review of installed projects lists seven projects in Germany (Breede 2015).

The largest mine water geothermal district heating project in the world is in **Heerlen, Netherlands**. The project has reduced CO_2 emissions by 50% and spurred development of additional buildings in the area. It has also attracted investors, providing a new income for the community, and serves as an interpretive demonstration site and attraction for tourists, engineers, and researchers from around the world.

- Began operating in 2008.
- Heats and cools 350 residences, 40,900 ft^2 of commercial space, and 174,400 ft^2 of community buildings as well as healthcare and educational buildings.
- Uses both hot (28°C) and cold mine water (16°C) from four wells.

The **town of Marienberg in Saxony, Germany** uses a mine pool to heat a pool, a tennis hall, and supermarkets.

- Installed in 2006
- Accesses a 351 ft deep mine.
- An open-loop system with three submersible pumps and a maximum combined flow rate of 120 m^3/h and total consumption of 120 kW, with a secondary closed-loop.
- Mine water temperature is 54°F
- The potential heating capacity of the system is estimated to be 690 kW.

A geothermal system is used to heat and cool two buildings on the campus of the **University of Oviedo and the Álvarez Buylla Hospital in Asturias, Spain**.

- The abandoned coal mine contains about 5.8 million m^3 (1.5 billion gallons) of water.
- Water temperature ranges from 62 ° to 73° F.
- The shaft used to extract the mine water is 820 ft away.
- The Oviedo system is closed-loop while the hospital system is open-loop.
- Estimated annual energy saving of 73% for Oviedo, a reduction of CO_2 emissions of up to 39% per year, and monetary savings of 15% for a student residence and up to 20% for a research facility.

In **Gateshead, Tyne and Wear, England** an old mine in the High Main coal seam is being used to heat warehouses for a winery, a distribution center, and a bakery.

- Water temperature of 59°F.
- Used to heat 400,000 ft^2 of warehouse.

The UK Coal Authority, which is responsible for the country's disused mines, is exploring the feasibility of about 70 mine water heating projects and believes it is one of the UK's largest underused clean energy sources. One estimate of the volume of water available across Wales, central Scotland, northern England, and the Midlands is 4.4 billion gallons. (British Broadcasting Company 2021)

Next Steps to Understand West Virginia's Potential

The next step in developing West Virginia's mine pools is to gain a fuller understanding of the resource. This would include designing an engineering study to plan to test various pools and determine which mine pool(s) to develop. Following those analyses, a pilot system could be developed in partnership with an existing institution.

Dalhousie University developed a communications plan for the Cumberland Energy Authority for the Springhill Geothermal Park focused on the economic development potential of the park, which even references leveraging the geothermal capacity as part of a broader tourist strategy. Recommendations for the CEA, and applicable to WV, are to:

- Further define the water quality from the mine to encourage investment.
- Leverage strong case studies of success that are currently using the geothermal resource to further establish proven usage.
- Assign autonomy over the promotion, development, and control of the geothermal resource via licensing and resolution of ownership issues.
- Communicating a viable economic payoff and future energy cost stability
- Assess each mine pool with respect to other mining activity in the area.
- To attract additional users at least one geothermal system has to be in operation and have a proven track record of reliable operation over a number of years
- A potential user has to be able to analyze the benefits of geothermal energy and determine the potential cost savings.
- A potential user has to be able to determine what retrofits will be required and what the associated costs will be.

Observe Systems in Place

With existing geothermal systems in place and proposed projects in the works, Nova Scotia and Pennsylvania offer numerous opportunities to observe the operational and technical undertakings such systems entail. The Cumberland Energy Authority is promoting expanded use of the resource via a planned district mine pool geothermal system, the Springhill Geothermal Business Park, and through an energy efficiency consultant.

