JOINT STATE GOVERNMENT COMMISSION

General Assembly of the Commonwealth of Pennsylvania

Unearthing the Potential of Geothermal Energy Systems in Pennsylvania

Staff Study

August 2025

Serving the General Assembly of the Commonwealth of Pennsylvania Since 1937

REPORT

(2023 HR185)
Unearthing the Potential of Geothermal Energy Systems in Pennsylvania

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The Joint State Government Commission was created in 1937 as the primary and central non-partisan, bicameral research and policy development agency for the General Assembly of Pennsylvania.[1]

A fourteen-member Executive Committee comprised of the leadership of both the House of Representatives and the Senate oversees the Commission. The seven Executive Committee members from the House of Representatives are the Speaker, the Majority and Minority Leaders, the Majority and Minority Whips, and the Majority and Minority Caucus Chairs. The seven Executive Committee members from the Senate are the President Pro Tempore, the Majority and Minority Leaders, the Majority and Minority Whips, and the Majority and Minority Caucus Chairs. By statute, the Executive Committee selects a chairman of the Commission from among the members of the General Assembly. Historically, the Executive Committee has also selected a Vice-Chair or Treasurer, or both, for the Commission.

The studies conducted by the Commission are authorized by statute or by a simple or joint resolution. In general, the Commission has the power to conduct investigations, study issues, and gather information as directed by the General Assembly. The Commission provides in-depth research on a variety of topics, crafts recommendations to improve public policy and statutory law, and works closely with legislators and their staff.

A Commission study may involve the appointment of a legislative task force, composed of a specified number of legislators from the House of Representatives or the Senate, or both, as set forth in the enabling statute or resolution. In addition to following the progress of a particular study, the principal role of a task force is to determine whether to authorize the publication of any report resulting from the study and the introduction of any proposed legislation contained in the report. However, task force authorization does not necessarily reflect endorsement of all the findings and recommendations contained in a report.

Some studies involve an appointed advisory committee of professionals or interested parties from across the Commonwealth with expertise in a particular topic; others are managed exclusively by Commission staff with the informal involvement of representatives of those entities that can provide insight and information regarding the particular topic. When a study involves an advisory committee, the Commission seeks consensus among the members.[2] Although an advisory committee member may represent a particular department, agency, association, or group, such representation does not necessarily reflect the endorsement of the department, agency, association, or group of all the findings and recommendations contained in a study report.

[1] Act of July 1, 1937 (P.L.2460, No.459); 46 P.S. §§ 65–69.

[2] Consensus does not necessarily reflect unanimity among the advisory committee members on each individual policy or legislative recommendation. At a minimum, it reflects the views of a substantial majority of the advisory committee, gained after lengthy review and discussion.

Over the years, nearly one thousand individuals from across the Commonwealth have served as members of the Commission's numerous advisory committees or have assisted the Commission with its studies. Members of advisory committees bring a wide range of knowledge and experience to deliberations involving a particular study. Individuals from countless backgrounds have contributed to the work of the Commission, such as attorneys, judges, professors and other educators, state and local officials, physicians and other health care professionals, business and community leaders, service providers, administrators and other professionals, law enforcement personnel, and concerned citizens. In addition, members of advisory committees donate their time to serve the public good; they are not compensated for their service as members. Consequently, the Commonwealth receives the financial benefit of such volunteerism, along with their shared expertise in developing statutory language and public policy recommendations to improve the law in Pennsylvania.

The Commission periodically reports its findings and recommendations, along with any proposed legislation, to the General Assembly. Certain studies have specific timelines for the publication of a report, as in the case of a discrete or timely topic; other studies, given their complex or considerable nature, are ongoing and involve the publication of periodic reports. Completion of a study, or a particular aspect of an ongoing study, generally results in the publication of a report setting forth background material, policy recommendations, and proposed legislation. However, the release of a report by the Commission does not necessarily reflect the endorsement by the members of the Executive Committee, or the Chair or Vice-Chair of the Commission, of all the findings, recommendations, or conclusions contained in the report. A report containing proposed legislation may also contain official comments, which may be used to construe or apply its provisions.[3]

Since its inception, the Commission has published over 450 reports on a sweeping range of topics, including administrative law and procedure; agriculture; athletics and sports; banks and banking; commerce and trade; the commercial code; crimes and offenses; decedents, estates, and fiduciaries; detectives and private police; domestic relations; education; elections; eminent domain; environmental resources; escheats; fish; forests, waters, and state parks; game; health and safety; historical sites and museums; insolvency and assignments; insurance; the judiciary and judicial procedure; labor; law and justice; the legislature; liquor; mechanics' liens; mental health; military affairs; mines and mining; municipalities; prisons and parole; procurement; state-licensed professions and occupations; public utilities; public welfare; real and personal property; state government; taxation and fiscal affairs; transportation; vehicles; and workers' compensation.

Following the completion of a report, subsequent action on the part of the Commission may be required, and, as necessary, the Commission will draft legislation and statutory amendments, update research, track legislation through the legislative process, attend hearings, and answer questions from legislators, legislative staff, interest groups, and constituents.

[3] 1 Pa.C.S. § 1939.

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To the Members of the General Assembly of Pennsylvania:

We are pleased to release *Unearthing the Potential of Geothermal Energy Systems in Pennsylvania* in response to House Resolution 185 of 2023, which directed the Commission to assess the potential benefits that geothermal technologies can provide to Pennsylvania and to research the siting of mine water energy systems in abandoned mines throughout the state.

Future energy demands mean the commonwealth must pursue new energy sources while investing in energy-saving technologies. Existing and emerging geothermal systems have the potential to fulfill both needs. Engineered geothermal systems, oil and gas co-production, and well water reuse have the potential to add geothermal electricity to the state's energy portfolio. Such systems also have a high degree of compatibility with existing oil and gas jobs.

The report recommends that definitions of geothermal be expanded to include heat as well as electricity. It also recommends that mine pools be modeled by DCNR's Bureau of Ecological Survey, that DEP pursue Class V Primacy from the EPA, and that a regulatory process for geothermal system approval be developed. Furthermore, the language of state funding programs should be harmonized to increase their applicability to geothermal heating systems. Finally, education and advocacy efforts are needed to increase the acceptance and adoption of mine water energy systems in Pennsylvania communities.

Respectfully submitted,

Glenn Pasewicz
Executive Director

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INTRODUCTION

Throughout the world there are places where the tremendous energy stored beneath the earth sits closer to the surface than others. In such places, where the right geological conditions are present, hot springs, geysers, and even volcanoes release this heat to the surface. Traditionally, when discussing sources of geothermal energy, what are most commonly referred to are facilities which can harness the Earth's heat into steam to drive turbines that generate electricity.

Geothermal technologies are important to study in Pennsylvania as they offer the opportunity to help the state sustain energy leadership. Pennsylvania has long been a leader in American energy production, beginning with coal mines in the 1700s and the nation's first commercial oil well in 1859.[4] Pennsylvania has also led in recent years as one of the world's top natural gas producers.[5] As new technologies are on the rise in the energy sector, Pennsylvania is well-positioned to adopt geothermal technologies due to its long history of innovation, existing infrastructure, and extensive skilled workforce.

Despite its abundance of natural resources both above and below the surface, Pennsylvania was not blessed with geographical conditions necessary to produce geothermal energy as is done in the western portions of the United States. Conventional geothermal power plants typically involve minimum temperatures of 300°F. Throughout much of Pennsylvania, the temperature of the ground below is not hot enough to create electricity at a depth that it would be economical to drill. Furthermore, the type of earth present is neither permeable nor porous enough to channel what heat there is to the surface. Because of these factors, Pennsylvania was historically considered to be a poor candidate for geothermal as a renewable energy source.

As technology has improved, however, so has researchers' ability to map beneath the earth, allowing them to detect the pockets of thermal reserves scattered throughout the state. Additionally, through so-called "next generation geothermal" methods it becomes possible to create new channels into the ground and access these stores of heat through drilling deep boreholes or by hydraulic fracturing to artificially create the conditions necessary for heat to travel to the earth's surface as is found in traditional geothermal. These emerging developments in the geothermal field have the potential to be transformative in Pennsylvania's energy landscape as outlined in "The Future of Geothermal Energy in Pennsylvania: Leveraging the Commonwealth's Legacy of Energy Leadership," a report released in March 2025 through a collaboration between Pennsylvania State University and Project Innerspace. While earlier sections of this report will discuss some matters related to the nascent geothermal electrical capabilities within the

[4] Jay Apt, Max Clark, Carlee Joe-Wong, et al., "The Future of Geothermal Energy in Pennsylvania: Leveraging the Commonwealth's Legacy of Energy Leadership," *Penn State Center for Energy Law and Policy*, 2025, https://celp.psu.edu/wp-content/uploads/2025/02/Pennsylvania-Report.pdf, 16.
[5] Apt et al., "The Future of Geothermal," 16.

Commonwealth, geothermal heat pumps are another method to advantageously use underground resources for the Commonwealth's benefit.

Over the decades, terminology surrounding the "Geothermal" label has shifted to be inclusive of a broader range of technologies that utilize the earth for heating and cooling purposes. This report examines ground-sourced heating and cooling systems, which are frequently marketed as geothermal heat pumps, or sometimes geo-exchange. These electricity-powered pumps do not access energy that comes from deep within the earth, but instead use shallow underground temperatures of 55° to 60°F. While the surface of Pennsylvania has a continental climate and is accordingly subject to the heat of summer and the chill of winter, the water beneath the earth is insulated by rock and exists at a generally constant temperature six feet below the ground.

In the spring of 2025, Commission staff toured Swarthmore College, which had recently installed a geo-exchange system. This can be thought of as a bank to deposit or withdraw heat as determined by the needs of the season. Using heat pumps, energy can be drawn from the ambient temperature beneath the earth in summer months and stored in the earth again during the winter. While closed-loop geo-exchange systems like Swarthmore's utilize thousands of small wells containing water and have great potential, throughout the world there is a desire to scale up geo-exchange systems across city districts. These thermal energy networks have been known to provide carbon-free heating and cooling throughout Scandinavian countries as well as Iceland and Spain; however, efforts to supply geothermal heating and cooling to larger segments of the population are at a pilot stage in some areas of the United States.

While residential and multibuilding scale geo-exchange is the most common type of geothermal system seen in Pennsylvania today there are other variations. Another type of heat pump configuration employs open-loop designs which typically uses subterranean rivers, lakes, or aquifers. Practically any large reserve of underground water could be used in an open loop design. Throughout the world, geologists, engineers, urban planners, and a host of other professionals have investigated the use of underwater sources as a way of heating and cooling their cities. Unknown to many, Pennsylvania has vast stores of unknown and unused water in abandoned mines beneath the state that could potentially be used to heat and cool our homes and businesses.

While unconventional, mine water energy systems are not theoretical. These systems are based around heat pumps, a mature and commonly used technology. Recently, ongoing efforts in Nova Scotia, the United Kingdom, and the European Union have worked to popularize the idea that mine water energy systems can be used to heat and cool buildings. In these cases, the mine pools act both as a water source and a heat sink. Mine water energy systems already exist in Pennsylvania at Marywood College and in the United Kingdom's newly constructed Gateshead housing development. The subsequent chapters of this report will explore the potential of these systems, identify the challenges to their uses, and raise questions that must be answered to spur the development of mine water heating and cooling system as well as other emerging geothermal technologies.

A full list of findings and recommendations can be found in the last chapter of this report.

Glossary

There are many types of energy sources in the world, each with their own set of jargon and definitions. Decades of experimentation and refinement have helped to settle terminology used so that both experts and lay people can understand each other when discussing the characteristics of a particular energy system. While geothermal energy production is not particularly new, terminology surrounding its use is fractured and different industries which utilize these technologies may not be in alignment with each other. Even industry veterans have commented that one of the largest challenges in promoting geothermal energy is that it does not refer to one type of energy system but a whole family of technologies who each have different capabilities and costs.[6] Much of the confusion stems from the differences between deeper reserves which are higher temperature reserves frequently used for electricity production, and shallow reserves which tend to be lower temperature water sources used in heating and cooling systems.

Geothermal Systems can refer to technologies using heat from the earth in many ways such as direct use, electricity production, heating and cooling.

Geo-exchange is a system of ground source heat pumps paired with a closed-loop of pipes that extract and return heat to the ground in a renewable cycle. This process is done on a seasonal basis to allow for cooling in the summer and heating in the winter.

Mine Water Energy Systems are water source heat pumps in mines which extract and sometimes store geothermal heat. Closed and open loop variations exist. Frequently they will be paired with a heat exchanger and a secondary closed loop of clean water.

The additional definitions below are from The Future of Geothermal Energy in Pennsylvania: Leveraging the Commonwealth's Legacy of Energy Leadership and may aid readers in understandings terminology used in this report.

Conventional Hydrothermal Systems (CHS) also known as traditional geothermal systems or hydrothermal geothermal systems, this geothermal resource is often accessible close to the surface and at times has surface manifestations, such as hot springs, volcanic rock formations, geysers, or steam vents, among others. CHS have a combination of sufficient permeability in the subsurface, sufficient heat transfer into the system, and the natural presence of circulating water which produces an exploitable geothermal resource. Heat flow is convection dominant, i.e., conduction and advection contribute to the movement of heat. Most of the world's developed geothermal capacity is currently produced from CHS resources.

Next-Generation Geothermal is an umbrella term for any geothermal extraction technology that harvests subsurface energy outside the geography of Conventional Hydrothermal Systems (CHS). In most cases, next generation geothermal technologies rely on advances from the oil and gas

[6] Geothermal Canada, "Geothermal Vs. Geoexchange: Which Could Work and Where in Canada," April 11, 2024, https://www.geothermalcanada.org/news/2022/6/22/geothermal-vs-geoexchange-which-could-work-and-where-in-canada.

industry which enable expanded geographic potential or are used to more effectively tap into existing conventional resources.

Engineered Geothermal Systems (EGS) is an underground hydrothermal reservoir created by drilling wells into hot rock. Those wells are then connected through hydraulic fracturing. Fluid is circulated through the fractured rock, captures the heat, and is brought back to the surface.

Advanced Geothermal Systems (AGS) AGS is similar to EGS, but the fluids are circulated within a closed loop of pipes that allows the fluid to absorb heat and carry it back up to the surface.

Conventional Geothermal is a geothermal extraction method that requires a hydrothermal system and doesn't use hydraulic fracturing to artificially engineer a subsurface reservoir. Horizontal drilling may be used, but only to improve access to otherwise naturally occurring reservoirs and naturally occurring fluid.

Ground Source (Geothermal) Heat Pumps (GSHP) these pumps harvest the ambient temperature in the top one to two meters of the subsurface, where the ground remains at a relatively constant temperature of 55°F (13°C). GSHPs have traditionally been used to heat and cool buildings but are increasingly used in higher-temperature industrial and commercial applications.

Direct-Use Geothermal Systems unlike using geothermal heat to generate electricity Direct-Use Geothermal Systems use the heat contained in geothermal fluids to enable various heating and cooling applications. These systems can be shallow or deep.

Thermal Energy Networks (TEN) when direct-use geothermal energy is supplied to a large area, clusters of buildings, or in a district from a central location, it is called a Thermal Energy Network. This is also referred to as District Heating.

Oil and Gas Well Reuse (Well Reuse) is a geothermal application in which geothermal energy is produced from existing oil and gas wells. There are two possibilities. First, an existing hydrocarbon well could be repurposed to produce geothermal energy only, known as conversion. Second, an existing well could produce hydrocarbons and heat simultaneously, known as co-production.

Working Fluids convey geothermal heat from the subsurface and deliver it to the surface in geothermal applications. Working fluids can be, and have been historically, water or brine. Next-generation geothermal concepts seek to use novel, non-water "engineered working fluids" with lower boiling points than water to increase system efficiencies and performance, particularly in lower-temperature geothermal resources.

Methodology

Commission staff conducted an extensive search of industry and government reports as well as examined reports from selected other states and countries. In particular, staff reviewed data and reports from the UK, while also attending webinars regarding the UK's current geothermal activities. Staff gathered data from experts integral to the installation of a mine pool geothermal unit within the Commonwealth and visited a higher education institution that is currently installing a district heating geothermal system in southeastern Pennsylvania. During this time frame, staff attended and received testimony from the hearing held by the PA House of Representatives Energy Committee on May 7, 2025. Throughout the study, staff consulted with departmental and legislative liaisons, the Pennsylvania state geologist, lobbyists, and the Governor's Office of Critical Investments.

In instances throughout the report GIS software and analysis tools were used to demonstrate how infrastructure within Pennsylvania such as public school locations were located near mine water sources. In such cases school proximity to water sources from abandoned mines was measured using data from the Department of Environmental Protection's Abandoned Mine Land Inventory data set which contains information on Acid Mine Drainage discharge points and flooded mine locations. Additional analysis was carried out to determine other infrastructure near mine water sources. Finally, public school locations were also compared to active natural gas wells as part of a separate analysis on well reuse.

GEOTHERMAL ELECTRICITY

What is Geothermal?

Geothermal is a combination of the Greek words for earth and heat. Geothermal can refer to an array of related technologies which all aim to manipulate the relationship between heat sources and the earth for a beneficial purpose. The U.S. Department of Energy (USDOE) defines geothermal resources as:

> Reservoirs of hot water that exist or are human-made at varying temperatures and depths below the earth's surface. Wells ranging from a few feet to several miles deep can be drilled into underground reservoirs to tap steam and very hot water that can be brought to the surface.[7]

One of the most commonly discussed benefits of geothermal technology is electricity production. Geothermal power plants have many benefits compared to other types of renewable energy sources. For example, geothermal plants have smaller land use footprints as compared to a utility-scale solar array and can be used as a baseload power source because the earth's heat is constant, unlike the variability of the wind or sun. Its main downsides are high upfront cost relating to the uncertainty of locating and drilling for a geothermal resource. Electricity production from geothermal power plants can be adjusted as needed. However, the main limitation of generating geothermal electricity is that it is highly location-dependent, and heat, liquid, and permeation must be present at a given location to develop conventional geothermal resources.

Within the U.S., there are several sources of geothermal energy.[8] Geothermal reserves of very hot water can be found near the Earth's surface in locations throughout the western U.S., as well as in Alaska and Hawaii. In other parts of the country, geothermal systems might take the form of heat pumps placed in the shallow ground near the Earth's surface, where temperatures maintain a relatively constant 50° to 60°F. These resources will be examined in subsequent chapters. The final source of geothermal energy involves drilling boreholes which can access hot rocks, hot water, or steam reservoirs that are located deep below ground.

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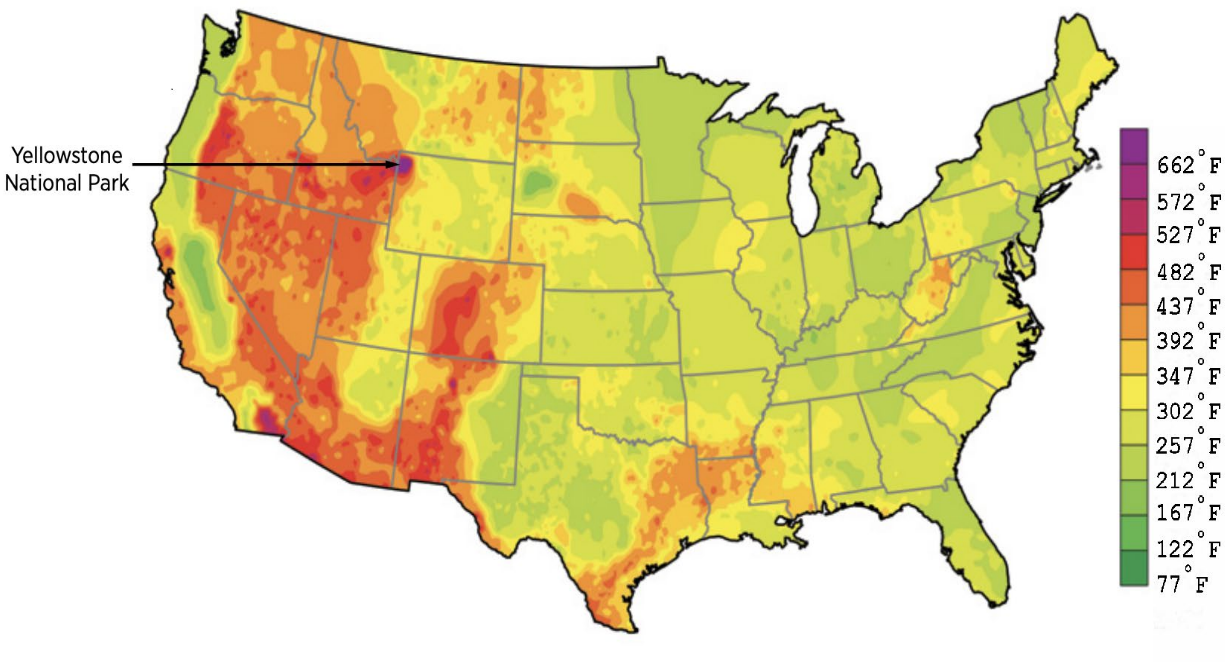
[7] U.S. Dept. of Energy, "Geothermal Basics," Energy.gov, accessed April 11, 2025, https://www.energy.gov/eere/geothermal/geothermal-basics.
[8] National Renewable Energy Laboratory, "Geothermal Energy Basics," accessed June 12, 2025, https://www.nrel.gov/research/re-geothermal.

There are several ways in which geothermal energy is frequently used. These include electric power plants, district heating, direct use of hot water drawn from underground, and ground source heat pumps.[9] Three of the key ingredients to conventional geothermal power plant are: heat within a drilling distance, fractured rock that provides a pathway for the heat, and water to carry the heat.[10] Many of the places which meet all three of these characteristics are in the western U.S. In the east, sufficiently high temperatures are not found at an economical depth, there is a lack of water to convey the heat, or the rock does not have the channels necessary to allow the heat to escape. [11] See map 1. Later, this chapter will discuss how those limitations may be overcome through scientific advances.

Map 1
Geothermal Resources of the United States
2018



Source: National Renewable Energy Laboratory, Geobridge.

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[9] National Renewable Energy Laboratory, "Geothermal Energy Basics."
[10] Casey Crownhart, "What It Will Take to Unleash the Potential of Geothermal Power," MIT Technology Review, December 8, 2021, https://www.technologyreview.com/2021/12/08/1041511/potential-geothermal-power-infrastructure-bill/.
[11] Crownhart, "What It Will Take to Unleash the Potential of Geothermal Power."

Conventional Geothermal Power Plants

The first known geothermal power plant was installed in Italy in 1904; operations in the U.S., however, did not start until 1971.[12] Geothermal energy is reliable, a constant output of power that can provide baseload energy, in contrast to other types of renewable energy sources that are intermittent.[13] By some metrics, geothermal power sources are highly desirable due to their lower operating costs and minimal emissions, particularly when compared to burning hydrocarbons for fuel. Geothermal power plants produce minimal greenhouse gases, fewer particulates, 99 percent less carbon dioxide, and 97 percent less sulfur dioxide per kilowatt (kW) than coal does.[14]

As mentioned earlier, geothermal power plants are located in places that have three characteristics: hot underground rocks, fluid that can absorb this heat, and channels the fluid can move through. Thus, the main stages of geothermal power development are resource exploration, drilling, reservoir and plant development, and power generation.[15] In conventional geothermal plants, wells are drilled into the heat sources, the heat energy is collected to convert water into steam, and the steam is then channeled through a turbine to generate electricity.

The process of how geothermal power plants work is detailed in Figure 1. In most conventional hydrothermal power plants, drills are used to access underground reservoirs of water heated in the Earth's crust.[16] After a casing around the borehole is constructed, hot water is drawn up from the earth in a production well. The water becomes steam as it loses pressure and is channeled through a turbine causing it to spin. The spinning magnets cause the generator to create an electrical current which can then be distributed through the power grid. At this stage some water vapor may be emitted through a cooling tower. Remaining water is then returned to the ground through an injection well. Underground, the water will reheat, and the process can start anew. This continuous cycle is what differentiates geothermal as a renewable resource from other types of ground-based resource extraction.

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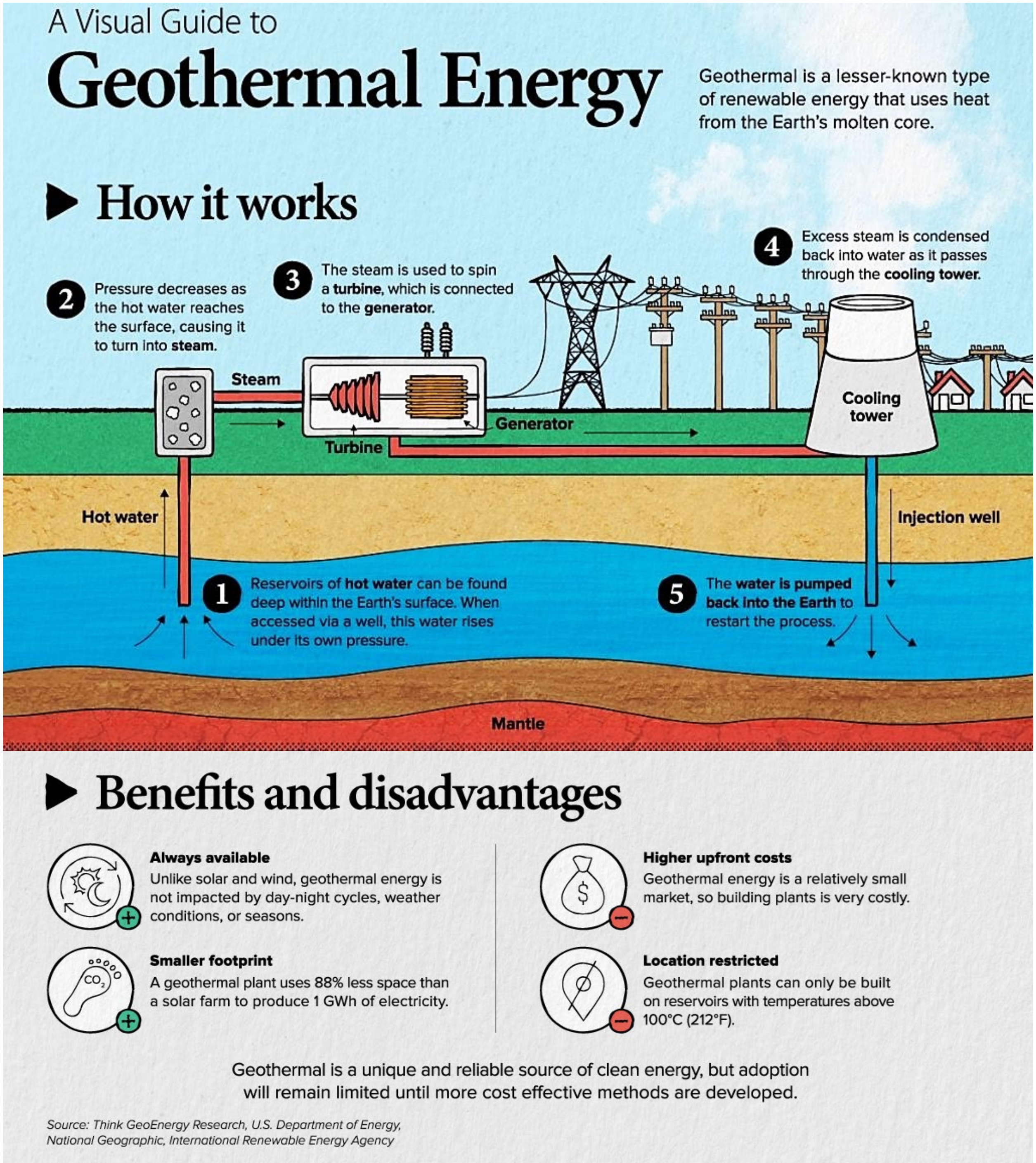
[12] "5 Things to Know About Geothermal Power," Energy.gov, February 14, 2018, https://www.energy.gov/eere/articles/5-things-know-about-geothermal-power.
[13] Crownhart, "What It Will Take to Unleash the Potential of Geothermal Power."
[10] U.S. Energy Information Administration, "Geothermal Explained: Geothermal Energy and the Environment," December 19, 2024, https://www.eia.gov/energyexplained/geothermal/use-of-geothermal-energy.php.
[15] National Renewable Energy Laboratory, "Geothermal Energy Basics."
[16] Geothermal Technologies Office, "Electricity Generation," Office of Energy Efficiency & Renewable Energy, accessed October 22, 2023, https://www.energy.gov/eere/geothermal/electricity-generation.

Figure 1
Visual Guide to Geothermal Energy
2022



Source: Visual Capitalist.

While the above process is a generalization, there are several technologies and techniques which have been developed for electricity generation at conventional geothermal power plants. Each design emphasizes different strengths:[17]

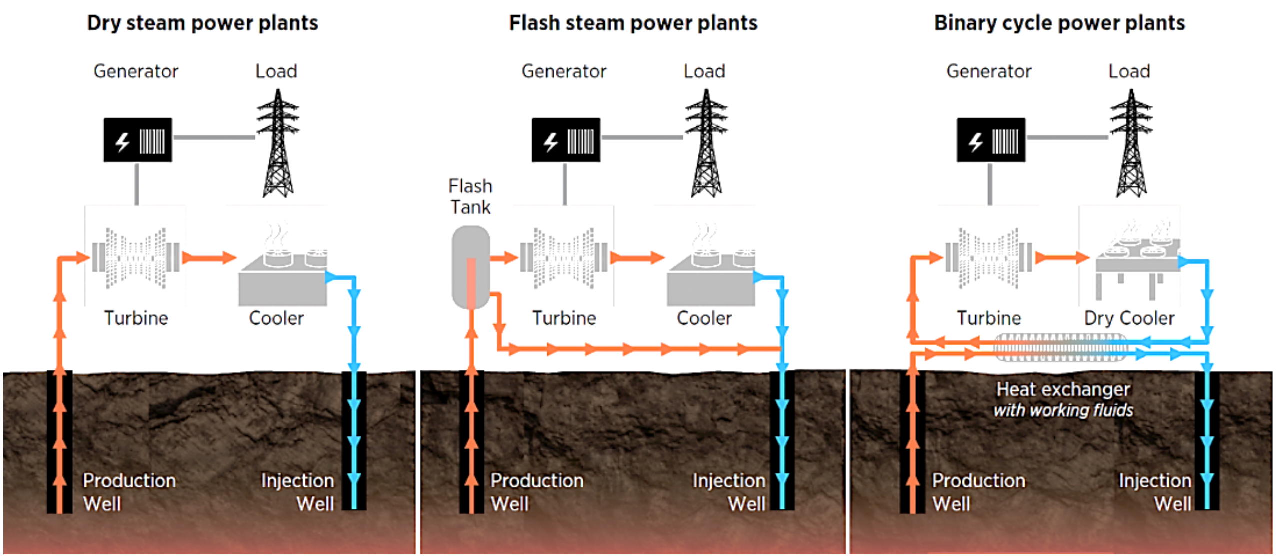
- Dry steam systems work by drilling into the earth and directing hot water vapor to the surface to spin turbines to make electricity. This configuration requires the hottest temperatures to run (400° to 650°F).

- Flash steam plants pressurize underground hot water (360°F). The pressurized water is turned into steam and channeled to low pressure parts of the plant to spin a turbine.

- Binary cycle power plants use both water and working fluid in a closed loop. The hot water heats a working fluid that has a low boiling point (200° to 330°F). The resulting vapor is used to spin a turbine.

These concepts can be used in conjunction with each other and put into multi-cycle plants. When the water is finished cycling through the plant, it is pumped back underground to maintain pressure.

Figure 2
Types of Geothermal Power Plants
2019



Source: USDOE, "Geovision: Harnessing the Energy Beneath our Feet."

[17] Geothermal Technologies Office, "Electricity Generation."

As of 2023, the U.S. produced 17 gigawatt-hours (GWh) of electricity from geothermal power plants.[18] This represented only 0.4 percent of the country's total utility-scale electricity generated. Despite this small share of the overall energy market, geothermal capacity is expected to double by 2030.[19] Currently, much of this power comes from California and Nevada, while five other states in the western U.S. also have geothermal generation capacity.[20] Estimates of geothermal potential within the country have grown as the technology continues to develop. In 2019, the USDOE projected that geothermal energy production could reach a total installed capacity of 60 gigawatts (GW) by 2050, providing nine percent of electricity in the U.S.[21] Five years later, this estimated capacity was increased to 90 GW power within the same time frame.[22] While these figures highlight the enormous potential within of geothermal energy production, the current technology and available infrastructure make accessing that heat both costly and difficult.

Conventional geothermal power plants require heat sources over 300°F, as well sufficiently high enough pressure and volume.[23] Such locations are rare and there are only 64 conventional geothermal power plants in the U.S.[24] Typically commercial drilling for oil or gas does not exceed a depth of four miles, which poses a large barrier to the widescale adoption of geothermal as many potential geothermal reserves may not be economical to access at that depth. Recent research suggests that only a handful of sites in Pennsylvania would have sufficient temperatures at 2.5 miles below the earth, and only a few sites less than 1.5 miles deep (in northern areas) are hot enough.[25]

Even if a site can be found where the right conditions are present, the drawbacks associated with geothermal power plants are long development and construction times, high upfront costs, and risks of operation.[26] Geothermal power plants can take up to ten years to construct, in part due to the length of time necessary to secure the necessary permits.[27] With streamlined permitting, the process could be halved, possibly helping to double the projected amount of geothermal capacity by 2050.[28] If geothermal power plants are to capitalize on the incentive structures provided to other types of renewable energy sources, they must be in place long term, as the incentives could expire before a project's competition.

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[18] U.S. Energy Information Administration, "Use of Geothermal Energy," eia.gov, accessed July 21, 2025, https://www.eia.gov/energyexplained/geothermal/use-of-geothermal-energy.php.
[19] Sunneva Bernhardsdottir, "Power from Within: A Primer on Geothermal Energy," February 2018.
[20] U.S. Energy Information Administration, "Use of Geothermal Energy."
[21] Casey Crownhart, "What It Will Take to Unleash the Potential of Geothermal Power."
[22] U.S. Dept. of Energy, "Next-Generation Geothermal Power Commercial Liftoff," accessed December 5, 2024, https://liftoff.energy.gov/next-generation-geothermal-power/.
[23] Sunneva Bernhardsdottir, "Power from Within: A Primer on Geothermal Energy," February 2018, JSGC Staff Conversion.
[24] Statista, "Number of Geothermal Power Plants in the U.S.: 2001-2023," July 18, 2025, https://www.statista.com/statistics/1558922/geothermal-power-plants-united-states/#.
[25] Apt et al., "The Future of Geothermal," 46.
[26] U.S. Dept. of Energy, "Next-Generation Geothermal Power Commercial Liftoff," accessed December 5, 2024, https://liftoff.energy.gov/next-generation-geothermal-power/.
[27] Crownhart, "What It Will Take to Unleash the Potential of Geothermal Power," December 8, 2021.
[28] Crownhart, "What It Will Take to Unleash the Potential of Geothermal Power," December 8, 2021.

Estimates to build a geothermal power plant vary tremendously, between $2,500 - $6,000 per KW of installed capacity. [29] Much of the variation in this cost is explained by the difficulty in locating geothermal location: "Costs of a geothermal plant are heavily weighted toward early expenses, rather than fuel to keep them running. Exploration activities—pre-drilling geotechnical studies, exploration, confirmation, and development drilling—have a collective impact on overall project costs and success."[30] In comparison, solar and wind plants typically cost between $1,700 and $2,100 per KW.[31] However, it should be noted that overall, geothermal power plants will produce more energy over their lifetimes even if the capacity of the system is the same, because of the small amount of time the plant will be down and not producing electricity as compared to intermittent power sources like wind and solar. A geothermal power plant's capacity factor, that is, the amount of electricity it produces compared to the maximum possible output, is typically 90 percent.[32] Therefore when comparing price, it may be better to compare geothermal prices to hydroelectric and nuclear.

Based on federal target goals set for geothermal energy, costs associated with geothermal energy production are expected to decline over time. While it has been estimated that the country is on track to meet a goal of $60 - $70 per MWh by 2030, prices could drop further to meet the industry target of $45/MWh by 2035.[33] In the next section, the emerging practices within the geothermal industry which are helping to lower prices and increase its availability are reviewed.

Next Generation Geothermal

Geothermal electricity has not been pursued in Pennsylvania, generally because the Commonwealth's geography typically lacks the necessary elements to create power. The earth is not as hot at the same depth compared to some western states, or if there is heat, the earth may not be porous or permeable enough, making it harder to access.[34] The U.S. has tapped only 0.7 percent of its geothermal resources, which may be accessible through next generation geothermal systems.[35]

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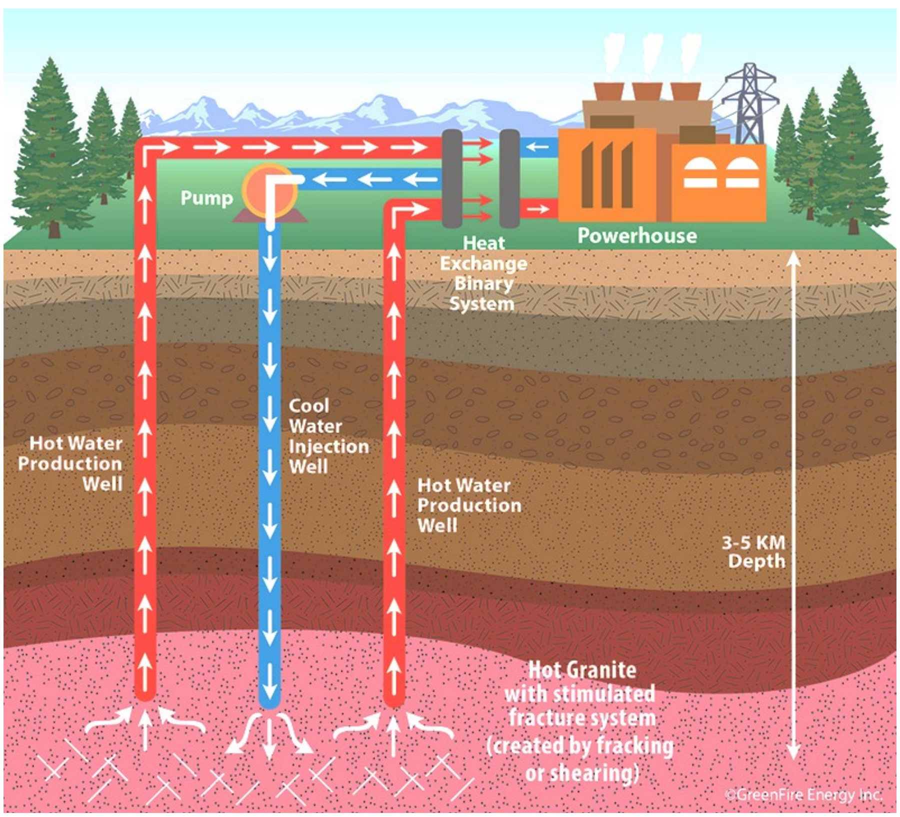
[29] David Banks, *An Introduction to Thermogeology: Ground Source Heating and Cooling*, 2008, https://doi.org/10.1002/9781444302677.
[30] U.S. Dept. of Energy, "Geothermal FAQs," Energy.gov, accessed April 29, 2025, https://www.energy.gov/eere/geothermal/geothermal-faqs.
[31] Crownhart, "What It Will Take to Unleash the Potential of Geothermal Power," December 8, 2021.
[32] U.S. Dept. of Energy, "Geothermal FAQs."
[33] U.S. Dept. of Energy, "Next-Generation Geothermal Power Commercial Liftoff," accessed December 5, 2024, https://liftoff.energy.gov/next-generation-geothermal-power/.
[34] Apt et al., "The Future of Geothermal," 54.
[35] IEA Geothermal and U.S. Dept. of Energy, "2022 Annual Report," June 2024, https://drive.google.com/file/d/1r9nfsBdSNSgdzxpPtIpX2sn7YYWz1emF/view.

In recent years, ongoing research has improved upon existing geothermal plant designs through the development of so-called next generation geothermal technologies. Using these new technologies to access deeper rocks that may be hotter, or to artificially create the permeability needed for hot fluid to move between the rocks is a potentially valuable innovation. "In Engineered Geothermal Systems, or EGS, engineers create a hydrothermal reservoir far underground by drilling wells into hot rock and connecting the wells via hydraulic fracturing. Then, to gather the heat, fluid is circulated through the fractured rock and brought back to the surface."[36] Another geothermal technology is known as advanced geothermal systems (AGS). Overall, AGS is similar to EGS, but the fluids are circulated within a closed-loop of pipes that allows the fluid to absorb heat and carry it back up to the surface. Fracking can lead to disruptions in ground water or cause disturbances in the ground if employed in the wrong places. However, fracking allows geothermal electric plants to access new locations across the U.S. Through using these technologies which were pioneered by the oil and gas industry, it is possible that Pennsylvania's geographical limitations relating to geothermal could be overcome. At the time of this report, these technologies are still in development.

Figure 3
Engineered Geothermal System
2023



Source: Greenfire Energy Company.

[36] Apt et al., "The Future of Geothermal," 17.

U.S. Demonstration of EGS

A geothermal energy company, Fervo, partnered with the USDOE to create a test site in central Utah called FORGE, which stands for Frontier Observation for Research in Geothermal Energy, to experiment with geothermal in conjunction with data centers.[37] Academic and industry researchers at FORGE are trying to find the best practices for deploying EGS, including drilling and reservoir maintenance. While FORGE has improved geothermal research, one of its limitations is that its observations are paired with a specific geology. In 2022 the federal infrastructure bill set aside $84 million for the USDOE to build four demonstration plants to test EGS in different geographical locations.[38] By 2024, the USDOE announced that three sites had been selected for EGS demonstration plants, one each in northern California, Utah, and Oregon, totalling $60 million.[39] With the new funding from the infrastructure bill, the USDOE will expand what researchers understand about setting up EGS facilities since they will be able to work in different places and with different kinds of rocks. One announced demonstration site will reportedly be built in the eastern U.S., where geothermal power plants are uncommon, however the site has yet to be selected.

Project Innerspace Report

In the past year, one of the largest changes in Pennsylvania's geothermal landscape was not the advent of new technologies but of growing industry advocacy and stakeholder recognition of geothermal energy's value to the Commonwealth. *The Future of Geothermal Energy in Pennsylvania: Leveraging the Commonwealth's Legacy of Energy Leadership* report by Penn State University and the federally funded Project Innerspace explores this topic in detail and highlights a possible future where the Commonwealth leverages EGS to meet its energy needs. The report, which is a large-scale collaboration of 10 lead authors with an additional 16 contributors and reviewers, including individuals from both academia and non-profits, examines the potential for growth in the geothermal industry within the Commonwealth.

Data shows that the underground heat available could provide more than a thousand times the energy that Pennsylvanians consume every year. Or to state it differently, if the existing resources and workforce of the current energy industry in Pennsylvania drilled for geothermal at the same rate that they drill for oil and gas, they could produce enough geothermal energy to meet all thermal demands for commercial heating and low-temperature industrial processes. According to *The Future of Geothermal Energy in Pennsylvania*:

> "Theoretically, if Pennsylvania's energy industry employed its resources and workforce to drill for geothermal at the same rate it drilled for other sources (790 oil and gas wells in 2022), within a year, geothermal could produce enough energy for all of the Commonwealth's commercial heating and low-temperature (<120°C)

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[37] Crownhart, "What It Will Take to Unleash the Potential of Geothermal Power," December 8, 2021.

[38] United State Department of Energy, "DOE Launches $84 Million Program to Demonstrate Enhanced Geothermal Energy Systems," Energy.gov, April 19, 2022, https://www.energy.gov/articles/doe-launches-84-million-program-demonstrate-enhanced-geothermal-energy-systems.

[39] United States Department of Energy, "Funding Notice: Enhanced Geothermal Systems (EGS) Pilot Demonstrations," Energy.gov, September 2024, https://www.energy.gov/eere/geothermal/funding-notice-enhanced-geothermal-systems-egs-pilot-demonstrations.

industrial processes. At a sustained drilling rate and with emerging technology, Pennsylvania could, in as few as 10 years, drill enough geothermal wells to meet 100 percent of the Commonwealth's electricity and heating needs as well as eliminate emissions from more energy intensive industrial processes." [40]

The report explains how Pennsylvania could use EGS and AGS to expand our energy production capabilities. Additionally, through a cataloging of established industries within the Commonwealth, the report's authors assert that different parts of the Commonwealth could benefit from direct-use geothermal technology. Potentially, the agricultural industry situated in York, Lancaster, and Chester counties could utilize geothermal energy. Philadelphia, Delaware, McKean, Butler, and Warren counties have petroleum and coal sectors that could benefit from the geothermal industry. The pharmaceutical industry in Montgomery County could employ geothermal technologies.

The Future of Geothermal Energy in Pennsylvania examines legal, regulatory, and policy questions surrounding geothermal energy development. One of the primary questions is who owns the resources, such as heat, water, and pores (or holes) within the Earth. Although no Pennsylvania court has addressed these specific questions, the report looks to case law and statutes for guidance and asserts that "heat and pore space are owned by the surface owner of real property, and they can be deeded or conveyed to another user."[41]

The report highlights reduced air pollution, lower emissions, and decreased pressure on land use and wildlife habitats as positive environmental outcomes that would likely arise from the use of geothermal energy. Additionally, the report states that repurposed abandoned oil and gas wells would allow for the improvement or upcycling of sites that have already been disturbed within the Commonwealth.

Further, the authors point out that an increase in the use of geothermal energy will require careful management of resources, including wastewater management, water use, traffic, and noise. Finally, because Pennsylvania has a substantial workforce directly involved in drilling, producing, refining, and transporting oil, gas, and coal, there exists a workforce that would require minimal retraining to benefit from an increase in this energy production sector.

Negative Impacts of Unconventional Natural Gas Wells

EGS uses oil and gas techniques which fracture rock with hydraulic fluids to create underground geothermal reserves in a process commonly known as fracking. Frequent comparisons have been made between the similarity of EGS and unconventional natural gas production. The possible range of health effects for implementing EGS are unknown at this time, however no instances of ground water contamination from EGS have been documented.[42] The relationship between the health of nearby residents and unconventional gas wells has been a source

[40] Apt et al., "The Future of Geothermal," 42.
[41] Apt et al., "The Future of Geothermal," 18.
[42] Smith Morgan, "Enhanced Geothermal Systems (EGS): Frequently Asked Questions," Congress.gov, July 7, 2024, https://www.congress.gov/crs-product/R48090.

of much academic research. Furthermore, a large amount of public scrutiny has been centered on the practice of fracking as it is employed at natural gas sites.

While proximity to natural gas wells appears to be linked to negative public health outcomes, many studies did not prove fracking was the cause nor could identify the mechanism by which the harmful health effects occurred. While fracking may be source of concern from the public, other activities at drilling sites could also be responsible. Past research has found that living in close proximity to gas well had impacts on the weight of newborns and prematurity.[43] Children who lived within a mile of a gas well had a five to seven times higher likelihood of developing lymphoma when compared to those who lived five or more miles away.[44] Other research into potential health effects was not limited exclusively to infants and children; areas with more natural gas activity had increased hospitalizations from heart attacks.[45]

It is unknown how relevant natural gas health outcomes are to EGS production, since many of the medical studies did not identify the mechanism by which proximity to unconventional gas sites was linked to declining health. While geothermal practices can be similar to natural gas extraction, there are also key differences.[46] The goal of unconventional gas wells is to open fissures where gas can escape. In the case of EGS, however, the purpose of fracking is to create a self-sustaining reservoir of water that can be used for binary cycle electric generation. Reportedly, fracking for geothermal may not use the same type of mixture as in natural gas exploration. Furthermore, "The lesser frequency, scope, and duration of hydraulic stimulation in most geothermal applications as compared with oil and gas operations will reduce both the magnitude and duration of any impacts associated with hydraulic fracturing."[47] Because of this difference, it remains unknown whether Pennsylvanians living in close proximity to EGS wells may experience similar health risks.

Safe and responsible development, monitoring, and regulation of geothermal technologies may lead to improved public health more broadly. For example, air emissions from "binary hydrothermal systems, where lower-temperature geothermal fluids are passed through heat exchangers with a secondary fluid rather than directly contacting the heat exchanger, have generally been found to have lower life cycle greenhouse gas impacts. The same is true for binary EGS systems, which are more likely than hydrothermal systems to be deployed for geothermal

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[43] Shaina L. Stacy et al., "Perinatal Outcomes and Unconventional Natural Gas Operations in Southwest Pennsylvania," *PLoS ONE* 10, no. 6 (June 3, 2015): e0126425, https://doi.org/10.1371/journal.pone.0126425;
see also Janet Currie, Michael Greenstone, and Katherine Meckel, "Hydraulic Fracturing and Infant Health: New Evidence From Pennsylvania," *Science Advances* 3, no. 12 (December 1, 2017),
https://doi.org/10.1126/sciadv.1603021.

[44] Talbott, et. al., "Hydraulic Fracturing Epidemiology Research Studies: Childhood Cancer Case-Control Study" (University of Pittsburgh, August 3, 2023), https://paenv.pitt.edu/assets/Report_Cancer_outcomes_2023_August.pdf.

[45] Jemielita T, Gerton GL, Neidell M, Chillrud S, Yan B, Stute M, et al. (2015) Correction: Unconventional Gas and Oil Drilling Is Associated with Increased Hospital Utilization Rates. PLoS ONE 10(8): e0137371. https://doi.org/10.1371/journal.pone.0137371.

[46] Paul Morgan, Nathan T Rogers, and Marie Hoerner, "OF-24-12 Geothermal in Colorado: Resources, Use Strategies, and Impact Considerations" (Colorado Geological Survey, July 1, 2024), 233.
https://doi.org/10.58783/cgs.of2412/zxit2727.

[47] Morgan, Rogers, and Hoerner, "OF-24-12 Geothermal in Colorado: Resources, Use Strategies, and Impact Considerations," 234.

electricity or district or industrial heating in Pennsylvania."[48] If geothermal electricity were to replace fossil fuels in the electric portfolio Pennsylvania's air quality could be significantly improved.[49]

Reuse and Co-production of Oil and Gas Wells

Beyond EGS, there are other types of emerging geothermal configurations which may prove well suited to the Commonwealth's energy portfolio. In recent years, emerging geothermal technologies can coproduce heat with oil and gas resources or alternatively, repurpose low producing wells to be used as geothermal resources.[50] Private companies are developing methods to screen which oil wells would be most appropriate to reuse. It is hoped that this method would not only reduce emissions compared to those that leak from gas wells but provide geothermal electricity in a more economical way. [51] An estimated 200,000 people could be employed in the Commonwealth to work on low-temperature geothermal projects.[52]

Pennsylvania Oil and Gas History

Pennsylvania has been a leader in American energy production for centuries, including in the oil and gas industry. America's first commercially successful oil well was drilled in 1859 in Titusville, located in northwestern Pennsylvania.[53] Over the past twenty years, Pennsylvania has contributed to the shale boom, becoming one of the world's top natural gas producers.[54] Because of the state's long history of oil and gas production, geologists and researchers have recorded and modeled the subsurface temperatures for years. Pennsylvania also has a strong workforce within the oil and gas sector, and a 2014 study by the U.S. Bureau of Labor Statistics indicates that Pennsylvania is one of the eight states containing counties with some of the highest relative concentrations of employment in oil and gas extraction.[55]

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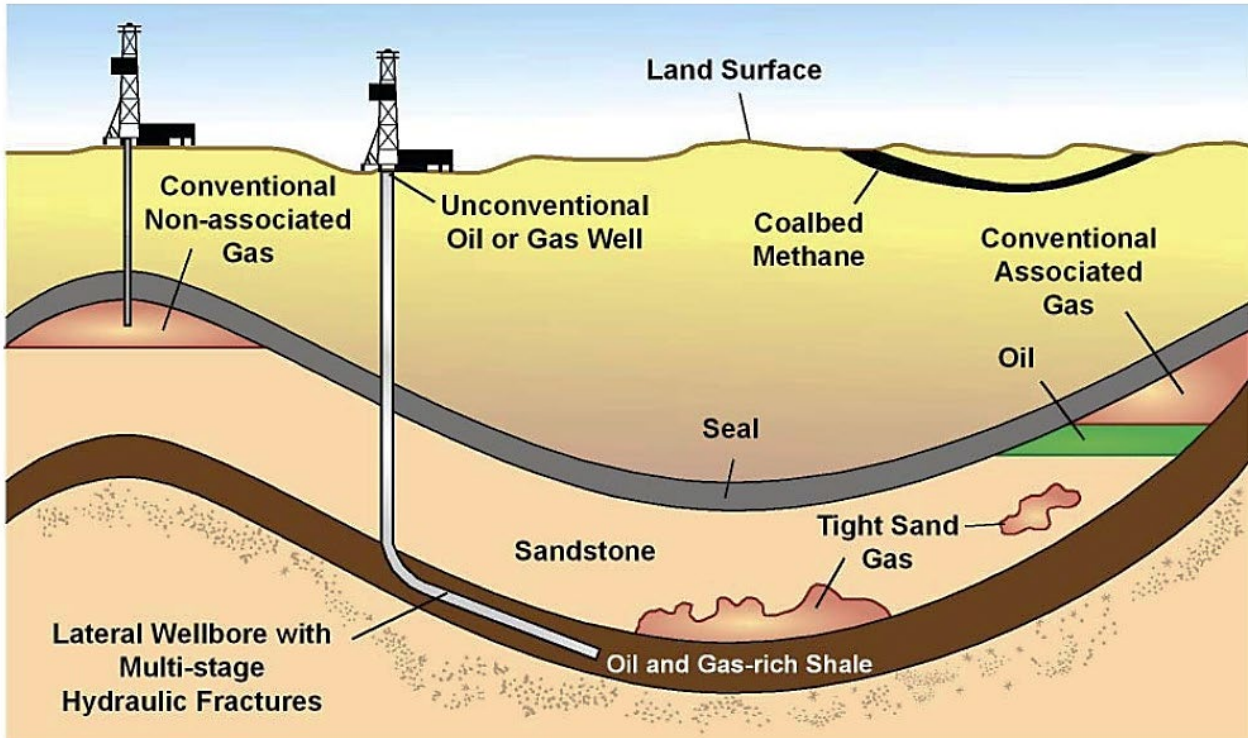
[48] Apt et al., "The Future of Geothermal," 118.
[49] Apt et al., "The Future of Geothermal," 118.
[50] Apt et al., "The Future of Geothermal," 14.
[51] Alexander Richter, "Call to Repurpose Abandoned Oil Wells in U.S. for Geothermal," Think GeoEnergy - Geothermal Energy News, April 10, 2021, https://www.thinkgeoenergy.com/call-to-repurpose-abandoned-oil-wells-in-u-s-for-geothermal/.
[52] Richter, "Call to Repurpose Abandoned Oil Wells in U.S. for Geothermal."
[53] Jay Apt, Max Clark, Carlee Joe-Wong, et al. "The Future of Geothermal Energy in Pennsylvania: Leveraging the Commonwealth's Legacy of Energy Leadership," *Penn State Center for Energy Law and Policy*, 2025, https://celp.psu.edu/wp-content/uploads/2025/02/Pennsylvania-Report.pdf, 16.
[54] Apt et al., "The Future of Geothermal," 16.
[55] U.S. Bureau of Labor Statistics, "Counties with highest concentration of employment in oil and gas extraction, June 2014," The Economics Daily, 2015, accessed July 15, 2025, https://www.bls.gov/opub/ted/2015/counties-with-highest-concentration-of-employment-in-oil-and-gas-extraction-june-2014.htm.

Figure 4
The Geology of Conventional and Unconventional Oil and Gas
2011



Source: U.S. Energy Information Administration, "The Geology of Natural Gas Resources."

A result of Pennsylvania's oil and gas legacy is numerous abandoned or underutilized oil and gas resources that are caused by the exhaustion of wells or reservoirs, a long history of "boom-and-bust" cycles within the industry, and a global transition away from fossil fuels.[56] In Pennsylvania, a well is considered to be abandoned once it has been dormant for 12 months. While a precise account of how many abandoned wells exist throughout the U.S. in general and Pennsylvania in particular cannot be made due to a lack of reliable records from the 1940s and earlier, a recent estimate placed the number of abandoned wells in the U.S. at around three million. Pennsylvania alone may have anywhere from 200,000 to 750,000 abandoned wells.[57] Another consideration is orphan wells, or wells that were abandoned before 1985 with no traceable owner. DEP has counted an estimated 30,000 orphan wells throughout the Commonwealth.[58] Taken together these represent a vast number of abandoned and underutilized oil and gas resources.