The plan for the district system is a 100-acre business park atop the town's former mines, with access to mine water between 54 and 63° F. The Authority has developed estimates of expected energy savings. Enabled heating costs are $31.20/MWh of delivered heat, compared to other expected costs for electric resistance ($130/MWh) and propane units ($132.39/MWh). Expected cooling costs are $22.00/MWh of delivered cooling, a favorable price compared to traditional air-source heat pumps ($35.10/MWh) or chiller and cooling towers ($26/MWh) (Pinchin Ltd. 2020).

The district idea is an opportunity to achieve large-scale utilization of the mine pool resource and induce economic activity the result of that resource in addition to energy cost savings for existing businesses in the area. Cumberland County's strategy includes a multi-step approach to study and market the resource, with a first step goal to have a greater understanding of the capacity, integrity, and future development opportunities.

The engineering team should also meet with researchers involved with the proposed district geothermal system in Johnstown, PA regarding any design work done there.

Design an Engineering Study

An engineering study should be conducted to select the optimal locations to drill test wells to better understand the characteristics of the mine pools in West Virginia. This would build on the studies undertaken by WVGES on existing mine pools and would likely include plans to monitor multiple pools over time. There are several factors an engineering study should consider.

The capital costs to construct a mine pool geothermal system can be significant. However, as noted by the WVGES, much of the work required for the geothermal system framework has already been undertaken by the mining industry, possibly reducing costs. However, site characteristics vary from mine to mine and will impose engineering challenges and potential ecological risks. Thus, additional detailed geologic and engineering review of each site will need to be conducted (WVGES 2020, West Virginia Mine Pool Pump Storage).

Geological and environmental characteristics include mine age, depth, roof type, location of the pool relative to drainage, the water quality of the pool, the expected recharge rate of the pool when receiving warmer (or cooler) water from the surface, and other uses of the mine water. An engineering study is important to identify and avoid problems. Some early mine pool systems had problems with production well collapse because of subsidence, with sediment buildup in the heat exchanger, and pump abrasion due to silty sediment (Korb 2012).

While the characteristics of the mine pool are very important for system design, researchers have observed that the versatility of mine pools allows usage with a fairly wide range of features. Systems can be designed independent of reservoir size and have been observed with a range of water temperature of 43 to 82° F and mine depths from 50 to 700 m (Breede 2015).

Mine Depth and Capacity

Digital elevation models (DEMs) that portray the underground landscape can depict where mine pools may be located within a mine, how water is distributed throughout a mine, and mine pool depths below the surface. One associated complexity is understanding the interconnectivity of adjacent mine pools, both laterally and vertically (Watzlaf 2006).

Mine Age

Newer mines have an advantage over older mines in that institutional knowledge of the mine may still exist, and as recordkeeping has improved over time. For older mines that closed decades ago there will not be access to engineers who worked in the mine. This is important for regulatory issues, including safety and water discharges. Several of the mines identified as candidates due to size of the pools and location above towns are very old and were closed as early as the 1930s e.g., the Sun mine below Mount Hope. Engineers may be unable to access records or individuals with knowledge of the mine. A newer mine may be a better prospect for a pilot project.

Mine Roof and Floor Lithology

Sandstone roofs, or another resistant lithology, are preferred due to their durability and to lessen erosional effects relative to other roof types. Longwall mines may be less desirable due to the possibility of debris remaining from roof collapse and overburden rubblization (WVGES 2020). At least one study states that geothermal wells can only be drilled where the mine shaft is supported by a ‘room and pillar’ structure (Dalhousie University, 2015).

Location of Pool Relative to Drainage

The location of water within a mine pool is also important. A pool located below drainage offers the most potential, as water continues to pool and is unable to flow elsewhere. Whether a mine pool is above, at, or below drainage can be determined by water flow direction within a mine and digital elevation models. The mines identified by the WVGES as candidates for development are all located below drainage (WVGES 2021).

Water Temperature and Quality

Mine water can contain suspended solids that can quickly clog pipes and equipment. Treatment can remove these solids but will add cost to a project. Thus, assessment of water quality is an important next step in establishing physical viability of a mine pool geothermal project. Closed-loop systems are not susceptible to clogging as the mine water does not mix with the system water.