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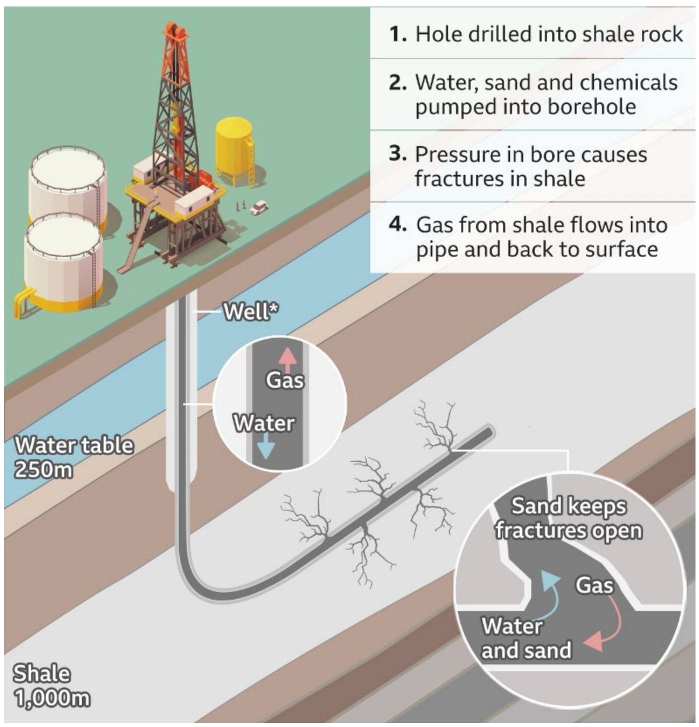
[56] Morgan Smith, "Oil and Gas Technology and Geothermal Energy Development," *Congressional Research Service*, 2023, https://www.congress.gov/crs-product/R47405, 3.
[57] Anthony Hennen, "State's $100,000+ cost to plug orphan wells 'outrageously enormous,'" *Times Observer*, 2024, accessed July 7, 2025, https://www.timesobserver.com/news/local-news/2024/09/states-100000-cost-to-plug-orphan-wells-outrageously-enormous/.
[58] Hennen, "State's $100,000+ cost to plug orphan wells."

A report by the Congressional Research Service (CRS) found that idle or abandoned wells are not just unproductive, but that they "may contribute to greenhouse gas emissions and are often costly to mitigate."[59] The CRS cites an EPA estimate that in 2020 alone, abandoned and unplugged wells emitted 552 million pounds of methane.[60] The CRS also estimated that median decommissioning costs for a well are $20,000 to plug it. Including surface remediation, the cost is estimated at $76,000 per well.[61] While these estimates could vary based on the specific conditions of the well and its surrounding area, it is clear that plugging wells is incredibly costly.

Abandoned oil and gas wells present a challenge to the Commonwealth when considering safety, finances, and the environment. Oil and gas co-production, a technique that introduces geothermal technologies to aging oil and gas wells, offers a potential solution to the problems posed by abandoned and aging oil and gas wells. Rather than giving up on these underperforming assets, co-production uses geothermal power to leverage aging oil and gas wells for continued energy production.[62]

Figure 5
How Gas is Extracted by Shale Fracking
2022



*Cement and steel casing.
Not to scale – Well depths can range from 1km-4km.
Source: British Geological Survey, Gov.uk, BBC News.

[59] Smith, "Oil and Gas Technology and Geothermal," 8.
[60] Smith, "Oil and Gas Technology and Geothermal," 8.
[61] Smith, "Oil and Gas Technology and Geothermal," 8.
[62] Smith, "Oil and Gas Technology and Geothermal," 3.

Geothermal Co-Production and Well Reuse

Geothermal reuse of abandoned oil and gas wells appears promising in Pennsylvania, however there are also possibilities to create geothermal energy from wells still in operation. While certain wells may not be considered productive enough to continue oil and gas production alone, CRS found that they may have significant geothermal potential to make up for their underperformance. When oil and gas sites extract hydrocarbons for energy, a hot working fluid is produced as a byproduct. This fluid, consisting of water and other constituents, is normally cooled and disposed of through deep injection sites. However, if the fluid is at an adequate pressure and temperature, it can be used for the extraction of geothermal heat to create simultaneous power production.[63] This process, summarized as the "simultaneous extraction of geothermal heat and hydrocarbons (oil or gas) from the same well," is known as co-production.[64]

Co-production is a potential solution to the problems of abandoned wells in Pennsylvania because it can effectively lengthen the economic viability of wells that are underperforming and nearing the end of their economically useful life.[65] Co-production repurposes aging oil and gas wells and slows the growing number of wells that have been abandoned, helping to slow the growth of a clear liability.

Oil and gas sites may be converted exclusively for geothermal electrical production, sometimes called well reuse. In such instances, it is important to consider the feasibility of reconfiguring oil and gas wells for geothermal energy. The geothermal and oil and gas industries have developed similarly, sharing common technologies such as those for drilling, well completion, and underground resource assessment. These technologies include directional drilling and hydraulic fracking. The geothermal industry also uses equipment similar to the oil and gas industry, as well as a workforce with a similar skill set and knowledge base.[66] The CRS report concludes that these similarities "may present opportunities to redeploy O&G industry assets to the geothermal power industry under the right circumstances."[67] While the CRS's findings focus heavily on EGS, co-production is another option that they propose. The similarities between the geothermal and oil and gas industries make co-production possible, and co-production takes advantage of these similarities between the two industries.

The reconfiguration of oil and gas wells for geothermal production has various advantages over standalone geothermal site development. First, if an oil and gas well has already been completed, data already exist on the subsurface conditions, such as temperature, rock, and seismic history, as well as data on the volumes and properties of extracted fluids, including hydrocarbons and hot water.[68] The knowledge that comes from previously installed oil and gas wells is valuable, and so is the elimination of costs for new construction and drilling. An extensive review of co-

[63] Smith, "Oil and Gas Technology and Geothermal," 5.
[64] Kurt Klapkowski, "Testimony of Deputy Secretary Kurt Klapkowski," *Pennsylvania Department of Environmental Protection*, May 7, 2025, https://www.palegis.us/house/committees/committee-archives/archive-file?file=2025_0198_0005_tstmny.pdf, 9.
[65] Klapkowski, "Testimony of Deputy Secretary Kurt Klapkowski," 9.
[66] Smith, "Oil and Gas Technology and Geothermal," 2.
[67] Smith, "Oil and Gas Technology and Geothermal," 2-3.
[68] Smith, "Oil and Gas Technology and Geothermal," 7.

production explains the significant value that comes from prior knowledge, similarities between the industries, and well reuse, saying that:

> The development of geothermal energy is limited because of different reasons such as subsurface exploration risk and high upfront capital cost for drilling and facility construction. However, similarities in infrastructure and operations between the oil and gas industry and the geothermal industry can optimize expense and development when exploiting geothermal resources.[69]

Coproduction at oil and gas wells can result in improved economics for the oil and gas operations and reduced water handling, disposal, and emissions mitigation costs.[70] Finally, using geothermal energy via active wells has a low environmental impact because it eliminates land transformation due to the drilling of new wells.

There are also challenges with the reconfiguration of oil and gas wells for geothermal energy. First, while there are general similarities, oil and gas wells are not typically designed specifically for geothermal power. This means that oil and gas wells may be smaller than optimal for geothermal wells, which are usually larger in diameter.[71] Second, oil and gas production may fail to produce a constant supply of sufficient water volumes or temperatures for geothermal power production.[72]

Some current cost projections conflict with some indications that reconfiguration will save money, while others suggest the opposite. Cost savings are suggested by those pointing to the elimination of new construction and drilling new wells. Cost savings are also a possibility because retrofits eliminate plug-and-abandonment costs for decommissioned wells. However, research suggests that the aging infrastructure within the wells may make them expensive to retrofit. Adapting these old wells to safe and modern standards within the geothermal industry would likely be costly.[73] Costs would vary between individual projects; however, more specific feasibility studies could be expected to provide more clarity.

The reconfiguration of oil and gas wells could appeal to many groups. Reconfiguration offers the possibility of ongoing production, financial viability, and cost savings for owners of aging oil and gas wells. Reusing old oil and gas wells may also appeal to some conservationists because it may help dissuade well abandonment. As noted by *The Future of Geothermal Energy in Pennsylvania*, environmental advocates may be supportive allies of well reuse, noting that they may "welcome the reuse of abandoned oil and gas wells in Pennsylvania because it represents an opportunity to mitigate fugitive methane emissions and reduce the need for new wells (minimizing the associated impacts of drilling and exploration), while decreasing the overall carbon footprint of energy production."[74]

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[69] Natalia A. Cano et al., "Power from Geothermal Resources as a Co-product of the Oil and Gas Industry: A Review," *ACS Omega* 7, no. 45 (2022), doi: 10.1021/acsomega.2c04374, 1.
[70] Smith, "Oil and Gas Technology and Geothermal," 5.
[71] Smith, "Oil and Gas Technology and Geothermal," 5.
[72] Smith, "Oil and Gas Technology and Geothermal," 5.
[73] Klapkowski, "Testimony of Deputy Secretary Kurt Klapkowski," 9.
[74] Apt et al., "The Future of Geothermal," 129.

Oil and Gas Workforce Potential

Pennsylvania's existing oil and gas workforce is a strong asset to the potential geothermal industry. The Pennsylvania Geothermal Future report identifies nearly 40,000 Pennsylvania workers who are directly involved in drilling, producing, refining, and transporting oil, gas, and coal, who could "immediately benefit from jobs created by the development of next-generation geothermal."[75] Further, the CRS notes a decline in total employment in the oil and gas industry nationally since 1982 and views the geothermal industry as a natural path for these workers to follow.[76] In theory, a transition from the oil and gas industry to the geothermal sector would be beneficial to Pennsylvania's workers in need of jobs, as well as a blooming industry in need of skilled, experienced workers.

In 2021, the U.S. Bureau of Labor Statistics organized employment within the oil and gas industry by occupation and categorized each job, based on the skills and experience involved, into groups of high, moderate, and low relevance to the geothermal power sector. The research found that 61 percent of total oil and gas employment is of high relevance to the geothermal sector, and 13 percent is of moderate relevance.[77] Just 25 percent of employment within the oil and gas sector is of low direct relevance to geothermal power, though many of these occupations would likely still be involved indirectly.[78] The research demonstrates a significant overlap between jobs within the oil and gas sector and the skills needed for the development of geothermal.

Table 1
Oil and Gas Occupations by Relevance to Geothermal Industry
United States
2021

Occupation Group	Examples	Relevance	Percent of total employment
Construction and Extraction	Derrick, rotary driller, and construction equipment operations; roustabouts; construction laborers and managers	High	20%
Transportation and Material Moving	Truck drivers, pumping station operators	High	14
Architecture and Engineering	Civil, electrical, environmental, mechanical, and petroleum engineers; surveyors	High	10
Installation, Maintenance, and Repair	Mechanics, technicians, and repair workers	High	7
Production-related	Plant construction and operation	High	6

75 Apt et al., "The Future of Geothermal," 21.
76 Smith, "Oil and Gas Technology and Geothermal," 9.
77 Smith, "Oil and Gas Technology and Geothermal," 10.
78 Smith, "Oil and Gas Technology and Geothermal," 10.

continued

Table 1
Oil and Gas Occupations by Relevance to Geothermal Industry
United States
2021

Occupation Group	Examples	Relevance	Percent of total employment
Life, Physical and Social Science	Physical, chemical, materials, environmental, hydrological and geological scientists and technicians	High	4
Legal Staff	Lawyers, paralegals, and title examiners	High	<1
Management	Operations and construction managers	Moderate	13
Others	Business and financial operations, office admin and support, computer and mathematical; Sales	Low	25

Source: U.S. Bureau of Labor Statistics, 2021.

Among the highly relevant occupations are jobs that involve direct work such as construction and extraction, transportation and material moving, architecture and engineering, installation, maintenance and repair, production, scientific research, and legal work.[79] Many of the moderately relevant occupations include the management of operations and construction.[80] Both the management and construction categories include workers with transferable technical skills and knowledge, such as knowledge of underground conditions and the skills for maintaining and operating wells.[81]

Low-relevance occupations include business, financial operations, computing, mathematics, and sales.[82] While these occupations may be of less technical relevance to the geothermal sector, the CRS argues that these supporting skills are also incredibly valuable to future geothermal projects. The oil and gas workforce has an abundance of experienced professionals in financing and risk management for subsurface resource development.[83] They already have relationships with investors and are familiar with the challenges posed by geological risk.[84] The CRS reports that "many of the developers creating and adapting technologies for geothermal applications include senior executives from the O&G industry who apply their knowledge and experience of the challenges and solutions from O&G to geothermal."[85]

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79 Smith, "Oil and Gas Technology and Geothermal," 10.
80 Smith, "Oil and Gas Technology and Geothermal," 10.
81 Smith, "Oil and Gas Technology and Geothermal," 18.
82 Smith, "Oil and Gas Technology and Geothermal," 10.
83 Smith, "Oil and Gas Technology and Geothermal," 19.
84 Smith, "Oil and Gas Technology and Geothermal," 19.
85 Smith, "Oil and Gas Technology and Geothermal," 18.

The oil and gas industry is valuable to future co-production efforts not only because of the technical expertise of its workforce, but also for its workers with experience that goes beyond technical skills and knowledge. The oil and gas workforce would be an incredible resource for projects looking to take aging oil and gas assets and use them for co-production.

Studies on Co-production in the United States

There have been several studies examining the potential for geothermal energy production at existing oil and gas sites in the U.S., many of which were cited in a review titled, "Power from Geothermal Resources as a Co-product of the Oil and Gas Industry: A Review."

First, a study by Augustine *et al.* estimated co-produced fluid-geothermal potential in the U.S. based on three different models: exergy, the Massachusetts Institute of Technology (MIT) model, and the commercially available "off-the-shelf" (COTS) model. [86] These models made use of a database containing well production data, such as volume, flow, rate, and bottom-hole temperatures.[87] The authors of this study found that every year, there are 176.4 billion gallons of co-produced water that would be useful for power production.[88] This figure indicates approximately 1,300 electric megawatts (MWe) of co-produced fluid-power potential with the exergy model, 650 MWe based on the MIT model, and 276 MWe when using the COTS model.[89] The exergy model is considered an upper limit, while the COTS model is more realistic.

Another study by Banks *et al.*, investigated the geothermal potential of the Virginia Oil Field using three methods. These models produced estimates of average power potential ranging from 16 MWe to 32 MWe.[90] Among various approaches used were the reservoir volume method and a Monte Carlo[91] approach. The variations stem from different assumptions and data inputs.

The findings from studies on geothermal energy production alongside existing oil and gas production suggest an exciting opportunity for the growing geothermal industry as well as the oil and gas industry. However, many of the existing studies focused on hypothetical models or simulations. The authors of the review urge, "More efforts should be made to conduct pilot tests to determine the proper feasibility of this type of project and gain the practical experience that will show skeptics that this technology is as beneficial as the large body of literature suggested."[92] Further feasibility studies and pilot projects will be necessary for the successful development of geothermal technologies through co-production.

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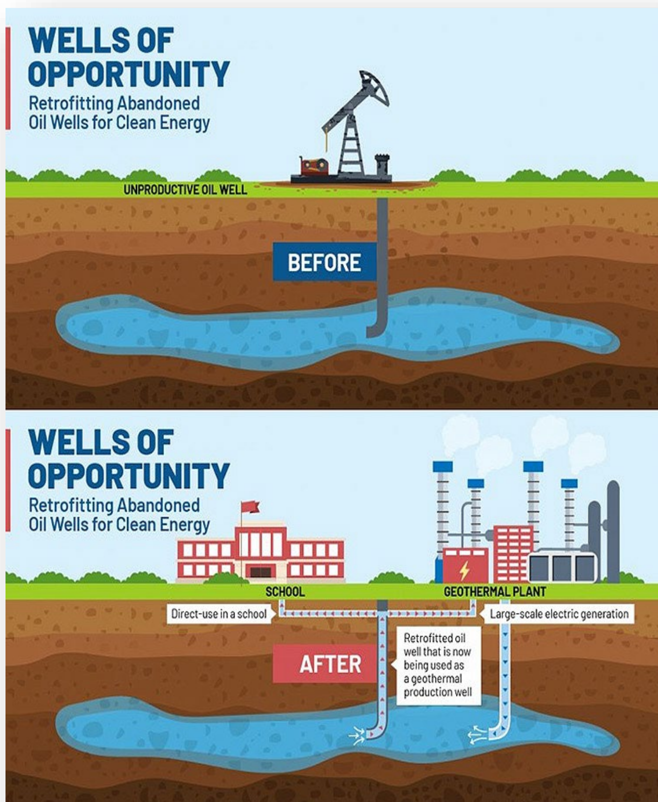
[86] Exergy is the amount of energy that can be extracted from geothermal heat given the source's temperature and the temperature of the environment where it will be used.
[87] Cano et al., "Power from Geothermal Resources," 8.
[88] Cano et al., "Power from Geothermal Resources," 8.
[89] Cano et al., "Power from Geothermal Resources," 8.
[90] Cano et al., "Power from Geothermal Resources," 8.
[91] A Monte Carlo approach is a statistical method to problem solving that uses random sampling.
[92] Cano et al., "Power from Geothermal Resources," 17.

Case Study: Marchard Project

In the fall of 2024, CNX Resources Corp. partnered with the Pennsylvania Department of Environmental Protection and several other companies and universities to pitch a geothermal pilot project in Marchard, a small town in Indiana County. In years prior, CNX had found that its attempts at gas production in Marchard were not meeting expectations. The pilot project focuses on the conversion of a gas well to geothermal use. With a proposed budget of $37.6 million, the project would either repurpose an existing well in Marchard or drill a new one.[93] The team would then circulate a liquid inside the well to pick up the geothermal heat and eventually produce about one megawatt of electricity.[94]

Mike Sommers, CEO of the American Petroleum Institute, argued that "Oil and gas will be around and dominant for a long time…But the more energy that can be produced with the same expertise and equipment, the better."[95] The Marchard project attempts to do just that by taking advantage of existing oil and gas infrastructure and experienced workers to launch a geothermal project. Official results of this pilot have not yet been released, but its results may inform how this technology progresses.

Figure 6
Retrofit of Oil Wells
2022



Source: U.S. Dept. of Energy, "Wells of Opportunity."

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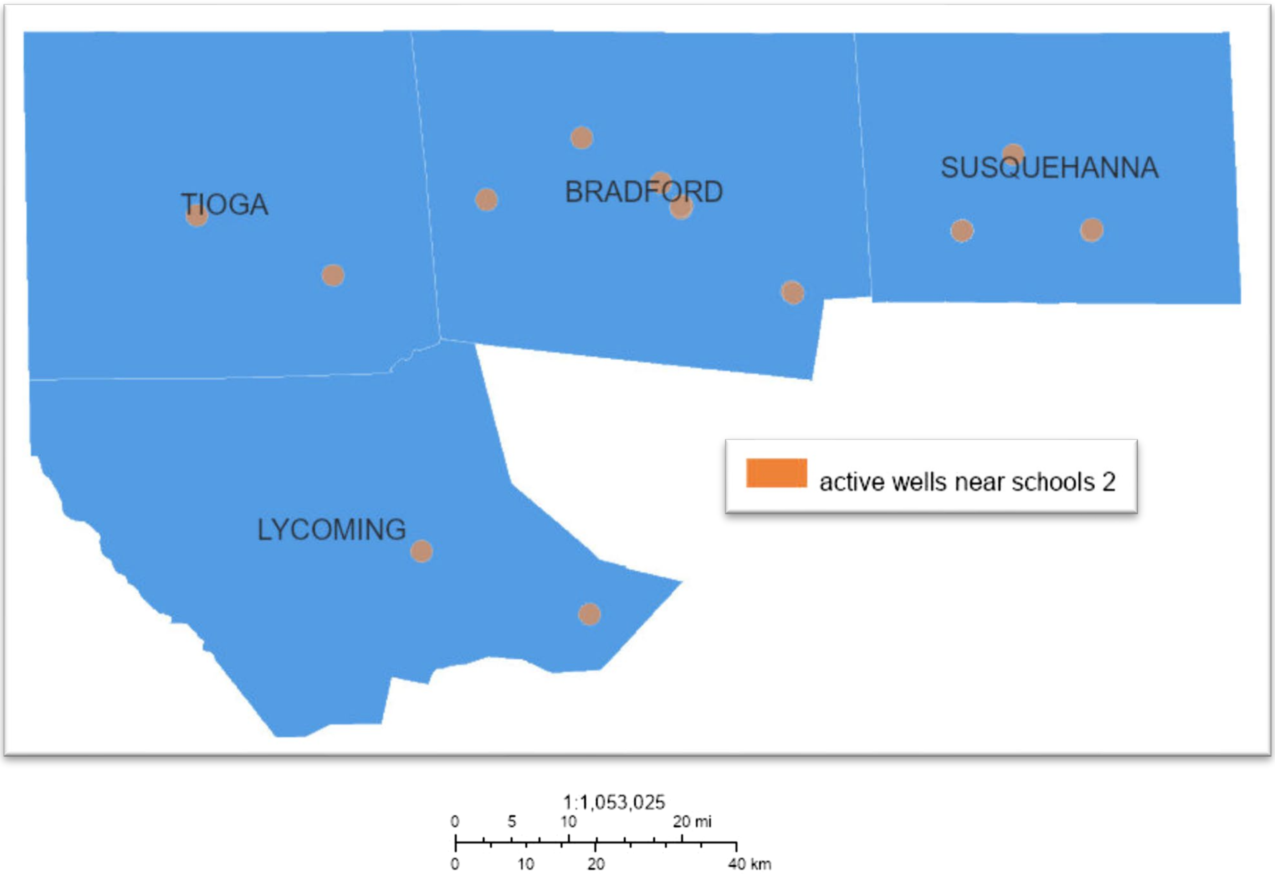
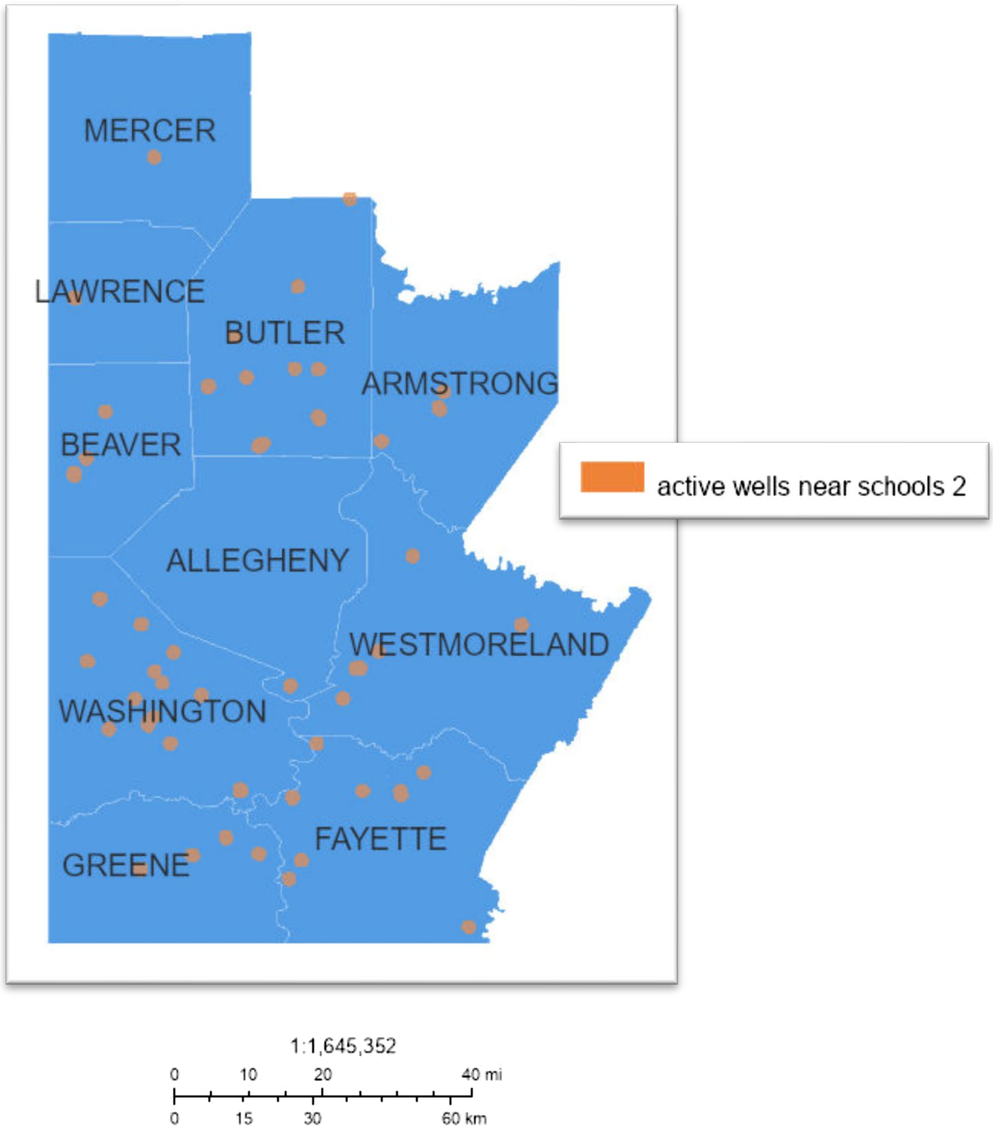
[93] Anya Litvak, "'Hot everywhere underground': A geothermal push in Pennsylvania enlists the oil and gas industry," *Pittsburgh Post-Gazette (PA*), 2025, accessed June 11, 2025, https://www.post-gazette.com/business/powersource/2025/02/26/geothermal-pennsylvania-energy-shale/stories/202502260051.
[94] Litvak, "'Hot everywhere underground.'"
[95] Litvak, "'Hot everywhere underground.'"

Map 2
Active Gas Wells within One Mile of
Northern Pennsylvania School Buildings
2025



Source: PA DEP data, JSGC spatial analysis.

Map 3
Active Gas Wells within One Mile of
Southwest Pennsylvania School Buildings
2025



Source: PA DEP data, JSGC spatial analysis.

Screening of Potential Co-Production Sites

Having a contract in place to supply electricity and heat for end users in proximity to the geothermal well instead of building out transmission infrastructure may increase project viability of well use or coproduction at this stage of its development. JSGC sought to examine potential users of co-production resources, however, available data on Pennsylvania infrastructure which may be ideal for such purposes was limited. Public schools were selected for this analysis for three reasons: school building data were easily accessible, schools have constant heating and cooling needs, and schools are distributed throughout regions of the state where natural gas wells are present. Furthermore, if industry claims about well reuse or coproduction being beneficial for emission levels are accurate, siting geothermal generation sources near school buildings could improve the air quality for the Commonwealth's children.

While media reports have emphasized the potential use of abandoned wells for co-production and reconfiguration, current research on this subject is sparse. One of the primary concerns is that older oil and gas wells may have deteriorated and be in poor condition after sitting derelict. This is confirmed from previous demonstrations showing that abandoned gas wells were too damaged to use in geothermal systems, such as one studied in Osage Nation Oklahoma.[96] Additionally, there may be legal complications to using orphaned wells, making them undesirable to the industry. If the co-production and well-reuse were to become more profitable, there would likely be incentive for companies to examine reuse potential. However, co-production can still work to deter emissions from future abandoned wells being abandoned because it makes these sites more valuable.

Operating under the assumption that active gas wells must be used for geothermal co-production and well reuse at this juncture, Commission staff conducted a screening for Pennsylvania school buildings located within one mile of active natural gas wells as potential sites for co-production. Because these configurations are still experimental, the exact distance away before the co-production becomes impractical is still being determined. While 95 schools were identified as being within a mile of active gas wells, a second screening revealed four sites under a third of a mile. See Table 2 and Table 3. Sites at this shorter distance would require more to be known about the safety of the co-production process beyond the known side effects of fracking. Furthermore, both school district and community approval would likely be necessary, along with gas operators' agreement to the arrangement. Less productive wells are preferred for reuse as geothermal projects; data on these wells were unavailable. Nonetheless, this review shows the potential for co-production sites near public buildings within the Commonwealth. A full listing of examined school buildings can be found in Appendix B of this report.

[96] GeoTribe, "Current Project," accessed July 30, 2025, https://free-4296955.webador.com/current-project.

Table 2
County Distribution of Schools Near Active Natural Gas Wells
2025

County	Schools within one mile of active gas well
Allegheny	1
Armstrong	4
Beaver	5
Bradford	8
Butler	15
Fayette	12
Greene	10
Indiana	0
Lawrence	3
Lycoming	2
Mercer	1
Susquehanna	6
Tioga	2
Washington	20
Westmoreland	6
Grand total	111

Source: JSGC, with data from DEP and National Center for Education Statistics.

Table 3
Gas Wells within a Third of a Mile of Pennsylvania Schools
2025

Name	City	County	Number of wells >1/3 Mile
SRU Middle School	East Smithfield	Bradford	3
Summit Elementary School	Butler	Butler	5
Bethlehem-Center Elementary School	Fredericktown	Washington	1
Western Area Career & Technical Education Center	Canonsburg	Washington	1

Source: JSGC, with Data from DEP and National Center for Education Statistics.

Co-Production and Well Reuse Testimony

On May 7, 2025, the Pennsylvania House Energy Committee conducted hearings on geothermal energy use. The Committee heard testimony relating to geothermal co-production from both industry and government agency perspectives. One of the testimonies was from Johanna Ostrum, Chief Operating Officer of Gradient Geothermal, a company that works to turn existing oil and gas wells into sources of geothermal energy. Its focus is co-production, and the company is already developing projects in states including North Dakota, Nevada, Louisiana, and Colorado.[97] Deputy Secretary Kurt Klapkowski from the Office of Oil and Gas Management in DEP also gave testimony before the House Energy Committee. More about the DEP's assessment of geothermal technology applications can be found in Appendix C.

Both testimonies noted the promise for co-production in Pennsylvania and expressed that co-production systems would be beneficial for oil or gas well repurposing and will align with state efforts to reduce the liabilities associated with abandoned wells.[98] Low or marginally producing wells, known as stripper wells, are currently thought to provide the most opportunity because co-production is a way to extend their economic usefulness.[99] From an industry perspective, co-production is faster and less expensive than is drilling new geothermal wells and it could also help Pennsylvania avoid well closure liabilities.

[97] Johanna Ostrum, "Testimony of Johanna Ostrum, Gradient Geothermal Before the Pennsylvania House Energy Committee," May 7, 2025, https://www.palegis.us/house/committees/committee-archives/archive-file?file=2025_0198_0003_tstmny.pdf, 1.
[98] Klapkowski, "Testimony of Deputy Secretary Kurt Klapkowski," 9.
[99] Klapkowski, "Testimony of Deputy Secretary Kurt Klapkowski," 9.

GEOTHERMAL HEATING AND COOLING

While the previous chapter focused on electricity production derived from high temperature geothermal reserves, the term geothermal also can encompass lower temperature heat that is stored underground and systems that use pumps to draw and store heat underground as needed. Despite Pennsylvania's lack of conventional geothermal reserves, wide scale adoption of ground source heat pumps (GSHP) could enable significant cost savings by reducing the amount of energy production required for heating and cooling. However, unlike the geothermal sources discussed in the report thus far, GSHPs do not tap into heat generated deep within the earth. In Pennsylvania, the ground is typically at a constant 55°F three to seven feet below the earth. While these pumps are efficient at heating and cooling homes, they can also be employed in industrial and commercial settings.[100] According to the U.S. DOE:

> Geothermal heat pumps, or GHPs, use the constant temperature of the shallow Earth (40–70°F) to provide heating and cooling solutions for buildings wherever the ground can be cost-effectively accessed to depths below seasonal temperature variations. The thermal energy storage properties of the rocks and soils allow GHPs to act as a heat *sink*—absorbing excess heat during summer, when surface temperatures are relatively higher—and as a heat *source* during the winter, when surface temperatures are lower. This increases efficiency and reduces the energy consumption of heating and cooling for residential and commercial buildings.[101]

To help differentiate between high temperature geothermal reserves and lower temperature geothermal resources, the label geo-exchange is sometimes applied when a heat pump is used to cool as well as heat. This term helps clarify that GSHPs do not create heat, they simply move it from one location to another. Geo-exchange systems still require a source of electricity to operate and can be powered by energy received from the electric grid or combined with on-site generation to minimize the costs of operation. In addition to heating and cooling, these systems can also be configured to provide hot water. A summary of geo-exchange benefits that will be explored in this chapter:

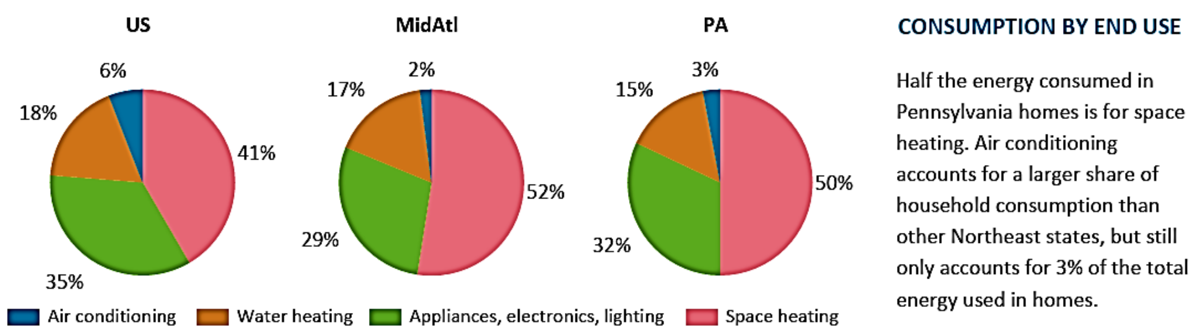
- Reliable, long term, low maintenance costs, user comfort,
- Local resources that can increase energy independence,
- Efficient and renewable heat and cooling,
- Low greenhouse gas emissions,
- Eliminates air pollutants common to burning fossil fuels, potentially improving public health.[102]

[100] Apt et al., "The Future of Geothermal," 14.
[101] U.S. Dept. of Energy, "Geothermal FAQs," Energy.gov.
[102] "Geothermal Heat Pumps," Energy.gov, accessed July 22, 2025, https://www.energy.gov/energysaver/geothermal-heat-pumps.

Heating and Cooling Needs within Pennsylvania

One of the reasons to pursue GSHP and geo-exchange systems as a course of state policy is to use energy more efficiently and decrease heating and cooling costs within the state. While generalizations about Pennsylvania's climate can be difficult because of its diverse geography, winter temperatures range between 0°F and 40°F.[103] An estimated 25 percent of Pennsylvania households use electricity for heating, 50 percent use natural gas, and 20 percent use petroleum products such as oil or propane.[104] Despite small overall use, Pennsylvania has the highest use in the country of coal stoves to heat homes. Increasingly, air conditioning for cooling is also seen as more important in parts of the state due to the increasing number of summer days over 90°F, which poses a risk to elderly and other vulnerable populations.[105]

Figure 7
Survey of Pennsylvania Household Electricity Use
2009



Source: U.S. Energy Information Agency, "Household Energy Use in Pennsylvania."

Over half of the energy used by Pennsylvania homes is for heating and cooling.[106] This means that a significant portion of total energy use may be reduced through adoption of high efficiency heat pumps. Despite this benefit, adoption rates of GSHP appear low given that the technology has been available for over 75 years. An estimated one million GSHP are operating around the U.S., and the number of new residential installations is growing by 80,000 a year.[107]

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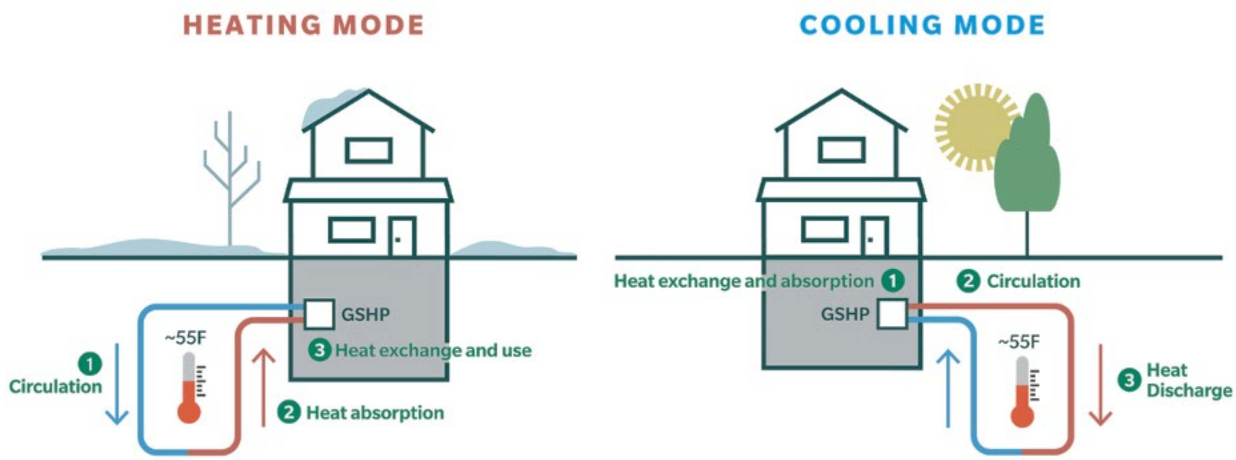
[103] "Pennsylvania State Climatologist," accessed May 7, 2025, https://climate.met.psu.edu/data/state/.
[104] U.S. Energy Information Administration, "Pennsylvania State Profile and Energy Estimates," eia.gov, January 16, 2025, https://www.eia.gov/state/analysis.php?sid=PA.
[105] Pennsylvania Climate Impact Assessment 2024, https://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/Climate%20Change%20Advisory%20Committee/2023/8-22-23/ICF-Presentation_to_CCAC_10.24.23.pdf.
[106] U.S. Energy Information Agency, "Household Energy Use in Pennsylvania," 2009, accessed July 21, 2025, https://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/PA.pdf.
[107] Dandelion Energy, "Residential Geothermal Heating & Cooling," March 13, 2025, https://dandelionenergy.com/.

Figure 8
Seasonal Use of Heat Pumps
2022

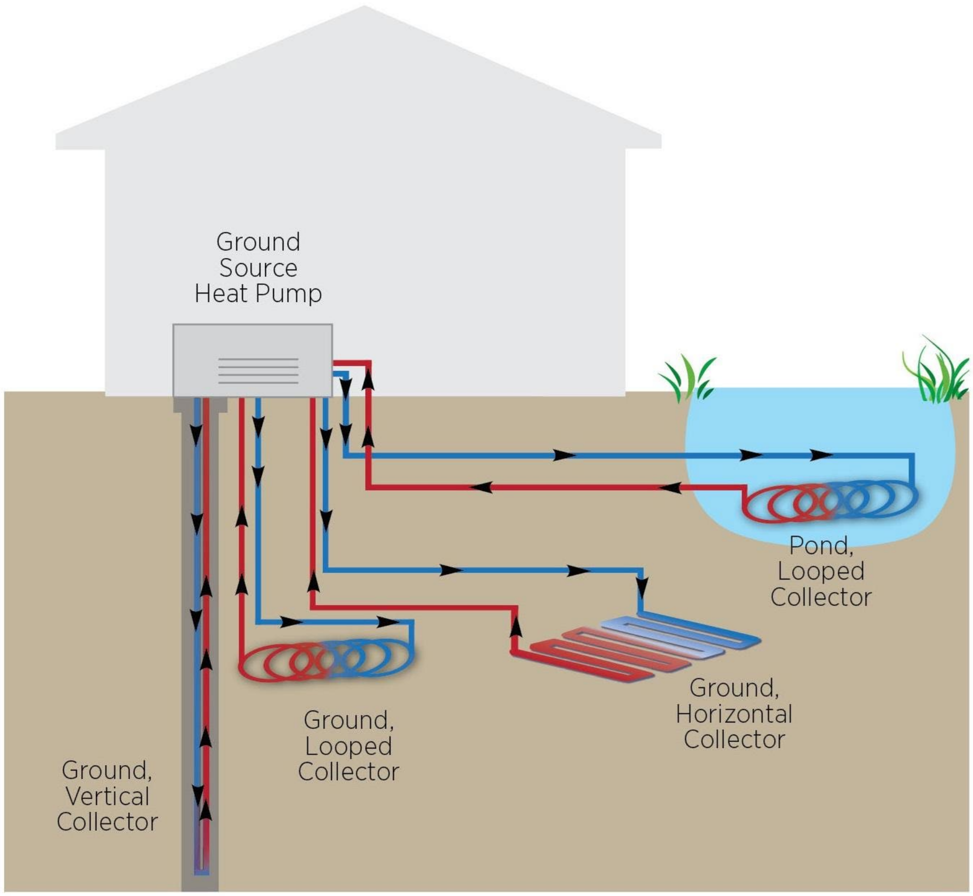


Source: Eversource, Geoexchange Diagram, 2022, https://www.eversource.com/content/business/save-money-energy/clean-energy-options/geothermal-pilot-program-in-massachusetts.

Broadly, there are two types of geothermal heat pumps, open-loop and closed-loop. Of the two, open-loop pumps feature efficiency, lower installation costs, and are typically paired with clean water sources that will not clog pumps. Conversely, a closed-loop style of pump uses water that is contained within piping and does not have direct contact with ground water. Frequently, antifreeze is added to the closed-loop system in colder climates to prevent freezing. Despite the higher cost, renewable energy developers choose to install closed-loop GSHP systems because of local regulations or engineering requirements. In other instances, they may be seeking the most environmentally friendly option.

The piping within a closed-loop GSHP can be found in a variety of configurations each with different strengths. See figure 9. While vertical system piping may be efficient, it can also be expensive to drill, especially under a house that is already built. To reduce installation costs associated with drilling, some systems employ horizontal coils or trenches for their piping instead. However, this can disrupt earth and require a larger amount of land. Those with water on their properties might be able to set their closed-loop systems in the water source.

Figure 9
Ground Source Heat Pump Loop Configuration
2011



Source: U.S. Department of Energy, "Ground-Source Heat Pumps."

Costs of GSHP

The installation of geothermal systems initially requires drilling, additional site work, and the cost of components such as heat pumps and circulating pumps, which together generally leads to higher initial investments than would occur from the installation of conventional heating and cooling systems. Moreover, this type of heating system requires more expertise and care to construct. Those higher upfront costs, however, are then offset by lower operating costs. Operating costs for a geothermal system generally consist of electricity costs for running the heat pumps and water pumps.[108]

[108] Risch, Christine, Andrew Nichols, Mehdi Esmaeilpour, Begley, Richard Begley and Sinaya Dayan. "Mine Pool Geothermal Resources – Phase 1 Engineering Study" (Center for Business & Economic Research, Marshall University, West Virginia, 2022), 3.

Table 4
Annual Residential Benefits of GSHP
2016

Benefit	Unit Type	Northeast		United States	
		Amount	Percent	Amount	Percent
Primary Energy Savings	Quads BTU*	0.9	42.9%	4.6	42.2%
CO2 Emission Reduction	Million Metric Tons	62.4	44.2	296.6	42.4
Summer Peak Electrical Demand Reduction	Gigawatts	28.9	53.8	144.0	42.2
Energy Expenditure Savings	Billion Dollars	$15.5	47.2	$57.8	45.7

* A quad is a quadrillion British Thermal Units.

Source: Xiaobing Liu et al., "An Overview of Geothermal Heat Pump Applications and a Preliminary Assessment of Its Technical Potential in the United States," GRC Transactions 40.

GSHP can also create a more stable energy market that is insulated from the peaks caused by air conditioning in the summer and heating in the winter. A report to the Maryland Public Utility Commission estimated "that 1kW of electricity grid demand reduction can be achieved for each ton of GSHP technology installed. This amounts to roughly 1MW of demand reduction for every 250 homes connected to GSHP systems. For commercial buildings, 1MW of demand reduction can be achieved for approximately every 400,000 square feet of conditioned space."[109] A 2024 analysis from Oak Ridge National Laboratory noted that widespread adoption of GSHP in the Mid-Atlantic region could save 9.3 percent of its annual energy while reducing CO2 emissions by 77 percent.[110]

While across the country closed-loop GSHPs can average 70 percent lower energy costs than conventional heating systems, in the northeast residential GSHPs are estimated to be 47 percent and business' GHSPs are 41 percent less expensive to operate.[111] GSHPs operating costs are dependent on regional geological and site-specific conditions. Overall, organizations that can handle the initial financing are more likely to use GSHPs systems because they can afford to wait for the payback period.

A horizontal layout can be the least expensive type of closed-loop installation. In this configuration, the pipe loops are typically buried four to six feet below ground at lengths ranging from 125 to 300 feet of trench per ton of cooling-heating capacity. It is worth noting that while the expense of digging is lower in this type of system, it requires much more space and many of

[109] AECOM, "Electrical Grid Impact of Ground Source Heat Pump Technologies," December 2023, https://energy.maryland.gov/Reports/Electrical%20Grid%20Impact%20of%20Ground%20Source%20Heat%20Pump%20Technologies.pdf.

[110] Liu, Xiaobing, Ho, Jonathan, Winick, Jeff, et al., "Grid Cost and Total Emissions Reductions Through Mass Deployment of Geothermal Heat Pumps for Building Heating and Cooling Electrification in the United States," (2023), https://doi.org/10.2172/2224191.

[111] Xiaobing Liu et al., "An Overview of Geothermal Heat Pump Applications and a Preliminary Assessment of Its Technical Potential in the United States," GRC Transactions 40 (2016).https://www.geoexchange.org/geothermal-benefits/.

the components are more exposed to seasonal temperature fluctuations.[112] In an open-loop system, the water is pumped from a water source close to the surface and then discharged back to the same water source or into another water source. Typically, this type of system costs less to install, however, it requires clean groundwater and long-term system maintenance.[113]

While GSHPs at individual residences may save Pennsylvanians money on operational costs for heating and cooling if they have the necessary money to invest in such a system, the concept can also be employed at a commercial scale. See Table 5 below. A geothermal heat pump can last between 20 to 25 years. However, the pump can be replaced as the ground loop component of closed systems can last up to 50 years.[114]

Initial costs of installing a geothermal heating system vary based on the size of the building, the features of the equipment, and the performance of the GSHP system. The coefficient of performance (COP) is the heating effect produced by the unit divided by the energy equivalent of the electrical input, or the heating performance. One analysis has suggested that for geothermal heat-pumps to be practical in a given area, electricity costs must be approximately a third of the cost of natural gas prices.

Table 5
Annual Commercial Benefits of GSHP
2016

Benefits	Unit Type	Northeast		United States	
		Unit	Percent	Unit	Percent
Primary Energy Savings	Quads BTU*	0.5	41%	1.8	29%
CO_2 Emission Reduction	Million Metric Tons	29.6	41	116.1	29
Energy Expenditure Savings	Billion Dollars	$6.4	41	$19.5	30

* A quad is a quadrillion British Thermal Units.

Source: Xiaobing Liu et al., "An Overview of Geothermal Heat Pump Applications and a Preliminary Assessment of Its Technical Potential in the United States," GRC Transactions.

Increasing Adoption of GSHP

Homes in rural and suburban areas may have the most potential for retrofits simply because they have the space necessary to install geothermal systems. Residential geothermal heat pump

[112] Risch, Christine, Andrew Nichols, Mehdi Esmaeilpour, Begley, Richard Begley and Sinaya Dayan. "Mine Pool Geothermal Resources – Phase 1 Engineering Study" (Center for Business & Economic Research, Marshall University, West Virginia, 2022) 17.
[113] Dandelion Energy, "Open Loop Vs Closed Loop Geothermal Systems," Dandelion Energy, July 27, 2023, https://dandelionenergy.com/open-loop-vs-closed-loop-geothermal-systems.
[114] U.S. Department of Energy, "Heat Pump Systems," Energy.gov, accessed August 4, 2025, https://www.energy.gov/energysaver/heat-pump-systems.

systems cost $2,500-$8,000 per ton in capacity.[115] Many homeowners can expect geothermal systems to cost between $30,000-$60,000. One analysis suggested that a 2,000 square foot home located in northeastern Pennsylvania could save 62 percent of its annual energy bill through a geo-exchange system that supplies heating, cooling, and hot water, and reduce its carbon footprint by 70 percent.[116] The typical payback period for home systems ranges between three to ten years, depending on the location, type of ground loop, and available incentives.[117]

While the pumps themselves are not dissimilar between GSHP and the more commonly seen air source heat pump, the total cost for installing the GSHP systems can be substantially higher as there are additional tasks necessary for installation including drilling, trenching, and laying piping. These high upfront costs can be mitigated through incentives to help reduce and spread-out costs**.** For example, as of this report, Connecticut is a regional leader in geo-exchange and offers up to $15,000 for residential systems and $4,000 per ton on commercial, institutional, and municipal systems.[118] Connecticut has several programs that help make investing in GSHP more affordable. Low interest financing, starting at zero percent, from Energize Ct and Connecticut Green Bank can help spread out installation costs over a period of up to 20 years.[119] Only certified installers can be employed through the incentive program, as the policy recognizes the adverse effects on GSHP adoption and public sentiment if it funded improper installations. Across the U.S., as of this report, federal Inflation Reduction Act (IRA) tax credits can be used to cover between 30 percent of upfront costs on qualified GSHP installed between 2006 to 2034, at which time the incentive will be reduced.[120]

Assessing the benefits of a geothermal system is calculated by comparing how the ongoing lower operating costs offset the initial higher system implementation costs.[121] The five-to-ten-year payback period can be a substantial concern that limits geothermal system appeal. The payback period can be reduced, however, by using various government programs and incentives aimed at lowering the installation costs of GSHPs. For example, Pennsylvania's Penn Energy Savers program offers rebates for heat pump products shown in the table below. The program aids

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[115] U.S. Dept. of Energy, "How Geothermal Heat Pumps Work," *Guide to Geothermal Heat Pumps*, February 2011, https://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf; see also, Vikramdeora, "Geothermal Heating &Amp; Cooling Costs Alberta [2024]," *Envirotech Geothermal Ltd.* (blog), November 18, 2024, https://envirotechgeo.com/cost-of-geothermal-heating-and-cooling-system-for-homeowners-2024-guide/.
[116] Michael C. Korb, "Save Money, Save the Environment: Another Discussion of Mine Water Geothermal," Presenter (Lewisburg, PA, June 4, 2025.), https://static1.squarespace.com/static/61803b18879f384941cdda36/t/68507adcfe8ab60d1bcae98e/1750104807123/Korb+Mine+Water+Geothermal.pdf.
[117] Alison F. Takemura, "Geothermal Heat Pumps Are Crazy Efficient. Should You Get One?," Canary Media, February 3, 2025, https://www.canarymedia.com/articles/heat-pumps/geothermal-heat-pumps-are-crazy-efficient-should-you-get-one.
[118] Connecticut Dept. of Energy & Environmental Protection, "Geothermal," CT.gov, accessed July 22, 2025, https://portal.ct.gov/deep/energy/renewable-energy/geothermal.
[119] Connecticut Dept. of Energy & Environmental Protection, "Geothermal."
[120] Connecticut Dept. of Energy & Environmental Protection, "Geothermal."
[121] Risch, Christine, Andrew Nichols, Mehdi Esmaeilpour, Begley, Richard Begley and Sinaya Dayan. "Mine Pool Geothermal Resources – Phase 1 Engineering Study" (Center for Business & Economic Research, Marshall University, West Virginia, 2022), 18.

Pennsylvanians with eligible income levels and is currently funded by the IRA.[122] The benefits of this program are noted in Table 6.

Table 6
Penn Energy Savers Rebates
2025

Applications	Value
Heat Pump Water Heater	$1,750
Heat Pump for Space Heating or Cooling	8,000
Heat Pump Clothes Dryer or Heat Pump Washer/ Dryer Combo	840

Source: Penn Energy Savers, www.pennenergysavers.com.

One risk in attempting to standardize the sales of geo-exchange systems is that homeowners may be sold systems larger than they need, while others may have systems that meet base heating and cooling needs but cannot handle peak load times.[123] The U.S. Dept. of Energy estimates that 65 percent of HVAC systems within the country are installed incorrectly or are performing suboptimally.[124] Due to the increased complexity associated with GSHP compared to traditional HVAC systems, improper installation is a cause for concern. However, accredited designers and installers may be limited by region within the state. Within Pennsylvania, 18 people had received certification from the International Ground Source Heat Pump Association throughout Pennsylvania:[125]

- 16 installers
- One trainer of installers
- Two certified geo-exchange designers

Furthermore, there were 55 accredited geothermal businesses that listed Pennsylvania as a service area, however only four were based in-state: two engineering firms and two contractors. Nine heat pump companies were located in neighboring states. Other companies were as far away as California or Great Britain. Currently, there is no way for consumers to know whether these installers are still active within the state or if they have the most recent versions of the accreditation.

Increasing the number of accredited designers and installers or encouraging heat pump manufacturers to move to Pennsylvania may help increase adoption rates. Similarly, improper installation and design of GSHP systems is one of the leading concerns within the industry as it

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[122] Pennsylvania Department of Environmental Protection, "Check Your Eligibility," Penn Energy Savers, accessed July 31, 2025, https://www.pennenergysavers.com/eligibility.
[123] Joanna R. Turpin, "In Geothermal Designs, Don't Succumb to Rules of Thumb," *2016-02-15, ACHR News*, February 13, 2016, https://www.achrnews.com/articles/131767-in-geothermal-designs-dont-succumb-to-rules-of-thumb.
[124] "A Field Study to Characterize Fault Prevalence in Residential Comfort Systems," Energy.gov, April 16, 2019, https://www.energy.gov/eere/buildings/field-study-characterize-fault-prevalence-residential-comfort-systems.
[125] International Ground Source Heat Pump Association, "Certified Individual Directory | International Ground Source Heat Pump Association," December 23, 2024, https://igshpa.org/certified-individual-directory/.

can erode consumer trust. To be most effective and to support positive customer experiences a geo-exchange system likely needs to be tailored to the individual site. It is best that state programs that financially assist geothermal development include stipulations about obtaining certification in geothermal system design and installation. According to the U.S. DOE, qualified system designers, contractors and installers usually see the greatest efficiencies.[126]

Setting goals for GSHP and geo-exchange systems and tracking progress toward meeting these objects is a useful tool for determining the effectiveness of state policy. For example, Connecticut's heat pump adoption program focused on measurable outcomes as the state grew from 50 recorded residential GSHP in 2020 to over 400 in 2024.[127] These advances in adoption were seen in municipalities where they are placed in town halls, libraries, and schools. GSHPs were installed on at least six college campuses throughout the state. Other examples of commercial GSHP uses include corporate headquarters, retirement communities, museums, daycare centers, condominiums, private schools, and healthcare facilities.

However, it will likely be more productive for programs to aid geothermal networks in newly designed residential communities or to retrofit existing multi-family units, than to focus on programs aimed at single-family dwellings. One limitation of targeting multi-family units or residential communities is that landlords and building managers may be constrained by available land to site the systems. Pennsylvania boasts many examples of innovative geothermal building designs. Downtown Pittsburgh's Century Building, a 12-story, 80,000 square foot building, first constructed in 1907 and redeveloped in 2009, is an award-winning multi-unit apartment that features an open-loop geothermal system.[128] Some retirement communities in the state also have geothermal systems.[129]

More broadly, the federal government set a goal of having 17,500 geothermal installations and 28 million GSHP households by 2050 across the country.[130] While federal policy objectives may have changed, this is still a notable example of how to drive investment and engagement with energy savings technologies. Energy producers boosted renewable energy use in 2015 by issuing certificates for 2.75¢ per kWh.[131] Consumer demand for more green energy options has been growing. In 2017, there was estimated to be over 850 utilities in the U.S. which offer green energy options.[132]

[126] U.S. Dept. of Energy, "Geothermal Heat Pumps," Energy.gov, accessed July 22, 2025, https://www.energy.gov/energysaver/geothermal-heat-pumps.
[127] Connecticut Dept. of Energy & Environmental Protection, "Geothermal."
[128] Urban Land Institute, "The Century Building, Pittsburgh Pennsylvania," uli.org, 2012, accessed July 29, 2025, https://uli.org/wp-content/uploads/ULI-Documents/Century-Building_in-layout_FINAL.pdf.
[129] Foulkeways at Gwynedd, "Environmentally Friendly Senior Living" June 18, 2024, https://www.foulkeways.org/the-foulke-way/greening-initiatives/.
[130] Geothermal Technologies Office, "Multi-Year Program Plan: Fiscal Years 2022-2026," *U.S. Department of Energy*, February 2022, https://www.energy.gov/sites/default/files/2022-02/GTO%20Multi-Year%20Program%20Plan%20FY%202022-2026.pdf.
[131] National Renewable Energy Laboratory, "Renewable Electricity: How Do You Know You Are Using It?," Press release, August 2015, https://docs.nrel.gov/docs/fy15osti/64558.pdf.
[132] U.S. Department of Environmental Protection, "Utility Green Power Products," accessed March 20, 2025, https://www.epa.gov/green-power-markets/utility-green-power-products.