The Pittsburgh coal seam is known to contain high concentrations of some metals. Analysis of flooded mines in the Pittsburgh coal basin reveal increased alkalinity, with below-drainage mine water being generally alkaline with iron, but not aluminum, occurring in significant concentrations (Denicola 2013).

Mine pools in the Sewell and Pocahontas seams are not associated with high metals content. The Sewell coal seam is considered to be “of global significance because of its exceptional quality due to its low sulfur content, few metal impurities, and high heat value (Mahan 2004).” An older analysis of spoils from the Pocahontas 3 and Pocahontas 6 seams indicated that acidity is not a major problem in those seams or in the Sewell seam, but that the Sewell seam does contain more aluminum than the Pocahontas seams (U.S. Department of Agriculture 1973).

Production of the *West Virginia Mine Pool Atlas* had an initial goal to collect and evaluate available water quality data as part of the coal seam evaluation. However, per the report “much of the available water quality data were from treated mine water, and these analyses were not useful in determining in-situ water quality (West Virginia Geological & Economic Survey 2012).”

Other Uses of the Mine Water

Another matter to consider is whether a mine is supplying water to a municipality, as this may impact the availability of mine water from some seams. Mines in the Pocahontas 3 seam are a source of water for the public supply system for the City of Welch (U.S. Geological Survey 1992). Parts of Raleigh County also use mine water for public supply.

Identify Interested Adopters

A review of economic activity above mine pools identified by the WVGES revealed a large number of commercial facilities that are potential candidates to take advantage of the resource. Many of these facilities are schools, mostly K-12 schools but also universities. There are also several hotels, hospitals, jails, and other public buildings that may be good partners for pilot projects to demonstrate the viability of the resource.

Once sources of mine water have been tested and viability established, partners can be identified as potential users of the resource.

Ensure Legal Arrangements are in Place

Before mine pool geothermal resources can be developed it may be necessary to establish clear legal standards to guide leasing and ownership of the water. Cumberland County, Nova Scotia is again a potential model that can be used to facilitate development. The Springhill Geothermal Business Park has been a longstanding goal of the community of Springhill. This project is enabled by a mineral rights lease granted to the County of Cumberland to control development of the geothermal resource (Cumberland Energy Authority 2021).

Long-term solutions could also include establishment of a geothermal utility.

Summary

A mine pool geothermal projects can save energy and lower energy costs, reduce associated emissions from avoided energy consumption, and provide a way to benefit from closed and legacy coal mines that are currently seen only as liabilities. These projects are also potential ways to bring economic activity to former coal-mining areas.

Former coal-mining areas of Nova Scotia and Pennsylvania have been utilizing mine pool water for decades. These places and the facilities currently using the resource are excellent sources of expertise for West Virginia.

Following completion of an engineering assessment and pilot project the district geothermal system under development in Nova Scotia is a potential plan to emulate. This is an innovative use of the resource that could bring benefits to an entire city or town like Triadelphia, Fairmont, Oak Hill, Mount Hope, or Welch. A pilot project with a public institution, like a school or an administrative building would demonstrate the resource.

The combined acid mine drainage treatment and district mine pool geothermal project proposed in Johnstown, PA is another effort to track. That project was proposed as part of reclamation project within the Abandoned Mine Lands (AML) program, with the mine pool as a source of energy to reduce heating and cooling costs for public facilities in Johnstown (Office of Surface Mining Reclamation and Enforcement 2017).

Another significant effort is the work underway in Wise County, VA to use a mine pool to provide energy efficient space conditioning for a data center. This proposed project is at coal mine that has recently closed, allowing utilization of modern mining records.

While these projects take many years to design and implement, West Virginia's mine pool resource offers potential for long-term energy savings that can serve the State well in its mine reclamation and economic development efforts. Such a project can also contribute to a positive legacy for the coal industry.

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