Siting Limitations in Pennsylvania

One of the general strengths of closed-loop geo-exchange compared to electricity producing geothermal technologies is it can be sited all over Pennsylvania rather than just in areas with favorable temperature gradients.[133] However, while this statement may generally be true, a review of site-specific conditions is still required. Based on recent experiences in the lower tier of New York state, the installation of geo-exchange in northern areas of Pennsylvania may face additional environmental and engineering difficulties. "The hydrogeology of the … Allegheny Plateau poses challenges to CLG (closed-loop geothermal) bore drilling and casing; managing drill cuttings, discharge water, and gas; and grouting. The potential to encounter severe challenges typically increases with bore depth."[134] Researchers noted that, because of the complicated geology of this region, drilling boreholes may encounter areas of saltwater, gas, or oil below 500 feet.[135]

Physical space limitations in Pennsylvania should also be considered. The average residential yard size is 16,342 square feet, or 0.38 acres.[136] While exact measurements vary, a horizontal loop geothermal system for a 2,000 square foot home requires between 0.25 and 0.5 acres.[137] In some areas, horizontal loops would be impossible. Philadelphia residences, for example, average half as much yard space as Pennsylvania as a whole; lots within the city of Chester are also known for their small acreage.[138] Vertical loops require far less horizontal space but require deep drilling and are dependent on having the correct conditions below ground. Loops submerged in ponds are typically the least expensive for residential homes but are also the least common since few properties have such water sites available.

To encourage the adoption of closed-loop geothermal, the Pennsylvania General Assembly could require that governments review the possibility of geothermal installation when replacing aging infrastructure. Additionally, part of the review could include the location of nearby underground mines.

Overall, geo-exchange is part of the current trend of moving away from using fossil fuels for energy and coincides with more widespread use of air conditioning, which leads to increased electricity usage during critical times. Geothermal heating and cooling can help reduce those peaks in power usage.

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[133] Apt et al., "The Future of Geothermal," 35.
[134] John H. Williams, William M. Kappel, and Joshua C. Woda, "Hydrogeologic Framework and Considerations for Drilling and Grouting of Closed-loop Geothermal Bores in the Erie-Ontario Lowlands and Allegheny Plateau of New York State,"*U.S. Geological Survey Open-file Report 2025*, January 1, 2025, https://doi.org/10.3133/ofr20251013.
[135] Williams, Kappel, and Woda, "Hydrogeologic Framework and Considerations for Drilling and Grouting of Closed-Loop Geothermal Bores in the Erie-Ontario Lowlands and Allegheny Plateau of New York State."
[136] Sam Wasson, "The Average Yard Size by State," Today's Homeowner, November 14, 2024, https://todayshomeowner.com/lawn-garden/guides/average-yard-size/.
[137] "Geothermal Ground Loop Design," Comfortworks, Inc., May 8, 2025, https://comfort.works/ground-loop-design/.
[138] Hope Walborn, "Philly Ranks No. 6 for Cities With the Smallest Yards," Pennsylvania Association of Realtors®, March 13, 2025, https://www.parealtors.org/blog/philly-ranks-no-6-for-cities-with-the-smallest-yards/.

Generating electricity is an expensive endeavor, regardless of its energy source. However, the efforts to make buildings more efficient and to take advantage of emerging technology can lead to lower long-term expenses. While expanding the Commonwealth's capacity to produce electricity is necessary and unavoidable, it is also true that, by seeking greater efficiencies and investing in cost-saving technologies, more could be done with existing energy sources. For example, expansion of geothermal to larger scales requires utilization of large heat sinks, which can be accessed by either tapping into large, underground sources of water or by creating extensive networks of pipes to store the heat that is extracted. Experts believe that, with proper planning, design, and resources, GSHP systems can be scaled to provide heating and cooling for neighborhoods, industrial sites, or even city-wide areas.

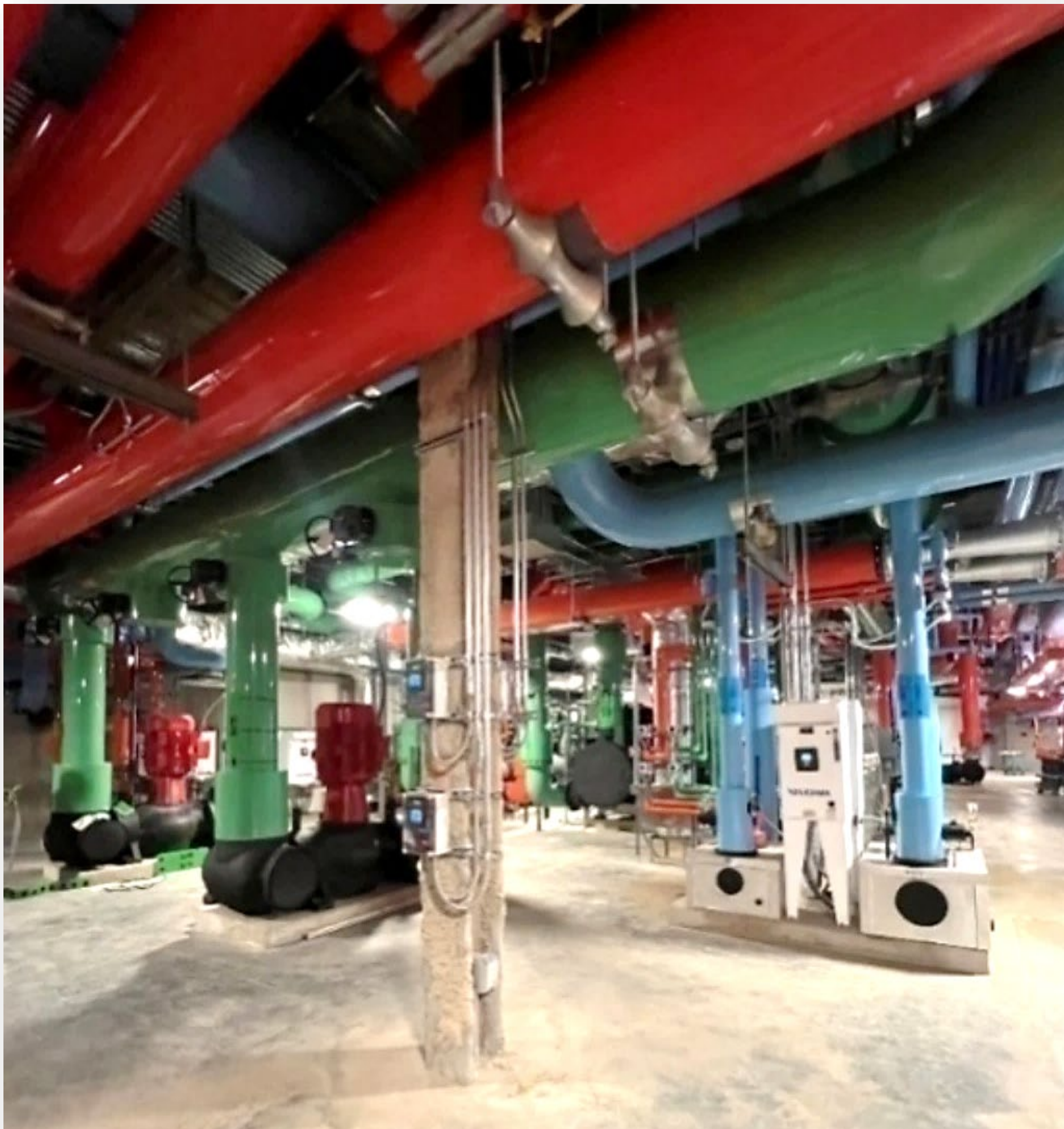
Swarthmore Geo-Exchange Case Study

According to a 2021 National Renewable Energy Laboratory (NREL) report, higher education institutions form key emerging markets and opportunities within the U.S. for geothermal power production and district heating.[139] There are records of installed ground-source geothermal systems for heating and cooling at institutions including Ball State University, Ohio State University, Missouri University of Science and Technology, Cornell University, Juniata College, and Allegheny College of Maryland. In April 2025, Commission staff travelled to Swarthmore College, a private higher education institution in southeastern Pennsylvania, to tour the installation site of a district heating geo-exchange system. In this case, a geo-exchange system located in the centralized dining and commons building will provide heating and cooling to buildings throughout the college's 425-acre campus. This site utilizes a combination of heating concepts, primarily by merging geo-exchange, which banks and then removes heat from the ground as the seasons change, with district heat, which utilizes a centralized heating or cooling source to spread throughout a network of buildings, or in this case, a campus.

The geo-exchange plant is located in the basement of Swarthmore's Dining and Community Commons (DCC), which opened in the fall of 2022.[140] The components of the geo-exchange system, "including pipes, wiring, pumps, tanks, heat-recovery chillers and a sophisticated control system" are located in the basement.[141] The system uses red piping for hot water, blue piping for chilled air, and green for its geothermal waters. See Picture 1.

[139] Jody Robins, Amanda Kolker, Francisco Flores-Espino, Will Pettitt, Brian Schmidt, Koenraad Beckers, et al., "2021 U.S. Geothermal Power Production and District Heating Market Report," July 13, 2021, 6, https://doi.org/10.2172/1808679.
[140] Swarthmore College, "Geoexchange System FAQs" accessed March 25, 2025. https://www.swarthmore.edu/to-zero-thirty-five/geoexchange-system-faqs.
[141] Swarthmore College, "Geoexchange System FAQs" accessed March 25, 2025.

Picture 1
Color Coded Piping Corresponding
to Water Temperature Used in Geothermal System
2025



Source: Recorded by JSGC Staff at Swarthmore College Campus.

The new system will provide both heating and cooling to campus buildings and work on a yearly cycle. During summer months, heat-recovery chillers powered by renewable electricity remove heat from buildings and store it underground in wells. A heated fluid travels through pipes deep into the ground, where the thermal energy (heat) is deposited. In winter, the system reverses as fluid heated by the thermal energy below ground returns to the surface.[142] This closed-loop system is composed of hundreds of six-inch wide vertical pipes that extend to a depth of 800 feet. On the surface, the heated or cooled fluid is sent to buildings throughout campus where each building's HVAC system transforms the thermal energy to either warm or cool each building. Swarthmore expects to have sunk 900 such wells across a 200,000 square foot area when the construction project is complete.[143]

Picture 2
Industrial Air Chillers
2025

Source: Recorded by JSGC Staff at Swarthmore College Campus.

[142] Roy Greim, "$5 Million Gift to Help Fund Geoexchange Plant Inside New Dining and Community Commons" The Swarthmore website; July 26, 2021, https://www.swarthmore.edu/news-events/5-million-gift-to-help-fund-geoexchange-plant-inside-new-dining-and-community-commons.
[143] Swarthmore College, "Geoexchange System FAQs" accessed March 25, 2025.

All of the wells for the new system are installed underneath Parrish Lawn on the Swarthmore campus.[144] Well drilling will occur in phases through a thirteen year implementation plan.[145] The first phase of drilling was completed in October 2023 and included 350 wells.[146] According to James Adams, Director of Sustainable Energy Services at Swarthmore College, the system was commissioned in October and November of 2024. In December 2024, the system began to serve four buildings in the north distribution sector of campus. By March 2025, service had extended to six buildings, including several dormitories, the science center and the dining hall. As of April 2025, it was the university's intent to add four more buildings to the system by the end of the year.[147] Even with the necessary underground infrastructure in place, the system will not be completed for another 10 years because of the time and cost needed to upgrade the existing heat exchange technology in an additional 31 buildings. The old system, which will continue to operate in part until the new system is fully in place, is a high-pressure steam system built in 1911 and powered by the combustion of fossil fuels, primarily natural gas.[148]

The primary permit that the college needed to construct the system was a National Pollutant Discharge Elimination System (NPDES) permit, which focuses on ensuring the quality of runoff from construction. The college needed permits from Swarthmore Borough, as well.[149]

Swarthmore has the financial capacity to navigate this project. In 2022, Swarthmore ranked seventh on the National Association of College and University Business Officers' list of highest endowment values per full-time student.[150] This source of funds allows the college to pay for the substantial upfront investment. The initial life cycle cost analysis, which was completed in October 2019, concluded that the conversion will have a payback period of 18 to 23 years. The total savings projected by the college is between $33 million and $56 million dollars over 30 years, growing to between $144 million and $180 million over 50 years.[151] An alumnus donated $5 million to help fund the geo-exchange plant.[152]

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[144] Swarthmore College, "Geoexchange System FAQs" accessed March 25, 2025.
[145] Swarthmore College, "Geoexchange System FAQs" accessed March 25, 2025.
[146] Kiley Bense, "A Small Pennsylvania College is Breaking New Ground in Pursuit of a Clean Energy Campus," *Inside Climate News*, February 27, 2024. https://insideclimatenews.org/news/27022024/small-pennsylvania-college-pursuit-of-clean-energy-campus./
[147] James Adams e-mail message to Commission Staff, April 14, 2025.
[148]Roy Greim, "$5 Million Gift to Help Fund Geoexchange Plant Inside New Dining and Community Commons."
[149] James Adams e-mail message to Commission Staff, April 14, 2025
[150] Bense, "A Small Pennsylvania College Is Breaking New Ground in Pursuit of a Clean Energy."
[151] James Adams e-mail message to Commission Staff, April 14, 2025.
[152] Roy Greim, "$5 Million Gift to Help Fund Geoexchange Plant Inside New Dining and Community Commons."

Picture 3
Recycled Underground Steam Plant Tunnel
2025

Source: Recorded by JSGC Staff at Swarthmore College Campus.

The 2007 American College and University Presidents' Climate Commitment encouraged schools "to develop a climate action plan and set a target date for carbon neutrality."[153] When Swarthmore established its Energy Master Plan, it was titled "Roadmap to Zero" with the goal to eliminate 98 percent of all on-site and purchased-electricity greenhouse gas emissions.[154] When Swarthmore established an agreement, it chose 2035 as their timeline for achieving that goal.[155]

Bill Braham is a professor of architecture and director of the Center for Environmental Building + Design at the University of Pennsylvania. According to Braham, "The climate in Pennsylvania is ideal for geo-exchange, because the changing seasons mean the system works on a yearly cycle, the ground cooling as heat is pumped out to heat the campus in the winter, and then reversing that process in the summer, pulling heat out of buildings to air condition them, pushing that heat into the earth and warming the ground up again."[156] While reports on geothermal district heat often focus predominately on western states, Braham specifically highlights the benefits of geo-exchange within Pennsylvania.

Existing Geothermal District Energy Systems in the United States

Currently, geothermal heating and cooling systems on a district scale are rare and spread across the country. As of 2022, at least 17 geothermal heat pump-based district heating and cooling systems were found in the U.S., with 13 being on college campuses.[157] The authors of a study examining these systems in more detail chose five examples based on data availability, selecting Ball State University (BSU), Colorado Mesa University, Miami University, West Union City in Iowa, and the Whisper Valley community in Texas. Of these systems, all five used borehole fields and included ground loops with central connections.[158] Each helped supply thermal energy to groups of buildings throughout a distribution network.[159] There was a mix of central and decentralized district energy across these five systems. BSU and Miami University made use of central plants, while the others were decentralized.[160]

There are various generations of district heating, and there are important differences between these generations of technology. The earliest district heating systems relied on steam.[161] Over time, district heating has evolved to become more efficient and use cooler fluids.[162] Third and fourth generation systems use a centralized heat pump, while fifth-generation systems are decentralized.[163] Accordingly, the centralized systems of BSU and Miami University are based on third and fourth-generation technologies, while the decentralized geothermal heat pumps of the

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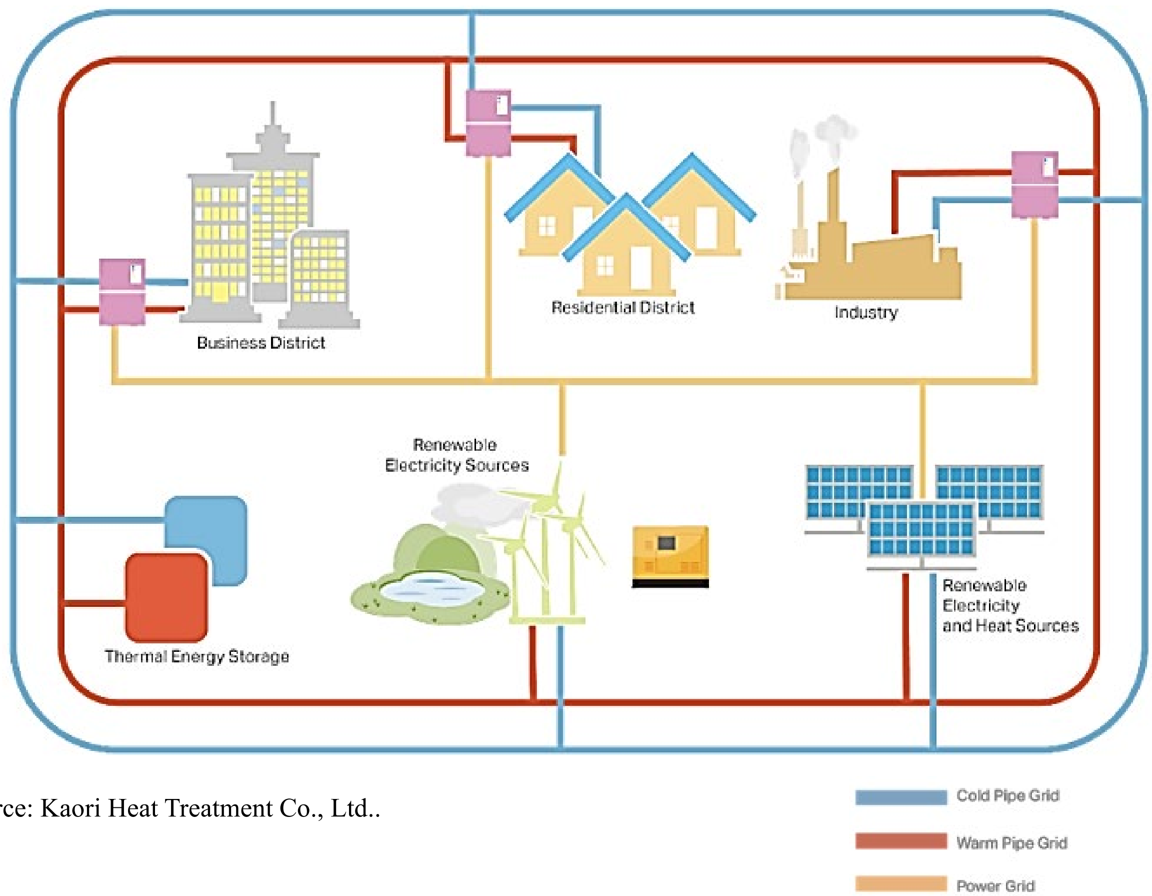
[153] Bense, "A Small Pennsylvania College Is Breaking New Ground in Pursuit of a Clean Energy Campus."
[154] Roy Grein, "Swarthmore College's Roadmap to Zero" March 12, 2021. The Swarthmorean, https://www.swarthmoreanarchives.com/articles/content/2021-3-12/swarthmore-colleges-roadmap-to-zero.
[155] Bense, "A Small Pennsylvania College Is Breaking New Ground in Pursuit of a Clean Energy Campus."
[156] Bense, "A Small Pennsylvania College Is Breaking New Ground in Pursuit of a Clean Energy Campus."
[157] Koenraad Beckers and Hyunjun Oh, "Cost and Performance Analysis for Five Existing Geothermal Heat Pump-Based District Energy Systems in the United States," *National Renewable Energy Laboratory*, 2023, doi:10.2172/1992646, 2.
[158] Beckers et al., "Cost and Performance Analysis," 12.
[159] Beckers et al., "Cost and Performance Analysis," 1.
[160] Beckers et al., "Cost and Performance Analysis."
[161] Beckers et al., "Cost and Performance Analysis," 1.
[162] Beckers et al., "Cost and Performance Analysis," 1.
[163] Beckers et al., "Cost and Performance Analysis," 1.

Colorado Mesa, West Union, and Whisper Valley systems are part of the more efficient fifth-generation district energy systems.

The BSU system uses centralized energy stations. The project began in 2009 when BSU started to replace its previous boilers and chillers with heat recovery chillers capable of producing water as cold as 42°F and as warm as 150°F. This process cost $82.9 million and consisted of two phases.[164] In the first phase, two borehole fields were produced, and another field of boreholes was drilled during the second phase. This system successfully reduced steam production at the central plant by 40 percent, reduced carbon emissions to just 19 percent of the baseline, and provided cost savings of $764,200.[165] Still, one challenge is that the "current configuration and control of the chillers resulted in overproduction of hot or chilled water, resulting in excessive chiller energy use and unexpectedly high ground loop temperatures."[166]

Figure 10
5th Generation District Heating and Cooling Diagram
2025



Source: Kaori Heat Treatment Co., Ltd..

[164] Beckers et al., "Cost and Performance Analysis," 6.
[165] Beckers et al., "Cost and Performance Analysis," 6.
[166] Beckers et al., "Cost and Performance Analysis," 6.

The Miami University project, located in Oxford, Ohio, makes use of a central energy plant that was started in 2012 and completed in 2016. The cost of phase one and phase two construction was $16 million for each.[167] There are six heat recovery chillers connected to ground loops and a borehole field. Data from 2008 to 2019 indicated a 45 percent reduction in carbon emissions, a 39 percent total energy reduction despite increased campus size, and 64.8 percent cost savings.[168] Another geothermal plant is planned, with additional savings projected.

The Colorado Mesa project, located in Colorado, is one of the fifth-generation projects, making use of decentralized geothermal heat pumps. This system was begun in 2007 and has continued to develop since then. The system heats and cools 16 buildings, following a total construction cost of $20.2 million.[169] This project uses eight borehole fields connected to a central loop. The project's monitoring system boosts efficiency because it "continuously monitors and controls the heating and cooling demand and supply, including space temperature, active setpoint, discharge air temperature, heat/cool mode status, and occupancy."[170] Further, two of the three total circulation pumps are operated based on demand.[171]

The West Union project in Iowa is another fifth-generation system that utilizes decentralized geothermal heat pumps. The project was completed in 2012, with a budget of $10.2 million.[172] There is a borehole field connected to a community loop with two circulation pumps. Additionally, each of the 11 buildings serviced has multiple geothermal heat pumps, with the number based on the building's need.[173] Each user is responsible for their equipment and pays an initial inspection fee of $250 along with a monthly fee of $15 plus $14 per ton of heating and cooling used.[174] In 2022, the overall expenses for system operation were $25,168.[175]

Whisper Valley is a residential development in Texas with the third example of a fifth generation decentralized geothermal heat pump system. Phase one of the project was completed in 2016, including 237 homes. Each of the homes has a geothermal heat pump that is connected to a vertical borehole linked to the community grid.[176] The system shares and optimizes energy, with each household paying a fixed monthly service fee of $60.[177] Additional phases are planned.

There are key differences between the centralized systems of BSU and Miami University and the decentralized systems of Colorado Mesa, West Union, and Whisper Valley. The authors summarize this well, noting that "Ball State University and Miami University systems include central heat recovery chillers in the energy plant connected to central loops and borehole fields, while the Colorado Mesa University, West Union, and Whisper Valley systems consist of decentralized GHPs in each building and/or house connected to the central/community loop

167 Beckers et al., "Cost and Performance Analysis," 9.
168 Beckers et al., "Cost and Performance Analysis," 9.
169 Beckers et al., "Cost and Performance Analysis," 7.
170 Beckers et al., "Cost and Performance Analysis," 7.
171 Beckers et al., "Cost and Performance Analysis," 7.
172 Beckers et al., "Cost and Performance Analysis," 10.
173 Beckers et al., "Cost and Performance Analysis," 10.
174 Beckers et al., "Cost and Performance Analysis," 10.
175 Beckers et al., "Cost and Performance Analysis," 10.
176 Beckers et al., "Cost and Performance Analysis," 11.
177 Beckers et al., "Cost and Performance Analysis," 11.

(connected to borehole fields and horizontal loops)."[178] Still, the study found no significant differences in performance and cost, and all five district energy systems have been reliable, requiring little to no reliance on backup systems. One remaining challenge is the possibility of excessive energy consumption, unnecessary ground loop usage, and high expenditures. These examples make it clear that further optimization of large geothermal district systems will be important moving forward.

Colorado System of State Geothermal Tax Credits (GETCO)

Among the various programs that the state of Colorado instituted in support of the exploration and production of geothermal energy are two programs worth highlighting. First, the Colorado Energy Office (CEO) administers the $12 million Geothermal Energy Grant Program (GEGP) which was statutorily established in 2022. The second type of programs, which were statutorily established in 2023, are tax credit programs, specifically including a geothermal energy tax credit program.

The GEGP is currently in its third round of grant distribution. The program was created to provide grants to "building owners, developers, local governments, geothermal installers, contractors, communities, gas or electric service public utilities or other entities approved by the office"[179] for three types of grants. The first focuses on geothermal electricity generation, the second focuses on installation of geothermal equipment for either heating-only or combined heating and cooling systems in new construction or to retrofit existing buildings and the third aspect of the grant program is the development of community thermal systems.[180] Community district heating grants could encompass scoping studies, detailed design studies and projects. The third round of the GEGP funds two subtypes: single-structure geothermal and thermal energy networks. This current funding round is anticipated to be the final funding distribution for the GEGP.[181]

The Colorado Legislature appropriated $35 million for state investment tax credits (ITC) to provide "a financial incentive for the development of electricity generation from geothermal sources."[182] These financial incentives are for both private entities, local governments or public/private partnerships within the state of Colorado to develop, produce and use geothermal energy. The CEO administers the grant process, which is conducted on a semi-annual cycle with the application process closing twice per year.[183]

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[178] Beckers et al., "Cost and Performance Analysis," 12.
[179] Co Rev. Stat. § 24-38.5-118 (3) (2024).
[180] Co Rev. Stat. § 24-38.5-118 (3) (2024).
[181] Colorado Energy Office, "Geothermal Energy Grant Program," accessed April 25, 2025, https://energyoffice.colorado.gov/geothermal-energy-grant.
[182] Co Rev. Stat. § 39-22-552 (2024). This statute is repleaded effective 12/31/2038.
[183] Colorado Energy Office, "Geothermal Energy Tax Credit Offering," accessed April 16, 2025, https://energyoffice.colorado.gov/geothermal-tax-credit.

According to the enabling legislation, geothermal energy projects can include:

1. The exploration and development of wells;
2. Drilling exploration and confirmation wells;
3. The use of any heat extracted with produced fluids in an oil and gas operation if the heat is only utilized to reduce emissions from the operation in the same location as the well from which it was produced and would otherwise not be economically feasible as a stand-alone geothermal energy project;
4. Drilling injection wells;
5. Flow testing;
6. Reservoir engineering;
7. Geothermal energy storage;
8. Co-production of geothermal energy; or
9. Power generation equipment.[184]

The program will continue until December 31, 2032, or until all funding is expended, whichever comes first.

As of April 2025, the Colorado Energy Office has awarded $13,825,451 out of the $35 million authorized for the geothermal energy tax credit. The first tax credit was awarded in the summer of 2024 and has gone into effect in 2025.

Thermal Energy Networks

A thermal energy network (TEN) uses a shared system of pipes to transfer heat in and out of buildings, with recipients across the network sharing a centralized supply to smooth demand patterns and increase efficiency.[185] Different types of TENs rely on unique energy sources, including bodies of water, wastewater systems, and geothermal heat. While there are many ways to deliver energy efficiently from a central source using TENs, these methods do not always intersect with geothermal technologies. Like TENs, district energy systems do not always utilize the newer geothermal technologies. For example, many of the district heating systems in Europe come from an earlier generation of heating technology other than geothermal technology.[186] Most relevant to this study are geothermal networks. For a TEN or district energy system to fall into this category, it must use geothermal energy within its networked structure.

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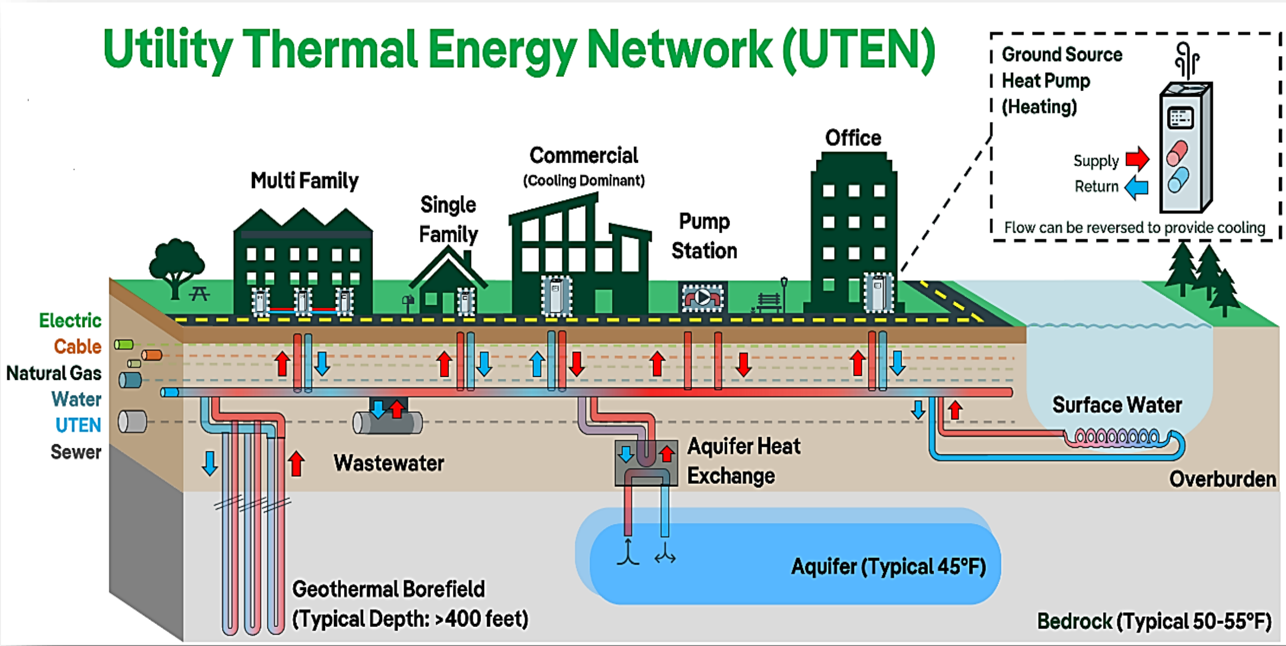
[184] Co Rev. Stat. § 39-22-552 (f) (2024).

[185] "Thermal Energy Networks (TENs)," *Building Decarbonization Coalition*, 2025, accessed June 23, 2025, https://buildingdecarb.org/resource-library/tens.

[186] Charles G. Gertler, Timothy M. Steeves, and David T. Wang, "Pathways to Commercial Liftoff: Geothermal Heating and Cooling," *U.S. Department of Energy*, 2025, https://igshpa.org/wp-content/uploads/LIFTOFF_DOE_Geothermal_HC.pdf, 26.

Figure 11
Utility Thermal Energy Network
2024



Source: Nyseg, "Utility Thermal Energy Network: Frequently Asked Questions (FAQ)."

Specifically, many geothermal networks are TENs that use shallow boreholes to harness the thermal energy from within the earth and transfer that energy to the network. Further, these boreholes can store excess heat underground for later use, acting as a "thermal battery" to smooth electricity demand.[187] Another model for district energy systems utilizes mine water for geothermal energy. One excellent example of this type of system is based in Heerlen, Netherlands, and will be explored in more detail in a later chapter.

Geothermal networks are even less common than individual geothermal heat pump systems, remaining limited mostly to pilot projects or single-owner campuses such as colleges or military installations, for whom shared ownership and funding are smaller concerns.[188] While there is clear interest in this technology, its market penetration in the U.S. remains small. Evidence shows that commitments to net-zero emissions at the state level, along with state-led pilot projects, are moving geothermal network technology forward.[189] Still, more pilot projects, business models, and installations of larger-scale systems are needed to achieve the broader benefits that are possible with geothermal networks.

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[187] "Thermal Energy Networks (TENs)," *Building Decarbonization Coalition*.
[188] Gertler et al., "Pathways to Commercial Liftoff," 26.
[189] Gertler et al., "Pathways to Commercial Liftoff," 24-25.

Advantages and Obstacles

TENs share many of the same characteristics of heat pump systems already detailed in this report. However, it is important to consider the advantages and drawbacks of implementing heat pumps systems at a network scale, both in general and specifically for Pennsylvania. Advantages include energy efficiency, energy affordability, reduced greenhouse gas emissions, improved air quality, the opportunity to replace old gas infrastructure, and a smooth transition for the existing gas workers.

The first of the key advantages of TENs is that they are efficient. By connecting several homes or buildings to the same central infrastructure, these systems can "smooth" demand patterns to allow for greater efficiency as the buildings take advantage of their coincident heating and cooling needs.[190] Another source of efficiency within networked geothermal systems is their reduced weather dependency. By using the ground as a source of heat rather than air-source heat pumps, the system benefits from the less volatile temperature of the Earth as a source and does not face the same strain during periods of extreme temperature changes.[191] The ground remains around 55°F throughout the year, which geothermal networks take advantage of to achieve high levels of efficiency. The coefficient of performance (COP) for a ground source heat pump can be up to five or six.[192] In other words, for every unit of energy input five to six Btu/hour are produced.[193] In contrast, air-source heat pumps typically have a COP of two to four.[194] A final component of efficiency of TENs is their potential to use the earth as a "thermal battery" to flatten peak electricity demand. To do so, the network's shallow boreholes capture and store excess heat underground to be used days or months later.[195] This valuable component of geothermal networks, along with its overall efficiency, can effectively reduce strain on the electric grid and avoid the costly spikes that occur within other types of heating and cooling systems. A Massachusetts study found that converting just 25 percent of buildings to TENs had the potential to reduce peak electricity demand in the winter by 25 percent when compared to air-source heat pumps.[196] Overall, TENs have great potential for efficiency and reduced electricity consumption.

The efficiency of geothermal networks makes heating and cooling more affordable and allows them to sustain low and consistent operating costs.[197] As the costs of decarbonization are spread across an entire network of homes and buildings rather than imposed on a single owner, the potential for affordability increases. Though the installation costs remain high, TENs could offer

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[190] Dan Aas et al., "Philadelphia Gas Works Business Diversification Study: Identifying Opportunities for Philadelphia Gas Works to Thrive in a Lower-Carbon Future," *Energy & Environmental Economics, Econsult Solutions Inc., Portfolio Associates*, 2021, https://www.ethree.com/wp-content/uploads/2021/12/PGW-Business-Diversification-Study-2021-12.pdf, 23.
[191] Aas et al., "Philadelphia Gas Works," 23.
[192] Miles et al., "Thermal Energy Networks in the United States: Emerging Opportunities, Challenges, and Needs," *Common Spark Consulting and Transformative Strategies Consulting*, 2025, https://www.transformativestrategies.net/_files/ugd/113511_4655e82411df46e1915b523483ccf044.pdf, 15.
[193] Joe Dammel, "What's up with networked geothermal?" *Fresh Energy*, 2022, accessed June 27, 2025, https://fresh-energy.org/whats-up-with-networked-geothermal.
[194] "Air Source Heat Pump Efficiency: A Comprehensive Guide," *Endotherm*, accessed June 27, 2025, https://www.endotherm.co.uk/air-source-heat-pump-efficiency/.
[195] "Thermal Energy Networks (TENs)," *Building Decarbonization Coalition*.
[196] Miles et al., "Thermal Energy Networks in the United States," 15.
[197] Aas et al., "Philadelphia Gas Works," 19.

savings in the long run. While TENS can make energy more affordable, U.S. DOE researchers have cautioned that if energy systems are not implemented across an entire community it could exacerbate existing inequities through energy pricing.[198] For example, the researchers' opinion is if TENS were only installed in high income areas, any future increases in energy prices would primarily be borne by low income residents, potentially leading to their displacement and the eventual gentrification of neighborhoods. Conversely, implementation of geothermal networks across income areas could achieve the goal of greater energy affordability for all community members.

A key benefit of geothermal networks is that they have the potential to drastically reduce greenhouse gas emissions. Because of the greater efficiency of ground-source heat pumps and the resulting reduced electric demand, geothermal networks are an effective path to decarbonization. The U.S. DOE estimates that geothermal energy has the potential to offset over 500 million metric tons (MMT) of greenhouse gases in the electric sector and 1,250 MMT in the heating and cooling sector by 2050, the equivalent of replacing 26 million cars on the road every year.[199] The report found that these sweeping reductions would only be possible with intervention, noting that if no pressure is applied to the market, less than 10 percent of its market potential will be met.[200] While every geothermal heat pump helps, TENs can help with a greater reduction by increasing the prevalence of geothermal technologies on a larger scale. Geothermal networks can also improve indoor air quality. Not only will the outside air be cleaner, but geothermal TENs provide better indoor air quality through the elimination of harmful pollutants.[201] As is the case with reduced emissions, air quality improvements are possible with the smaller-scale geothermal heat pumps, and these improvements would only become more widespread as entire neighborhoods and cities adopt geothermal technology collectively.

Another advantage of installing geothermal networks in Pennsylvania, specifically in cities with existing gas infrastructure, is that the installation of these systems can coincide with work on gas lines in places where old lines are near the end of their life. A study on the commercial liftoff of geothermal systems observes that residential retrofits of old gas infrastructure to convert it to geothermal systems may require less capital than a full replacement of gas pipes in certain regions.[202] Other studies also suggest that a well-timed installation of new geothermal systems may provide long-term cost savings. Many estimates of TEN construction costs seem astonishingly high but fail to consider the high costs of maintaining an aging fossil fuel infrastructure. While these costs vary by region, a study on infrastructure in New York estimates that replacing gas mains could require over $3 million per mile of pipeline in addition to the constant repairs and upgrades that are necessary.[203] With many of these pipes already in need of replacement, the installation of networked geothermal systems is a natural next step for gas utilities.

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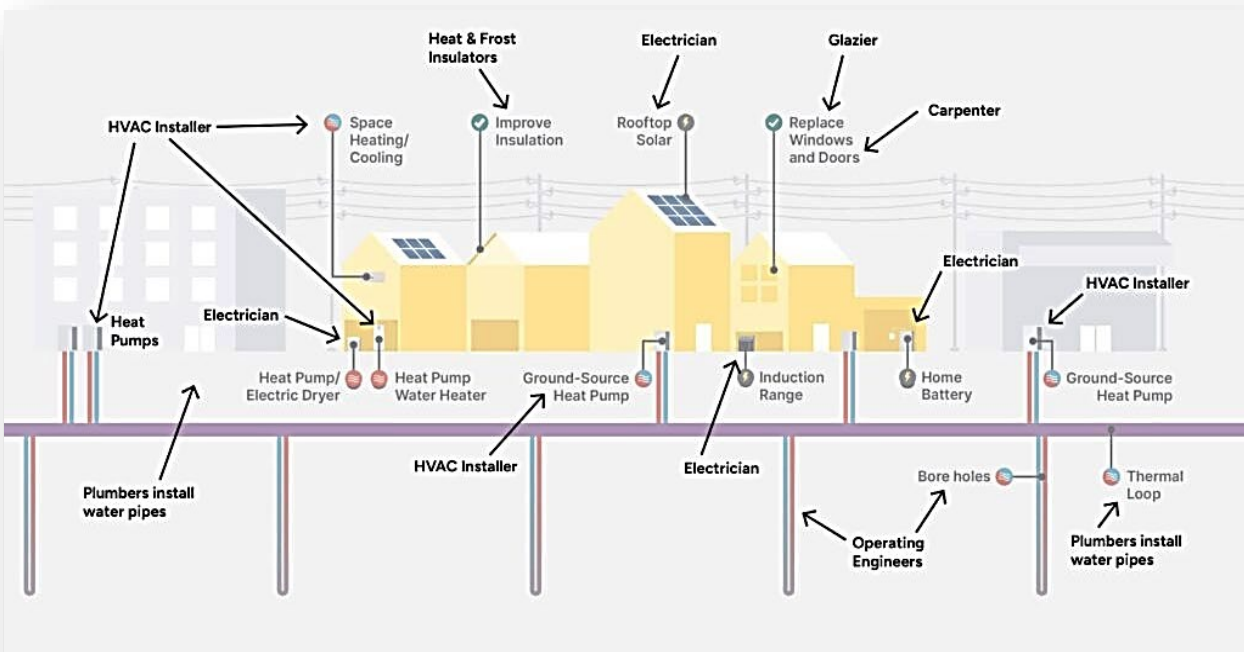
198 Gertler et al., "Pathway to Commercial Liftoff," 23.
199 Sean Porse, "Geothermal Technologies Office Multi-Year Program Plan (FY 2022-2026)," *Department of Energy*, 2022, 3.
200 Porse, "Geothermal Technologies Office," 3.
201 Miles et al., "Thermal Energy Networks in the United States," 18.
202 Gertler et al., "Pathways to Commercial Liftoff," 53.
203 Miles et al., "Thermal Energy Networks in the Unites States," 67.

Aside from the existing natural gas infrastructure, a transition to a TENs system would likely affect the existing natural gas workforce. Fortunately, there is a consensus that the installation of TENs would provide a smooth pathway of transition to the geothermal industry for displaced gas workers. As noted in previous sections of this report, there is high potential for natural gas workers to be employed in TEN infrastructure projects. For example, utility and pipe workers could install and repair thermal energy networks using skills like those required for the installation and maintenance of natural gas pipes. Engineers could also support these systems.[204]

Overall, the installation of geothermal networks would require a significant amount of labor. The U.S. Bureau of Labor Statistics and the Geothermal Energy Association estimate that a 50-megawatt geothermal plant would employ 697 to 862 workers, including those in construction, engineering, geology, and hydrology.[205] Further, the study notes that a partnership between the geothermal industry and labor unions would be beneficial to both parties.[206] Thermal energy networks present new job opportunities for the Pennsylvania workforce, requiring almost identical skills and expertise for tens of thousands of workers within the state.

Figure 12
Jobs Needed for Thermal Energy Networks
2025



Source: "Thermal Energy Networks (TENs)," Building Decarbonization Coalition.

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204 Apt et al., "The Future of Geothermal," 21.
205 Apt et al., "The Future of Geothermal," 129.
206 Apt et al., "The Future of Geothermal," 129.

Disadvantages of TENs include installation costs, difficulties in achieving community-wide adoption, retrofit challenges, reliance on underdeveloped technologies, a lack of successful business models, and difficulties related to existing regulatory structures.

The research is clear that high upfront costs are the main obstacle to the installation of geothermal heat pumps, as well as to the establishment of larger geothermal networks. Further, these costs are extremely difficult to estimate because the configuration of TENs can vary geographically or even by specific location.[207] The challenge posed by costs makes tax incentives and other state and federal funding extremely important for the continued development of geothermal technologies.

Achieving community-wide adoption is a challenge specific to TENs.[208] Any individual building, home, or campus can choose to install geothermal systems; however, it is much more difficult to achieve on a collective level. This may explain why many of the existing geothermal networks are limited to colleges, military installations, and hospitals.

Retrofits, despite their advantages when well-timed with the expiration of old gas infrastructure, can also present challenges. Retrofits can require a higher level of skill and planning than new construction because they require complex plans to integrate with the existing infrastructure, some of which is at the end of its useful life.[209]

Another disadvantage of geothermal networks is that they lack examples of successful business models. Demonstrated business cases for TENs, if successful, could create strong growth in the geothermal industry and encourage many businesses to follow the examples provided.[210] Until then, the industry will likely remain underdeveloped and rely on hypothetical scenarios. Further, there is a reliance on underdeveloped technologies in the geothermal industry because it has not yet reached a scale at which technologies are being refined. It is possible that as TENs are constructed and begin to operate, growing industry expertise will lower costs and increase the effectiveness of future TEN infrastructure.[211] Still, the geothermal industry has not yet reached this scale.

Regulatory challenges are another concern related to the establishment of TENs. Utility companies are a key group of potential owners of TENs because they already have the experience, workforce, and infrastructure to successfully develop TENs.[212] The difficulty is that these utility companies are highly regulated. Further, the changes that would be necessary for their business models may also be challenging to incorporate into a complicated regulatory structure. Other potential owners of TENs may also be unsure of how their actions would comply with business regulations. Because of these uncertainties and challenges, the establishment of TENs within the state would almost certainly require action from the Pennsylvania General Assembly.

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[207] Gertler et al., "Pathways to Commercial Liftoff," 5.
[208] Miles et al., "Thermal Energy Networks in the United States," 20.
[209] Miles et al., "Thermal Energy Networks in the United States," 21.
[210] Gertler et al., "Pathways to Commercial Liftoff," 56.
[211] Gertler et al., "Pathways to Commercial Liftoff," 49.
[212] Apt et al., "The Future of Geothermal," 104.

Despite some initial considerations of the advantages and obstacles to geothermal networks, further study is necessary to determine the specific feasibility for the state of Pennsylvania. Feasibility studies and pilot projects would be an excellent way to study the potential of TENs in Pennsylvania, specifically.

Ownership Models

The high prevalence of TENs that are funded by single owners, such as universities, makes it clear that ownership challenges amongst communities may be an obstacle to more widespread TEN development. The West Union and Whisper Valley examples offer ideas for communities but place a financial burden on the individual owners of homes and buildings. There are various ownership models for TENs, including private ownership, public ownership, and community ownership.[213] The ownership structure for a proposed TEN is significant because it determines where funding comes from and who will bear the financial risks and benefits of the geothermal network. In a study examining the emerging opportunities and challenges of TENs, the authors identify the importance of finding an appropriate ownership structure, arguing, "When examining the lifecycle of new technology adoption, the early stages are not necessarily the ideal time for widespread community ownership due to the high risks involved. Instead, government and private sector investment should absorb these risks in the early stage, ensuring the technology matures and becomes a stable, cost-effective option before transitioning to widespread community ownership."[214] For the successful implementation of geothermal networks, it is important that communities are not expected to absorb the financial risk of TENs before the technologies are more developed, the workforce is able to support TENs fully, and they are proven to be cost-competitive.

Philadelphia Gas Works

Philadelphia Gas Works (PGW) is the largest municipally-owned gas utility in the U.S., serving approximately 500,000 customers and employing over 1,600 workers.[215] PGW released a report in 2021 examining various pathways for achieving net-zero emissions, a goal that stems from the city's commitment to achieving carbon neutrality by 2050. Four unique reduction pathways were explored in the study, including networked geothermal systems.

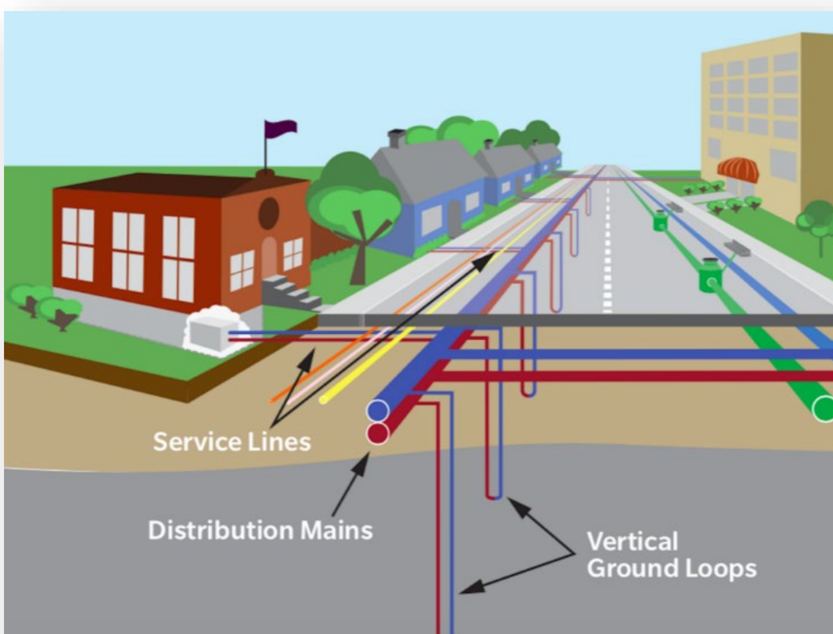
PGW's consideration of networked geothermal systems was as a hybrid model, which combined hybrid electrification and networked geothermal systems. PGW estimated, based on the challenges of completing retrofits and installing new systems, that geothermal systems would be limited to approximately 25 percent of its customers by 2050. In this scenario, the rest of the customers are assumed to adopt hybrid heat pumps; however, PGW notes that networked geothermal systems could be complemented by many other decarbonization strategies.[216]

[213] Miles et al., "Thermal Energy Networks in the United States," 30-31.
[214] Miles et al., "Thermal Energy Networks in the United States," 56.
[215] Aas et al., "Philadelphia Gas Works," 8.
[216] Aas et al., "Philadelphia Gas Works," 26.

In its study of networked geothermal systems, PGW identified several benefits. These included reduced weather dependency, smoother electric demand, and the similarities between geothermal infrastructure and the existing natural gas infrastructure in Philadelphia. These similarities could smooth the path to the geothermal industry for displaced natural gas workers. Further, PGW notes that networked geothermal systems may present an opportunity for PGW workers to gain new skills.[217] Operating a geothermal network could be an opportunity for PGW to shift its business model but still retain many of its current utility workers. PGW nonetheless had two major concerns related to potentially high and uncertain costs and the complex regulatory environment in which PGW operates.

As a gas utility, PGW works within a complex regulatory structure. PGW is owned by the City of Philadelphia and is managed by the Philadelphia Facilities Management Corporation, a non-profit group that oversees PGW through the conditions of a "Management Agreement." PGW's management, budgets, and gas transactions are also subject to the oversight of the Philadelphia Gas Commission (PGC). Some functions, such as PGW's capital budget, require approval directly from the Philadelphia City Council. Finally, the jurisdiction of the Pennsylvania Public Utility Commission (PUC) includes PGW, which must comply with the Pennsylvania State Public Utility Code and associated regulations.[218] It is becoming clear that if PGW and other gas utilities want to transition to a TEN system, they will need help navigating these regulations, likely in the form of authorization from the Pennsylvania General Assembly.

Figure 13
Outdoor Geothermal Network Service Lines
2022



Source: Eversource, "Outdoor Geothermal Network."

[217] Aas et al., "Philadelphia Gas Works," 44.
[218] Aas et al., "Philadelphia Gas Works," 13.

Overall, PGW saw much potential in the creation of a TEN but ultimately did not endorse any of the proposed courses of action, citing the regulatory environment and the cost. Still, PGW recommended exploring opportunities for several options. For geothermal district heating, PGW recommended a feasibility study to investigate the technical and geological potential of block-level networked geothermal district systems alongside a utility financial model for the systems.[219] A feasibility study was recommended rather than a pilot option based on the many uncertainties related to local geological conditions and the preferences of stakeholders. This study is valuable because it provides a perspective from the lens of a Pennsylvania gas utility company actively considering paths to decarbonization.

Notably, in the spring of 2025, PGW issued a request for proposals for a geothermal feasibility study to include a "detailed site survey and feasibility study to determine the technical and economic viability of implementing a shared geothermal heating and cooling system at the John F. McCloskey Elementary School and Dorothy Emanuel Recreation Center."[220] The site was chosen because it does not currently have air conditioning, but it does have ample space for the placement of geothermal wells. The building was built in 1956 and currently uses oil for heating.

Thermal Energy Network Policy Development

Pennsylvania already has various policies, programs, and incentives in place to support geothermal energy development within the Commonwealth, including the Alternative Energy Investment Act (AEIA) Programs, the Alternative Energy Portfolio Standard (AEPS), the Pennsylvania Energy Development Authority (PEDA) Funding, and Reducing Industrial Sector Emissions in Pennsylvania (RISE PA).[221] While these policies are a good foundation for progress, they tend to target individuals and small businesses rather than the larger areas that could be served through TENs. Further, statutory language governing natural gas utilities is ambiguous regarding services other than natural gas supply.[222] When considering the challenges posed by complex regulatory structures, high costs, and the many uncertainties surrounding the adoption of TENs, additional policies and initiatives to promote the development of geothermal district heating and cooling are necessary to encourage geothermal networks as part of a larger-scale movement.

To overcome regulatory challenges, legislation to allow gas utilities to build, own, and operate TENs would be beneficial. This would clarify ambiguities and challenges within the current regulatory structure of gas utilities within the state. Pennsylvania could take steps to encourage development of TENs. Financial incentives could spur the adoption of TENs by helping developers overcome risky and burdensome investments. Beyond allowing the creation of geothermal district heating networks, legislation could encourage expanded ownership pathways and pilot projects that will be important to overcome additional uncertainties. Successful business

[219] Aas et al., "Philadelphia Gas Works," 63.
[220] Carlo Cariaga, "RFP – Feasibility Study for Geothermal Heating and Cooling in Philadelphia, PA," *Think Geoenergy*, 2025, accessed June 27, 2025, https://www.thinkgeoenergy.com/rfp-feasibility-study-for-geothermal-heating-and-cooling-in-philadelphia-pa/.
[221] Apt et al., "The Future of Geothermal," 99.
[222] Apt et al., "The Future of Geothermal," 104.

cases for groups other than existing gas utilities could encourage further development of TENs. Further, specific pilot projects will help clarify the specific costs, benefits, and opportunities for geothermal networks in Pennsylvania.

A primary motivation for decarbonization efforts, including state-level TEN legislation, is to meet emission standards established by law.[223] On a smaller scale, this is demonstrated by the example of PGW, with the local emissions goals for the City of Philadelphia pushing the gas utility to study the feasibility of geothermal networks as a decarbonization strategy. State-level emissions standards could be important to the future study of geothermal networks through pilot projects; however, it is not necessary. Pilot projects can be grounded elsewhere, such as energy efficiency requirements, clean energy plans, renewable portfolio standards, energy reliability, local energy availability, job creation, and protection against stranded gas infrastructure assets.[224] Pre-existing climate legislation might be helpful, but it is not necessary for advancing effective TEN legislation.

Another interesting distinction when considering policy development specifically for TENs pilot projects is whether mandates or allowances are more effective. Each is effective for achieving somewhat distinct goals within their overall purpose of studying the feasibility of TENs.[225] Massachusetts and Washington have passed allowances for gas utility pilots, while Minnesota, New York, Colorado, and California have all passed mandates in some form.[226] Maryland has done both, depending on the size of the utility company. It is important to note that it is not feasible to mandate the creation of a statewide geothermal network, or even to mandate that these systems be installed directly. Some regions are better suited for the installation of geothermal systems. Authorizations would be much less drastic, simply requiring that utilities propose TEN pilot projects to get the process started. Legislation requiring that utilities propose TEN pilots has the advantages of sending a strong market signal for development, allowing for the comparison of multiple pilots, and ensuring that a diverse range of designs and ownership models are all considered. Still, the disadvantages of mandated proposals are that utilities simultaneously learning new systems may make costly repeated mistakes, and that the large number of proposals would likely require complex regulatory oversight of the projects.[227]

Legislation that allows but does not mandate utilities to propose TEN pilots has its own unique set of advantages and disadvantages. Allowances are beneficial because the smaller number means faster approvals, the stagger helps later pilots learn from lessons in earlier projects, and their voluntary nature encourages the most prepared and motivated utilities to file proposals and decreases the likelihood of poor designs. Various drawbacks of allowances are decreased participation, less market pressure, and smaller-scale adoption that does not achieve larger decarbonization goals.[228] The type of policy that is developed for the purpose of creating TEN pilots is influential not only for achieving this goal, but also for the signal that is sent to the market. Stronger policies will create the necessary pressure for continued innovation and development

[223] Eduardo Otero Bakai, Tracey Sharkey Collins, Ania Camargo Cortes, et al. "Thermal Energy Networks (TENs) Legislative Guidebook," *Building Decarbonization Coalition and Vermont Law and Graduate School Institute for Energy and the Environment*, 2025, https://buildingdecarb.org/resource-library/tens-legislative-guidebook, 31.
[224] Bakai et al., "Thermal Energy Networks (TENs) Legislative Guidebook," 32.
[225] Bakai et al., "Thermal Energy Networks (TENs) Legislative Guidebook," 10.
[226] Bakai et al., "Thermal Energy Networks (TENs) Legislative Guidebook," 9.
[227] Bakai et al., "Thermal Energy Networks (TENs) Legislative Guidebook," 11.
[228] Bakai et al., "Thermal Energy Networks (TENs) Legislative Guidebook," 10.

within the market, while softer policies will still create pressure, but likely stimulate less market growth. As geothermal technologies are still young, some level of market pressure and legislative action will be necessary to accelerate their development in Pennsylvania.

To promote geothermal technologies and learn more about their potential, many states have passed legislation relating to TEN pilot projects. It is likely that geothermal district systems will be applicable to a few cities or highly populated areas within each state.

Massachusetts was the first state to authorize utility TEN pilots, beginning in 2021, when the state allowed gas utility companies to develop pilot geothermal networks.[229] The following year, the state determined that these TEN pilots could be paid for using the funding from a pipe replacement program, the Gas System Enhancement Plan.[230] Massachusetts continued to legislate TENs in 2024 to further update the gas distribution system and smooth the transition to geothermal energy.[231] By 2024, five pilots had been approved in Massachusetts and Eversource Energy, a gas utility, began to operate the nation's first geothermal network pilot in June 2024.[232]

The Eversource pilot is based in Framingham, MA, and provides heating and cooling services to 36 buildings – 24 residential, a school district, a fire station, and various commercial properties. In sum, the project serves 135 customers using 90 boreholes and a one mile shared geothermal loop.[233] Notably, the Framingham project utilized recommendations from the community and agreed to cover the cost of removing and replacing the geothermal equipment if customers are dissatisfied after the two-year pilot phase.[234] The Eversource project received a $7.8 million grant from the U.S. DOE Geothermal Technologies Office after an initial $700,000 grant for a 2023 feasibility study.[235] While the above pilot has proven successful, a proposed TEN by Eversource in the city of Lowell had to be abandoned in February of 2025. Project managers cited inflation, high supply costs, site specific geological conditions, and an undeveloped market as reasons why this project was deemed infeasible.[236]

New York has also been a leader in decarbonization efforts. In 2022, the state enacted the Utility Thermal Energy Network and Jobs Act (UTENJA), which enables gas and electric utilities to build, own, operate, and distribute thermal energy.[237] The Act also promotes jobs for transitioning utility workers within the decarbonization sector, specifically for those who have lost their jobs or are at risk. By 2023, New York utilities proposed 13 TEN pilots in compliance with UTENJA, though one was withdrawn. By April 2024, nine pilots had been approved to advance from the feasibility to the engineering phase.[238]

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[229] 2021 Mass. Acts 7.
[230] Miles et al., "Thermal Energy Networks in the United States," 34.
[231] "Thermal Energy Networks (TENs) State Legislation," *Building Decarbonization Commission*, 2025, accessed June 26, 2025, https://buildingdecarb.org/resource-library/tens-state-leg.
[232] "Thermal Energy Networks (TENs) State Legislation,"
[233] Miles et al., "Thermal Energy Networks in the United States," 34.
[234] Miles et al., "Thermal Energy Networks in the United States," 59.
[235] Miles et al., "Thermal Energy Networks in the United States," 34.
[236] Miriam Wasser, "Gas Utility Cancels Networked Geothermal Pilot in Lowell," WBUR.Org, February 6, 2025, https://www.wbur.org/news/2025/02/06/national-grid-cancels-networked-geothermal-lowell.
[237] 2022 N.Y. Laws 1485.
[238] "Thermal Energy Networks (TENs) State Legislation," *Building Decarbonization Commission*.

Maryland began its legislative efforts to promote TENs in 2024, with the Working for Accessible Renewable Maryland Thermal Heat (WARMTH) Act. This act allows gas, water, and electric utilities to own TENs and also requires that companies serving more than 75,000 customers propose one or two pilot projects.[239] Smaller companies have the option to develop a pilot proposal if desired. Another interesting facet of this law is that it requires that at least 80 percent of the pilot customers are either low- or middle-income.[240]

Table 7
Summary of State Government Adoption of TEN Pilots
2025

State	Enacted Legislation	Law Name	Number of Required Pilots	Allowed or Mandated Pilots
MA	2021 Mass. Acts 7	An Act Creating a Next-Generation Roadmap for Massachusetts Climate Policy	NA	Allow gas utilities to create pilots
MN	2021 Minn. Laws 1113; Minn. Stat. § 216B. 2427 (2021)	Natural Gas Utility Innovations Plans	1 per utility company	Mandate utilities over 800,0000 customers
MY	2022 N.Y. Laws 1485	Utility Thermal Energy Network and Jobs Act	1-5 per utility company	Mandate for seven largest gas and electric companies
CO	2023 Colo. Sess. Laws 753	An Act Concerning the Implementation of Measures to Advance Thermal Energy Service	1+ per utility company	Mandate for large gas utilities with over 500,000 customers
WA	2024 Wash. Sess. Laws 2309	An Act Relating to Promoting the Establishment of Thermal Energy Networks	NA	Allows for pilots
MD	2024 Md. Laws Ch. 564	Working for Accessible Renewable Maryland Thermal Heat (WARMTH) Act	1-2 per large utilities	Mandate gas utilities for over 75,000 customers; those under this limit are allowed
VT	2024 Vt. Acts & Resolves 818	An Act Relating to Miscellaneous Changes Related to the Public Utility Commission (Act No. 142 of 2024)	NA	Mandate PUC study to determine legislation needed to authorize TENs

239 "Thermal Energy Networks (TENs) State Legislation," *Building Decarbonization Commission*.
240 2024 Md. Laws Ch. 564.

continued

Table 7
Summary of State Government Adoption of TEN Pilots
2025

State	Enacted Legislation	Law Name	Number of Required Pilots	Allowed or Mandated Pilots
CA	2024 Cal. Stat. 6008	The Priority Neighborhood Decarbonization Act (Ch. 602)	30 electrification pilots, some of which may take the form of TENs	Mandate for all gas utilities to file maps with pipe replacement plans
TX	2025 Tex. Gen. Laws Ch. 455	An Act Relating to the Projects Undertaken by a Public Improvement District, Municipal Management District, Water Control and Improvement District, Fresh Water Supply District, or Municipal Utility District	NA	Lists geothermal water conveyance as a type of public improvement project eligible for state financing within certain districts

Source: Adapted from "Thermal Energy Networks (TENs) State Legislation," *Building Decarbonization Commission*.

In 2024, Vermont updated its law on the Public Utility Commission to focus on opening various ownership pathways for TENs.[241] These pathways encompass various potential owners, including municipalities, existing utilities, businesses, developers, and nonprofits. The effects of Vermont's legislation will be clearer in a few years.

As demonstrated by these examples, states across the U.S. have used a variety of policy solutions and employed different approaches when developing TENs pilot projects. These examples are a helpful collection of options as Pennsylvania weighs geothermal network adoption.

[241] "Thermal Energy Networks (TENs) State Legislation," *Building Decarbonization Commission*.

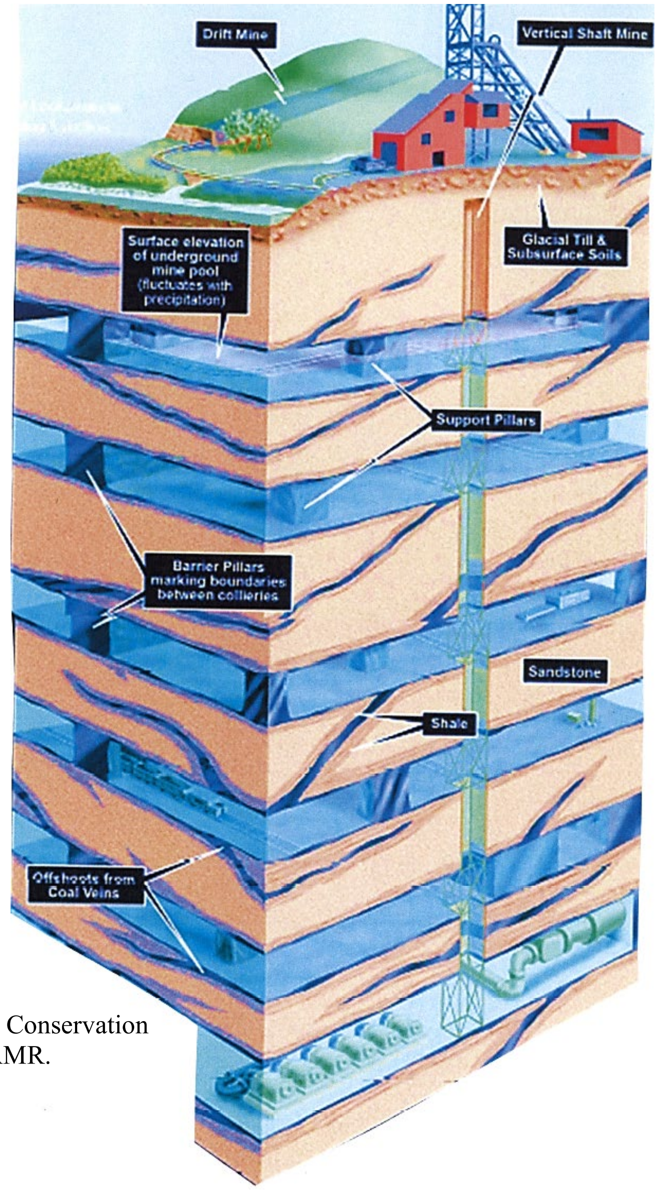
Background on Mine Pools

Pennsylvania has a rich tradition of coal mining dating back hundreds of years. "Since the mid-1700s, years before the Declaration of Independence, Pennsylvanians have mined 250,000 acres of land for coal, pulling more than 15 billion tons of the fossil fuel from the earth."[242] A quote commonly attributed to Aristotle states that "Nature abhors a vacuum" and it applies here. Thousands of mines left behind by this industry have collapsed, either by design or accident. In other instances, the cavities remaining from the extracted coal are filled with water. When in operation this water was pumped from the mines.[243] The structure of mine pools can be complex, according to the U.S. Department of the Interior, "A century of extensive underground coal mining has resulted in many square miles of interconnected mine workings. After mine closure, the mine voids are allowed to fill with ground water creating a vast network of interconnected mine pools."[244] See figure 14.

One environmental challenge to the Commonwealth occurs when mine waters rise to the surface, bringing with them minerals disruptive to above-ground ecosystems or that pose a danger to public health.[245] This is known as Acid Mine Drainage (AMD). It is worth noting that not all mine pools are equally dangerous, the danger depending on the characteristics of each particular mine pool.[246] While potentially beneficial uses for these mine pools have been discussed for decades, no widespread effort has been made to capitalize on this resource, partially because many mines were abandoned by their original operators. While the state oversees AMD sources to limit the amount of damage they contribute to the environment, redevelopment opportunities can be limited as entities wish to avoid liability that may come with the land. An examination of the legality of redeveloping abandoned mine lands is presented later in this report.

[242] Vellucci, Justin, "Coal, Once King in Pennsylvania, Leaves Abandoned Mines That Pose Concerns," *Trib Live*, December 8, 2024, https://triblive.com/local/westmoreland/coal-once-king-in-pennsylvania-leaves-behind-abandoned-mines-that-pose-concerns/.
[243] Nick Malawskey, "Why Some Pa. Streams and Rivers Are Orange: The Legacy of Abandoned Mines," PennLive, July 31, 2018, https://www.pennlive.com/news/2018/07/anthracite_minings_long_legacy.html.
[244] Office of Surface Mining Reclamation and Enforcement, "Mine Pools," accessed August 7, 2025, https://www.osmre.gov/programs/mine-pools.
[245] Malawskey, "Why Some Pa. Streams and Rivers Are Orange: The Legacy of Abandoned Mines."
[246] Michael C. Korb, "Minepool Geothermal in Pennsylvania," presentation at 2012 PA AML Conference New Frontiers in Reclamation, August 2-4, 2012, 9.

Figure 14
Mine Pool Cross Section
2025



Source: Lackawanna River Conservation Association, EPCAMR.

Mine Water Energy

While geothermal networks that utilize closed-loop borehole fields have been a clear focus of study within the United States, geothermal technologies using geothermal mine water are another option to consider. Mine water energy systems are a potential way to reinvent how the Commonwealth utilizes its old and abandoned energy infrastructure. Despite its unconventionality, mine waters should be considered for geothermal heating and cooling for two primary reasons.

First, creating geothermal systems has high capital costs. While the geo-exchange on a district scale has many benefits examined earlier in the report, the cost scales with its size, as thousands of small boreholes must be drilled into the ground, and then a system of pipes must be constructed and buried to distribute this heat. Using a preexisting body of water as a heat sink such as an underground lake or mine pool could avoid this expense. The deposit of blood, sweat and tears has already been paid for by Pennsylvania's bygone workforce. With ingenuity, careful planning, and enough investment, mine pool heating and cooling could honor Pennsylvania's mining history while working toward a more efficient and sustainable future.

Second, one of the main limitations of a geo-exchange system is that it relies on close proximity between the heat source and the end user, unlike natural gas that can easily be transported thousands of miles to its end user. However, numerous cities and towns of Pennsylvania exist near mines. According to the Deputy Secretary of the Office of Active and Abandoned Mine Operations, over a million buildings throughout the Commonwealth are built above these mines.[247] While far from evenly distributed across the state, 41 Pennsylvania counties have at least one abandoned mine.[248] This can sometimes be a precarious reality, as subsidence and even in extreme cases sink holes are a danger faced by legacy mining communities. However, there exists an opportunity to design mine water energy systems at individual, multi-building, or possibly community-wide scales. If such systems were created, a significant reduction in the cost to construct geothermal systems to heat and cool these communities could result, helping to stabilize the energy grid and lead to a more consistent energy load that is less prone to seasonal spikes in demand.

Characteristics of Mine Water Systems

Perhaps the most meaningful distinction between a standard geothermal heating and cooling system, like those explored in the previous chapter, and mine water energy systems is the type of water source utilized. Although conventional and mine water energy systems are both heating and cooling networks that use heat pumps, the water source is a crucial difference not to be underestimated. The use of mine water as a heat sink in a geothermal system has a strong bearing on where these systems are located, how they are designed, what type of funding is available, and the potential types of cost savings, and potential environmental impacts. As opposed to the closed-loop, geo-exchange systems, such as found at Swarthmore, open-loop geothermal systems are sometimes seen as less desirable because of uncertainty in their construction, greater potential for environmental risks, and regulatory complexity uncertainty despite their being less expensive and more efficient.

Mine water energy systems around the world employ heat pumps that draw water up through a borehole or shaft from mine pools. One frequent characteristic of these geothermal systems is that they tend to feature open-loop designs (though closed-loop variations exist as well). Many of the case studies reviewed in this report followed a typical process for creating mine water energy systems. A pilot borehole is drilled into the ground above a mine pool and the water is tested. Then the borehole is expanded into an extraction point. Pumps are installed to draw mine

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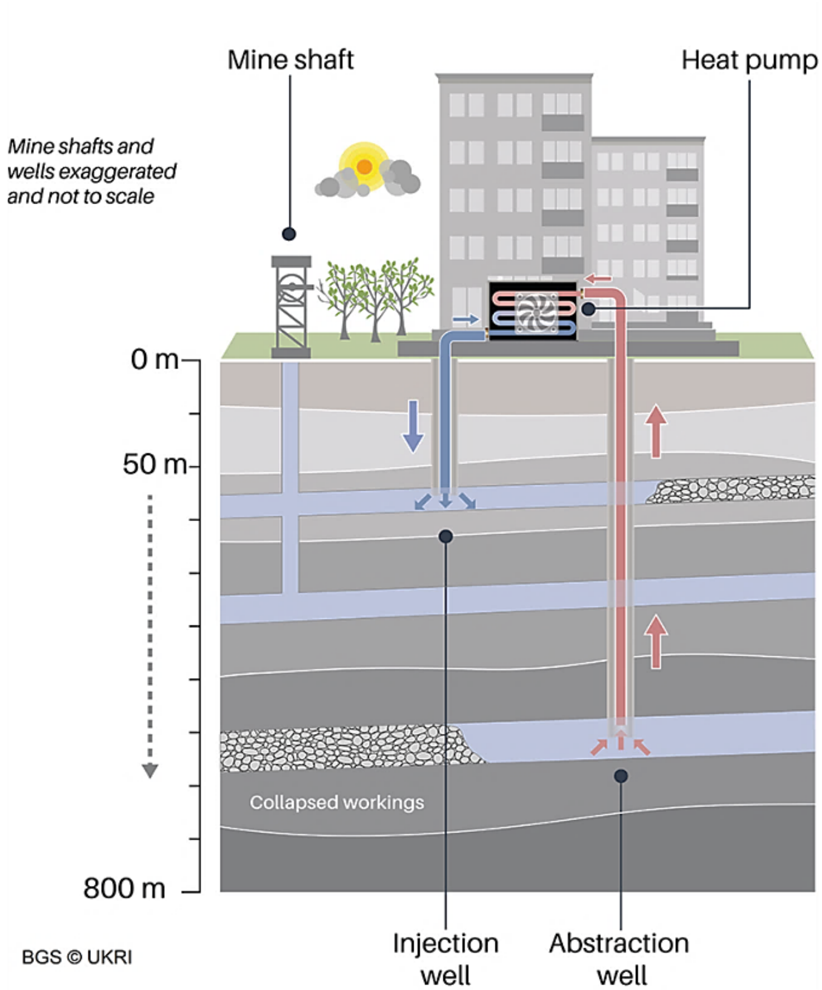
[247] "Check Pennsylvania Properties for Mine Subsidence Risks," Farmprogress, April 27, 2017, https://www.farmprogress.com/management/check-pennsylvania-properties-for-mine-subsidence-risks.
[248] PA Dept. of Environmental Protection, "Abandoned Mine Land Inventory Points, 2013."

water to the surface and transfer its heat via heat exchangers to a network of pipes containing clean water. The temperature of the water within the network is between 140°F to 158°F when used by homes and businesses.[249] Meanwhile, mine water, which is now 9°F cooler, is returned to the ground through a second borehole. There the water travels underground gradually reheating until it returns to the extraction point. One benefit of mine water energy systems is the small amount of physical space they occupy. When the project is completed, it is approximately the size of a manhole cover.

Figure 15
Diagram of Mine Water Geothermal System
2022



Source: UK Research and Innovation, Mine Water Energy System.

[249] Gareth Farr and Mining Remediation Authority, "Mine Water Heat Opportunities," Webinar (U.K.), February 13, 2025, https://www.youtube.com/watch?v=8m6Pk5aQMq0.

It has been noted in a previous chapter that designers creating open-loop geothermal systems prefer clean water sources. Despite common assumptions the public may have about the quality of mine water, it can vary greatly.[250] This is why water testing at different levels of a mine pool is important during feasibility stages of system design. Some sites may be suitable for open loop systems, but others may be better suited for closed-loop systems. Regardless of the systems configuration, a common component of a mine water energy system is a heat exchanger. The heat exchangers pass on the energy from mine water to a secondary loop of clean water without facing the risk of the mine water clogging the heat pump. However, the heat exchange may need to be periodically descaled or replaced because of its contact with mine water.

Wherever a mine water energy system is planned, operators should understand how the discharged mine water will be handled. Historically, there have been three options: releasing the water to the surface, releasing the water back down the same hole its drawn from, or reinjecting it through a separate hole into a different layer of the mine.[251] One of the greatest barriers to mine pool systems is that open-loop geothermal systems are frequently subject to environmental regulations designed to protect water quality or local ecology, which determine what options may be used.

Releasing mine water to the surface is generally not preferable for environmental reasons. However, in some geothermal system designs a heat pump could be collocated either at a gravity-based outflow from a mine or at an AMD treatment site. At such locations there is potential to recover heat from the mine water without risking the depletion of a mine pool.

At most sites, reinjecting mine water underground rather than pumping it to the surface is preferred to avoid environmental contamination with AMD, to prevent the depletion of the mine pool, or to risk changes to its water or pressure levels that could lead to subsidence on the surface.[252] It is also less common for mine water to be returned to the same hole it was drawn from. This is because there is a risk of the colder water being released too closely from its point of origin, where it might be drawn back up by the pump again before it has time to reheat. Most commonly, mine water is reinjected into a separate layer of the mine using a secondary borehole. It is preferable that water at the point of reinjection is still hydrologically connected to the water source of the geothermal system.

As a result of this preference for open-loop designs, many mine water systems, even some of the largest in existence, feature as few as two boreholes when compared to the thousands of boreholes needed to construct a closed-loop geothermal system. This open loop design is typically why mine water systems are less expensive than other types of shallow geothermal systems. Mine water energy systems can require substantially less drilling of boreholes and they have a higher level of efficiency than closed loop geothermal systems. However, while the mechanical design of a two-borehole geo-exchange may be simpler, it requires careful placement to function as intended.

[250] Michael C. Korb, "Minepool Geothermal in Pennsylvania."
[251] The Coal Authority. "Mine Water Heat Opportunity Maps for Wales: User Guide and Methodology." *Gov.Wales*, July 2024, https://www.gov.wales/mine-water-heat-opportunity-maps-background-and-guidance.
[252] Eylem Kaya, Sadiq J. Zarrouk, and Michael J. O'Sullivan, "Reinjection in Geothermal Fields: A Review of Worldwide Experience," *Renewable and Sustainable Energy Reviews* 15, no. 1 (July 31, 2010): 47–68, https://doi.org/10.1016/j.rser.2010.07.032.

Unlike closed-loop systems, open-loop systems need a thorough study of the water flows between the parts of the mine used in the geo-exchange system.

Mine Water Energy in Pennsylvania and the United States

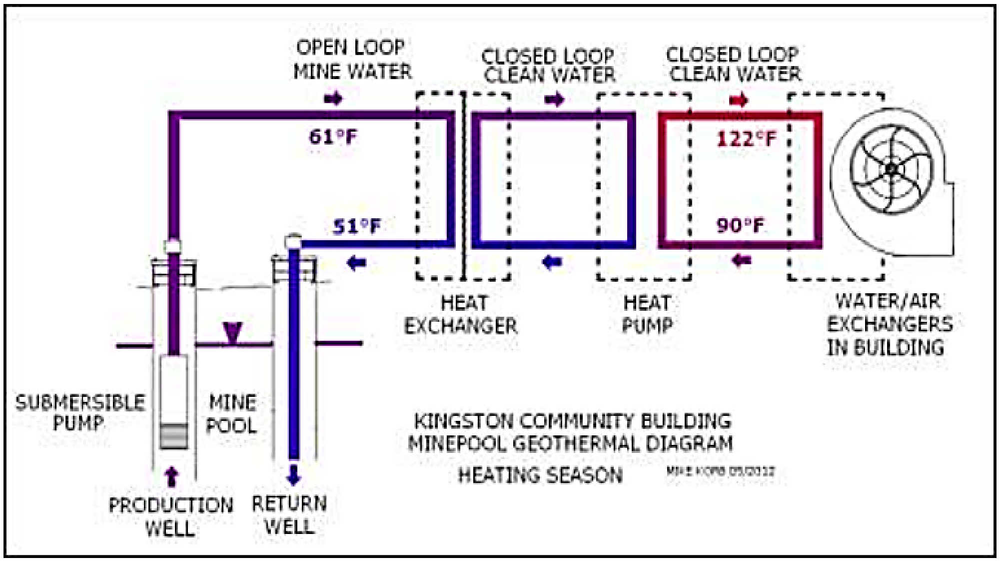
Pennsylvania has long been considered a center for energy innovation, from Benjamin Franklin's early experiments with electricity to Scranton's moniker as the country's Electric City because of its early adoption of electric lights and streetcars.[253] In fact, it is believed that the first geothermal cooling systems employed mine water and that these systems first appeared in the Commonwealth during the middle of the 20th century. One of the earliest documented instances of such a system was in West Pittston, in 1963, at the Consolidated Cigar Warehouse which cooled a 137,000 square foot building using a stainless-steel pump connected to mine water.[254]

A Wyoming Valley Radio Shack used a mine water energy system for twenty years between 1979 to January 2000. The system provided heating and cooling for the 3,200 square foot store. This system made use of a single, 8-inch diameter bore hole drilled 300 feet down, a pump located at 95 feet drew water up from the well. The system ceased operation due to a fire in the building.

The Kingston Community Center, in Luzerne County, was once the nation's longest running mine water energy system. The county's recreation center was fitted with a mine water energy system in 1979 using grant money from DOE and opened in 1981. This system heated and cooled a building which measures 17,000 square feet. Although the system needed repairs after 15 years, it was in operation for 39 years.[255]

[253] "The Electric City," Scranton history, May 20, 2011, https://scrantonhistory.wordpress.com/the-electric-city/.
[254] Michael Korb, "Is Advocating Mine Water Geothermal Quixotic?," Presentation (United Kingdom of Great Britain and Northern Ireland, April 2023).
[255] Michael C. Korb, "Minepool Geothermal in Pennsylvania," 9.

Figure 16
Kingston Geothermal Mine Water Heat System
2012



Source: Korb, Minepool Geothermal in Pennsylvania.

Table 8
Kingston Community Center
Estimated Annual Heating Cost
2012

Fuel Type	Cost	Percent Savings Comparisons
Fuel Oil	$40,000	500%
Electric Resistance	24,000	300
Gas	14,000	175
Mine Pool Heat Pump	8,000	--

Source: Korb, Minepool Geothermal in Pennsylvania.

In the estimates above, in Table 8, the annual costs of heating and hot water compared to other possible heating systems were calculated using February 2012 Northeast Pennsylvania fuel costs.

The system was replaced in 2019. Penn State technical advisors who were unfamiliar with mine water geothermal systems recommended it be replaced with a natural gas furnace due to their greater familiarity with the technology and low cost. This example demonstrates that mine water energy systems can fit poorly into existing energy frameworks used to evaluate energy choices. By some reports, the Kingston geothermal system was a pilot project to be studied in efforts to lead greater adoption of geothermal systems, however the project received little publicity after becoming operational. The problem with establishing new mine water energy demonstration programs is with ensuring that there is appropriate follow-up. Any efforts to create new mine water pilots need to have clear monitoring and benchmark standards. Preferably, such a system would be located at or have a partnership with a university studying energy systems so students could learn about and potentially improve mine water systems. Sharing information regarding the system online may also help to educate Pennsylvanians about mine water systems.

Marywood University, Scranton Pennsylvania

Marywood University in Scranton, Pennsylvania employs a mine water cooling system in its Center for Architectural Studies. Since the removal of the Kingston system, it is believed Marywood's is the sole operational mine water energy system in Pennsylvania.

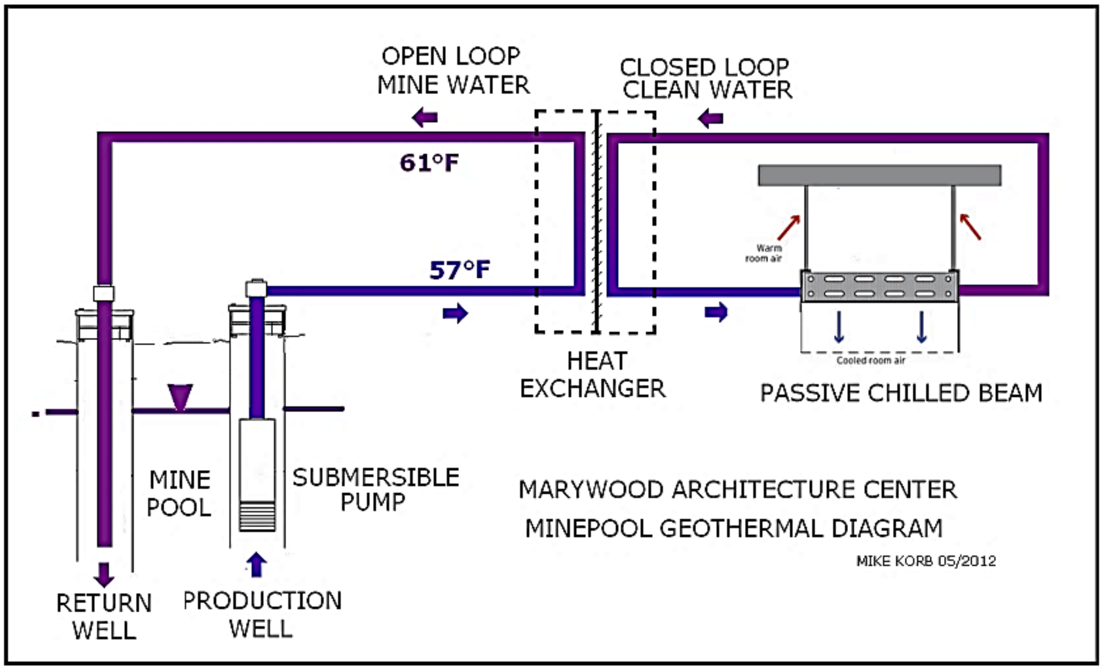
In 2010, Marywood University received a $530,000 grant from the PA Department of Environmental Protection (PADEP) to construct, test, and monitor a geothermal energy system using a mine pool located directly beneath the campus.[256] The funding for this project was provided by the federal US Department of Energy American Recovery and Reinvestment Act of 2009 (ARRA) and distributed through the PADEP's PA Energy Development Authority Sustainable Business Recovery funds.[257] The system was installed in 2010 to provide for the seasonal cooling needs of a new Center for Architectural Studies that had been constructed on the Marywood campus. The building was a renovated gymnasium that now houses design studios.

Characteristics of the Marywood Mine Pool Geo-exchange System

Unlike other geothermal systems reviewed in this report, Marywood's provides only cooling. As hot air rises from the architectural center it moves under a passive chilled beam cooling system that removes the heat from the air and passes it into a closed-loop of clean water, leaving colder air behind. As the loop of water circulates, it remains cool by using a heat exchanger to pass 4°F of heat into the open-loop containing mine water. The now 61°F mine water drops 340 feet into the mine pool through the recharge well. At another point in the mine pool, 57°F water is drawn up through the production well by a submersible pump and into the heat exchanger, starting the cycle over.[258] See Figure 17.

[256] Risch, Christine, Andrew Nichols, Mehdi Esmaeilpour, Richard Begle, "Mine Pool Geothermal Resources - Phase I Engineering Study," Center for Business & Economic Research, 2022, 5.
[257] Michael C. Korb, "Minepool Geothermal in Pennsylvania."
[258] Risch, Christine, Andrew Nichols, Mehdi Esmaeilpour, Richard Begley, "Mine Pool Geothermal Resources - Phase I Engineering Study," Center for Business & Economic Research , 2022, 5.

Figure 17
Marywood Geothermal Mine Water Cooling System
2012



Source: Korb, Minepool Geothermal in Pennsylvania.

The Marywood system installation required only two boreholes and 2,000 feet of pipe.[259] The holes are drilled about 100 feet from the school, and the recharge wells are 50 to 60 feet apart.[260] Water at the site was considered clean enough to use with the heat exchanger without treatment.

Table 9
Marywood System
2012

Specifications	
Year of install	2010
Scale	One academic building (30,000 square feet)
Function	Seasonal cooling
Cost	$530,000

Source: Korb, Minepool Geothermal in Pennsylvania.

259 Michael C. Korb, "Minepool Geothermal in Pennsylvania," 5.
260 Risch, Christine, Andrew Nichols, Mehdi Esmaeilpour, Richard Begley, "Mine Pool Geothermal Resources - Phase I Engineering Study," Center for Business & Economic Research , 2022, 5.

Future systems produced within the state that use state grants should have the requirement for ongoing study over the lifetime of the system. Such system reports should be openly published so potential stakeholders can learn about the cost savings and maintenance needs of such systems. While government funding has financed the development of mine water energy systems at the Kingston Community Center, Marywood University, and a few others, there has been minimal effort by the Commonwealth to promote wider adoption of these systems.

Park Hills, Missouri

Outside of Pennsylvania, there are scattered mine water energy systems throughout North America. One of the most well-known examples in the U.S. is a geothermal system in the City of Park Hills, Missouri. A repurposed lead mine was used for both the heating and cooling of a two-story building that is about 8,000 square feet.[261] The 57°F mine water is pumped from a depth of 390 feet at a rate of 74 gallons per minute into a system composed of nine heat pumps. After heat is extracted, the used water is then circulated back to the mine. In 1996, the initial cost of installing this system was estimated to be 20 percent more than a conventional system composed of natural gas for heating and regular air conditioners for cooling. The payback period was estimated to be 4.6 years. The largest rooms in the building also employ two air source heat pumps. Overall, the system supplies 71.6°F in winter and 75.2°F in summer.

International Mine Water Case Studies

There appears to be little standardization among existing mine water geothermal systems across the world. A 2015 systematic review of 18 systems found significant differences in temperature, circulation flow rates, mine water quality, and the location of end users.[262] Mine water systems may have significant versatility, there may also be difficulties in achieving build out since each mine water system may have a unique configuration to make use of features of the site and the needs of their designers. However, due to their individuality, each mine water system is a potential lesson in how these systems can be designed. As geological conditions can vary greatly, it may be best to focus on mine water systems and mine characteristics similar to that of Pennsylvania until more data can be collected from Pennsylvania mines.

Canadian Case Study

One of the few places in the world that has embraced the use of mine water energy systems for heating and cooling is in Springhill, Nova Scotia where several manufacturing facilities and public buildings use mine water to heat and cool interior space. The large, flooded mine pool

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[261] Christine Risch and William Sheils, "Mine Pool Geothermal in West Virginia," (Center for Business and Economic Research Marshall University, West Virgini, 2021), 13.
[262] Esmeralda Peralta Ramos, Katrin Breede, and Gioia Falcone, "Geothermal Heat Recovery From Abandoned Mines: A Systematic Review of Projects Implemented Worldwide and a Methodology for Screening New Projects," *Environmental Earth Sciences* 73 (March 22, 2015), https://doi.org/10.1007/s12665-015-4285-y.

underlaying the town contains approximately three billion gallons of water and has made the area a continental leader in the use of mine pool water for geothermal.[263]

Each heat pump uses a 3.73 kW motor. Heating and cooling are provided by drawing water from the mine pool from wells that range from 32 to 740 feet. Conditions within the Springhill mine pool are well recorded with a water temperature from 44°F to 59° F, and the acidity levels of the water range from 6.7 to 7.8 pH. The water is also more electrically conductive than typical potable water because of absorbed minerals.[264]

One of the major uses of mine water in Springhill is The BYWAY Packing Company which is a flexible packaging products manufacturing facility that uses mine pool geothermal to heat and cool 151,000 square feet of interior space. The supply well is 140 meters deep and pumps water at 63 gallons per minute. The system incorporates 11 heat pumps. The mine water temperature is 64°F with an outlet temperature of 55°F in the winter and 68°F in the summer. The water is then returned to the mine 30 meters below the surface.[265] Reported energy savings ranging from 12 percent to 44 percent when mine pool geothermal resources are compared to median consumption for comparable benchmark facilities.[266] The COP for these systems is 3.5.[267]

Although the capital cost for the BYWAY Packing mine water system was about 20 percent higher than a conventional oil system, the company estimated $160,000 in annual savings over a conventional oil system. The payback period was estimated at less than one year.[268]

Local governments near Springhill have plans to create a geothermal district that will house a 100-acre business park.[269] The plans for the business park have it situated on top of the town's former mines. The local energy authority believes it will be able to supply heating costs of $31.20/MWh of delivered heat, compared to other expected costs for electric resistance ($130/MWh) and propane units ($132.39/MWh). The expected cooling costs are $22/MWh of delivered cooling, a price that compares favorably to traditional air-source heat pumps ($35.1/MWh) or chiller and cooling towers ($26/MWh).[270] The Canadian government has granted a mineral rights lease to the county near Springhill, giving it local control over the development of the geothermal resources.[271]

Other than heating in Nova Scotia, a mine water system in Quebec supplies heating and cooling to 36 apartments. This system featured a decentralized design with each unit having its

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[263] Christine Risch and William Sheils, "Mine Pool Geothermal in West Virginia" (Center for Business and Economic Research Marshall University, West Virgini, 2021), 3.
[264] Christine Risch and William Sheils, "Mine Pool Geothermal in West Virginia," 12.
[265] Christine Risch and William Sheils, "Mine Pool Geothermal in West Virginia," 12.
[266] Christine Risch and William Sheils, "Mine Pool Geothermal in West Virginia," 8.
[267] Risch, Christine, Andrew Nichols, Mehdi Esmaeilpour, Begley, Richard Begley and Sinaya Dayan. "Mine Pool Geothermal Resources – Phase 1 Engineering Study" (Center for Business & Economic Research, Marshall University, West Virginia, 2022), 37.
[268] Christine Risch and William Sheils, "Mine Pool Geothermal in West Virginia," 12.
[269] Jody C. Robins et al., "2021 U.S. Geothermal Power Production and District Heating Market Report," National Renewable Energy Laboratory, 2021, https://docs.nrel.gov/docs/fy21osti/78291.pdf.
[270] Christine Risch and William Sheils, "Mine Pool Geothermal in West Virginia," 15.
[271] Christine Risch and William Sheils, "Mine Pool Geothermal in West Virginia," 18.

own heat pumps. The water source uses a flooded quarry which is estimated to hold two billion gallons of water.[272]

German Case Studies

Germany is another known adopter of mine water energy systems, with at least five identified in 2015.[273] Many of these systems were located in the Saxony region of the country and contained waters at similar temperatures to Pennsylvania mines. In one instance, the system was installed within a pre-existing mine shaft which averted the need to drill new boreholes into the mine. In another, a 61,200 square foot school building from 1907 that was retrofitted with a geothermal mine water system was able to decrease their annual energy consumption by two-thirds. The school retrofit included other energy improvements such as new windows, insulation for walls, and isolating hot and cool pipes. Today such a project may cost up to $5.6 million.

Another German example in Marienberg shows how mine water energy can be scaled for commercial use across multiple buildings. The system accesses a mine pool with a 350 foot well. The water within is 54°F (similar to Pennsylvania mines). The Marienberg system used three submersible pumps with a combined flow of 31,700 gallons per hour. A stainless-steel heat exchanger was placed six feet above the mine pool. Galvanized stainless-steel pipes were used in vertical sections to carry water out of the mine, while plastic pipes were installed horizontally to deliver energy to above ground customers. This system provides heat to a waterpark, tennis hall, and nearby supermarkets.

Netherlands Mine Water District System

Mine water energy systems can be integrated into district heating, as demonstrated by the Mijnwater B.V. project. This mine pool geothermal project is based in Heerlen, Netherlands, and serves as an example of a fifth-generation district heating and cooling system that uses water from abandoned coal mines as a source of heat and underground energy storage.[274]

The initial pilot phase of the Mijnwater project was developed from 2003 to 2008 and included five wells. Two hot wells were approximately 2,300 feet deep, two cold wells were situated at a depth of 820 feet, and a fifth well pumped the water with its heat already extracted back into the system.[275] Within this structure, the system provided heating and cooling services to two large buildings, the Central Bureau of Statistics and the Heerlerheide Centrum complex, at 36,000 and 323,000 square feet, respectively.[276]

One challenge of the initial pilot phase is that it used mine water solely as an energy source. This structure limited the expansion of the system because water that had been pumped back into

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[272] Peralta Ramos, Breede, and Falcone, "Geothermal Heat Recovery From Abandoned Mines: A Systematic Review of Projects Implemented Worldwide and a Methodology for Screening New Projects."
[273] Peralta Ramos, Breede, and Falcone, "Geothermal Heat Recovery From Abandoned Mines: A Systematic Review of Projects Implemented Worldwide and a Methodology for Screening New Projects."
[274] "The use of mine water in district heating systems – an example from Heerlen, Netherlands," *European Commission*, 2023, https://data.europa.eu/doi/10.2833/962328, 1.
[275] "The Use of Mine Water in District Heating Systems," *European Commission*, 2.
[276] "The Use of Mine Water in District Heating Systems," *European Commission*, 2; and JSGC Staff unit conversion.

the system needed time to reach extraction temperatures before it could be used again.[277] To address this limitation, the system expanded its energy storage. These upgrades have allowed the project to serve a more extensive total of 2.15 million square feet of buildings within four connected cluster grids.[278] As part of the upgrades system, "mine water was heated up (for heat storage) and cooled down (for cold storage) before being pumped back into the ground via bi-direction wells" to be stored for later use.[279] Since the first upgrades, another upgrade to the control system technologies has taken place. This additional optimization phase still needs to be developed to make the extra effort worthwhile.

The Mijnwater project has found success in its contribution to a 65 percent reduction in CO_2 emissions for the heating and cooling of buildings in the region when compared against the average gas heating and electric cooling technologies.[280] Further, the project provides a compelling example of the use of mine water within district heating systems. The use of mine water for district heating within Pennsylvania is a promising possibility. Still, it is important to consider the differences in geographic conditions. The temperature of the water from the initial two hot wells in northern Heerlen was approximately 82°F.[281] Without mine water at these high temperatures, Pennsylvania would not be able to recreate the conditions found in Heerlen as economically.

United Kingdom Case Study

There are thousands of disused coal mines across Great Britain and the rest of the United Kingdom (UK).[282] Similar to Pennsylvania, water was pumped out of these mines while in operation and they are now flooded due to inactivity. Historically, the UK mines were regarded as a risk to the environment, and the UK created over 80 mine water treatment systems to mitigate the damage caused by its legacy of coal mining.[283] Today, there is a concerted effort by the UK government to apply these mines to more beneficial uses. After extensive data collection, it was determined that temperatures collected from mine waters throughout the country ranging between 50-68°F, enough to be used for ground source heat pumps.[284] One reason this is being considered is that the mines frequently coincide with populated urban areas in need of heat. An estimated quarter of the properties in Great Britain are above coal fields.[285]

The Mining Remediation Authority, formerly the Coal Authority, was created by the UK's Coal Act of 1994 and is now the governmental body supervising the development of mine water systems.[286] The MRA is a non-departmental government body that owns and manages all the coal

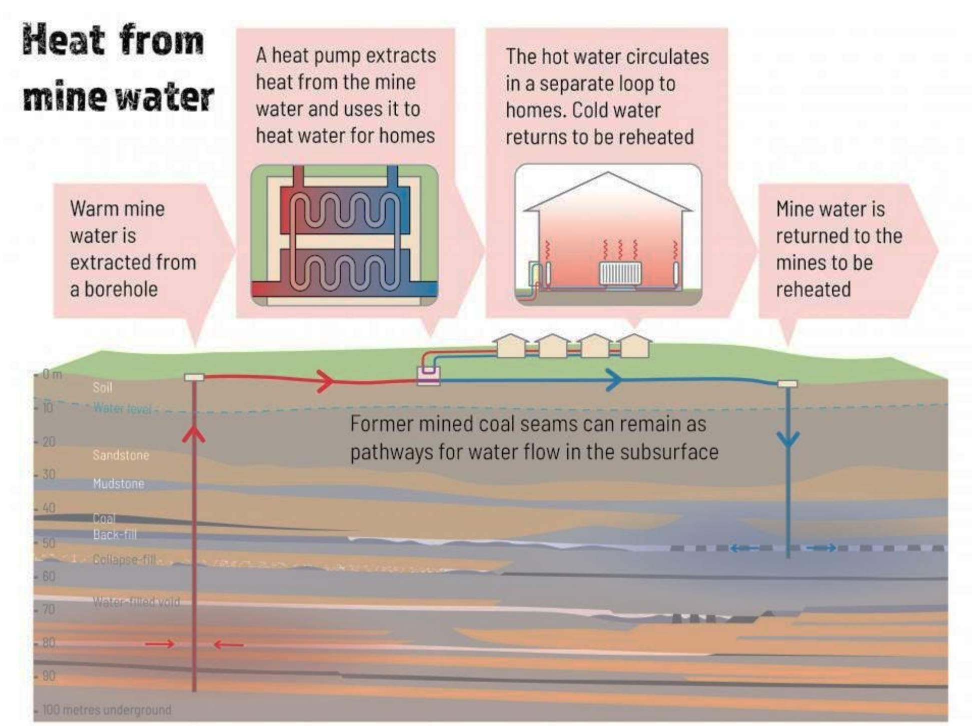
[277] "The Use of Mine Water in District Heating Systems," *European Commission*, 2.
[278] "The Use of Mine Water in District Heating Systems," *European Commission*, 2.
[279] "The Use of Mine Water in District Heating Systems," *European Commission*, 2.
[280] "The Use of Mine Water in District Heating Systems," *European Commission*, 5.
[281] "The Use of Mine Water in District Heating Systems," *European Commission*, 2.
[282] Gareth Farr and Mining Remediation Authority, "Mine Water Heat Opportunities," Webinar (U.K.) February 13, 2025, https://www.youtube.com/watch?v=8m6Pk5aQMq0.
[283] Gareth Farr and Mining Remediation Authority, "Mine Water Heat Opportunities."
[284] Gareth Farr and Mining Remediation Authority, "Mine Water Heat Opportunities."
[285] "Coal Authority Business Plan 2022 to 2025," GOV.UK, October 10, 2022, https://www.gov.uk/government/publications/coal-authority-business-plan-2022-to-2025/coal-authority-business-plan-2022-to-2025.
[286] British Geological Survey, "UK Mineral Ownership," August 27, 2024,

mine sites within the UK. One aspect of the MRA's mission is to steward the mining resources and benefit their taxpayers by creating wealth and protecting the environment in a cost-effective way. These efforts support a broader goal within the UK government to achieve zero carbon emissions by 2030.[287]

Types of UK Mine Systems

There are three types of mine water geothermal systems operating within the UK, single well, double well, and waste heat recovery. In the first two system types, water is drawn from a pool through a borehole or mine shaft. Depending on the system design the water is either returned down the same well or a separate one, ideally at a different layer of the mine. In the third type of system, heat pumps are placed either at spots whether pressure or gravity brings mine water to the surface or situated at places where the AMD is being treated. While not as common, one of the reasons this third type generated interest is to avoid the cost and uncertainty of drilling.[288] Retrofitting active mine water treatment facilities with heat pumps is considered an exciting possibility because it could add a revenue stream to help fund active AMD treatment plants.

Figure 18
Heat from Mine Water
March 5, 2021



Source: British Geological Survey, "Delivering Geoenergy Research Infrastructure in Glasgow."

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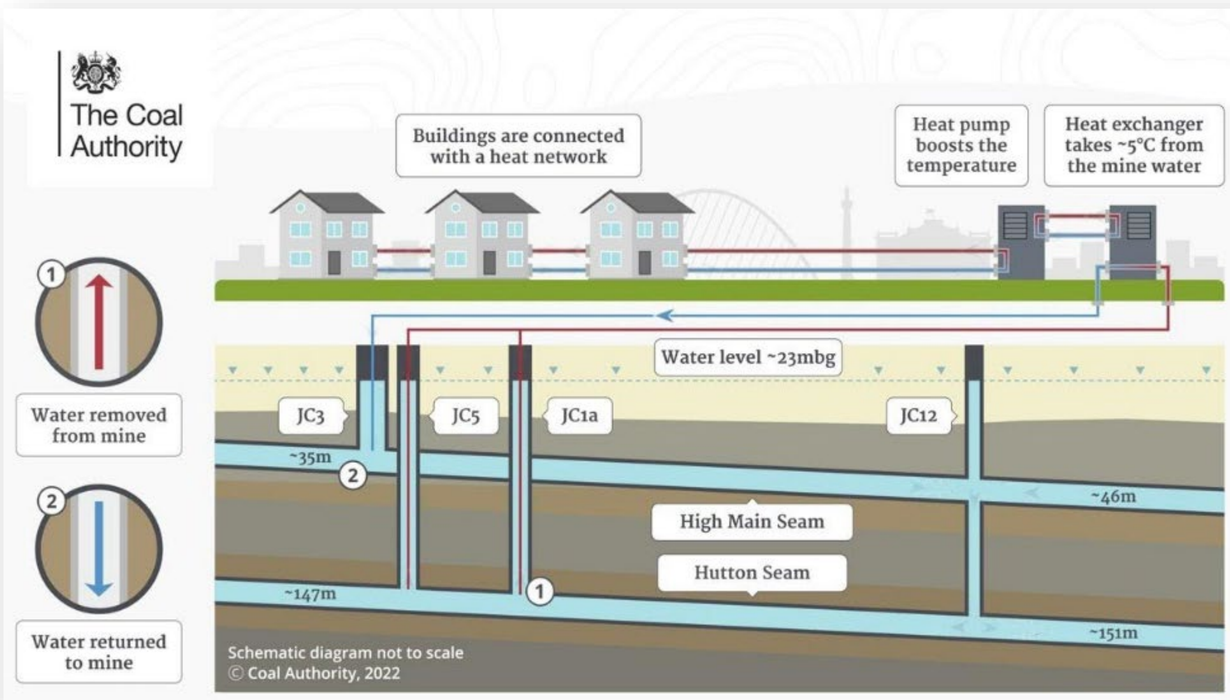
https://www.bgs.ac.uk/mineralsuk/planning/uk-mineral-ownership/.
287 Fiona Todd and Mining Remediation Authority, "Research and Development in Mine Water Heat," Webinar (UK) February 13th, 2025. https://www.youtube.com/watch?v=m8chfDjtcBo.
288 Gareth Farr and Mining Remediation Authority, "Mine Water Heat Opportunities."

Using mine water in heating systems in the UK dates back a quarter of a century. In its earlier experiments with mine water, a mine water energy system in Scotland was able to provide hot air and water to 16 houses, while another system resulted in 80 percent cost savings for the building.[289] In 2015, pilot programs were established at the National Mining Museum of England as well as other locations throughout the UK, which helped demonstrate the feasibility of the technology. Since that time the UK government has invested millions of dollars in mine water energy research and subsidizing the financing of these systems.

By the 2020s, the results of this funding could be seen with additional UK mine water energy systems becoming operational. The recently constructed geothermal system at Gateshead is now one of the largest mine water systems in Europe.

Figure 19
Gateshead Schematic
2022



Source: Mining Remediation Authority.

[289] Peralta Ramos, Breede, and Falcone, "Geothermal Heat Recovery From Abandoned Mines: A Systematic Review of Projects Implemented Worldwide and a Methodology for Screening New Projects."

The Gateshead mine water system was developed by the Gateshead town council, which formed their own energy company.[290] The Gateshead mine water district heating network extends over 3.4 miles and produces 10 GWh of heat per year.[291] The total capital expenditure for the project was nearly $18.78 million; a significant portion of this was supported by a $7.35 million commercialization and construction grant from the UK government.[292]

Unlike other mine water systems reviewed in this report which feature two wells, the mine water energy system at Gateshead has three in total. This system needed two extraction boreholes to draw the necessary amount of water out of the mine needed to meet the thermal demand. These wells are located in a deeper mined coal seam situated 480 feet beneath the development. After the water has passed through the heat exchange and cooled by 9°F it is returned via a single recharge well to a shallower mined coal seam at 115 feet. See figure 19.

The timeline for Gateshead mine water system development was:

- January 2019 - start date
- September 2019 - feasibility study finished
- March 2020 - grant funding awarded
- April 2020 - commercialization began
- June 2021 - construction started
- February 2022 - mine water borehole completed
- June 2022 - commissioning of mine water heat pumped
- March 2023 - heat pumps operational, load, and efficiency tests conducted
- June 2026 - expected operational date[293]

The Gateshead Facility has also partnered with an urban solar park that helps reduce the electricity cost of running the system and helps to showcase how various renewable energy sources can be used in conjunction with each other. Multiple buildings are served by this thermal network including a college, a contemporary arts center, office buildings, and 350 houses owned by the town council.[294] After the initial project was completed, the system was expanded to include 270 more homes, along with a conference center and hotel. The project is estimated to prevent nearly 2,000 tons of carbon emissions annually.[295] Part of the force behind this rapid embrace of geothermal heating and cooling is that natural gas connections for new buildings will be prohibited in the UK starting in 2025.

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[290] The Coal Authority, "Gateshead District Energy Scheme," *Triple Point Heat Networks*, August 2023, https://tp-heatnetworks.org/wp-content/uploads/2023/08/gateshead-district-energy.pdf.
[291] Gareth Farr and Mining Remediation Authority, "Mine Water Heat Opportunities,"
[292] The Coal Authority, "Gateshead District Energy Scheme," *Triple Point Heat Networks*; and currency conversion by JSGC Staff, 2025.
[293] The Coal Authority, "Gateshead District Energy Scheme."
[294] Mining Remediation Authority, "Mine Water Energy Scheme at Gateshead," November 7, 2023, https://www2.groundstability.com/major-grant-to-connect-gateshead-homes-to-coal-authority-mine-water-energy-scheme/.
[295] "Mine Water Energy Scheme at Gateshead: The Mining Remediation Authority;" and JSGC unit conversion.

While signs point to Gateshead being a success, the UK has also seen mine water projects either stumble or fail to come to fruition. The Lanchester Wines system was drilled in 2015 and licensed in 2017 as a heating system that is spread across two warehouses. It encountered difficulties relating to rust on the equipment, corrosion of water loggers, and a limited ability to reinject water to the mine due to "suboptimal connectivity of the mine."[296] A design for a site in Wales had to be abandoned. The mine water program encountered instability at one of the boreholes which prevented water from being extracted from the mine. The problem was partly caused by utilization of historic maps, and designers believe that there was no test which could have prevented this outcome. In this instance, attempts failed to widen one of the boreholes necessary for system operations. Despite setbacks the site continued as a renewable energy project through the use of solar panels, a combined heat and power unit, and air source heat pumps.[297]

Other Case Studies

In Russia a network with three heating districts is powered by mine water and natural gas. Boreholes extract mine water from approximately 160 to 490 feet deep and the end users are within a third of a mile from the heating pump station. The network showed how multiple boreholes can be combined into a heat network throughout a town and that these can be paired with natural gas generators. The total system capacity of 40MW.[298]

Spain has a large mine able to supply heat for multiple university buildings and a hospital within a mile. The project uses a system that transfers heat from the mine water to a buried clean water network. The university saw energy savings of 73 percent, and the system produced 39 percent less CO_2 per year.[299]

Some mine water systems have a short life span. One closed-loop system in Norway was placed in a mine with heavy levels of sulfides.[300] The system functioned for ten years and was then modified into an air source heat pump.

Mine water systems have been installed in apartments, offices, schools, museums, universities, hospitals, research centers, castles, and recreation centers around the world. There is significant variation in the sizes of buildings they serve and a wide range of temperatures of productions wells, spanning from 43°F to 90°F.[301] The important part of any geothermal system is the mine's thermal balance. It must be able to supply the needed heating and cooling demand without destabilizing the water source.

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[296] IEA Geothermal, "2023 United Kingdom Country Report," October 2024, 6 https://nora.nerc.ac.uk/id/eprint/538167/1/IEA%20Geothermal%202023%20UK%20Report.pdf.
[297] "Update on Hebburn Renewable Energy Scheme," South Tyneside Council, October 10, 2022, https://www.southtyneside.gov.uk/article/14913/Update-on-Hebburn-Renewable-Energy-Scheme.
[298] Peralta Ramos, Breede, and Falcone, "Geothermal Heat Recovery From Abandoned Mines," 6.
[299] Peralta Ramos, Breede, and Falcone, "Geothermal Heat Recovery From Abandoned Mines," 6.
[300] Peralta Ramos, Breede, and Falcone, "Geothermal Heat Recovery From Abandoned Mines," 6.
[301] Peralta Ramos, Breede, and Falcone, "Geothermal Heat Recovery From Abandoned Mines, " 8, Unit conversion by JSGC Staff.

Many mine water systems share similar components: heat exchanger, heat pump, piping, valves, buffers. What these are made of and where they are located may change based on the location of the water in relation to the end user. It has been noted that "[C]apacity and model of the heat exchanger and pump strongly depends on the heating requirements and the capacity of the heat source."[302] Within buildings there are also ways to distribute the heat gathered from underground such as floor heating or water to air heat pumps.

Many of the case studies reviewed showed a preference for open-loops geothermal paired with heat exchangers and a closed loop of clean water to prevent corrosion or scaling of mine water to the heat pump. Frequently, additional equipment such as boilers or chillers was used to increase or store heat. Extraction depth of water varied widely from as little as 165 feet deep to 2,300 feet. Two large factors identified in the cost of a mine energy system are the temperature of the inlet source and the cost of drilling, shaft remediation, and pumping the water.

Open-water loop geothermal systems are considered easier to scale up than closed-loop ones, however this potential is based entirely on the conditions of the site. In a closed-loop system utilizing pipes, costs of drilling wells grow in tandem with the size of a system as more wells need to be created. While mine water systems can be scaled from single household to an entire district's heating, much of it depends on the mines' depths, how much water they contain and the design of the system.[303]

Focusing on fewer systems that are larger in size may be the best path of development within Pennsylvania. It should be noted that conventional heating and cooling systems are cheaper up front and appear to be far easier to develop than mine water energy systems. While mine water energy systems may be more economical in the long term, and they reduce air pollution, one of the reasons for their adoption has nothing to do with costs or air emissions. Around the world, these communities have chosen to honor their past history of mining and repurpose this resource for geothermal heating. Creating a mine water system is a decision where values and community heritage play a significant role, otherwise projects are likely to be abandoned because of technical difficulties or investor unwillingness to assume financial or ecological risk. It is a decision that has the potential to pay off in years rather than financial quarters.

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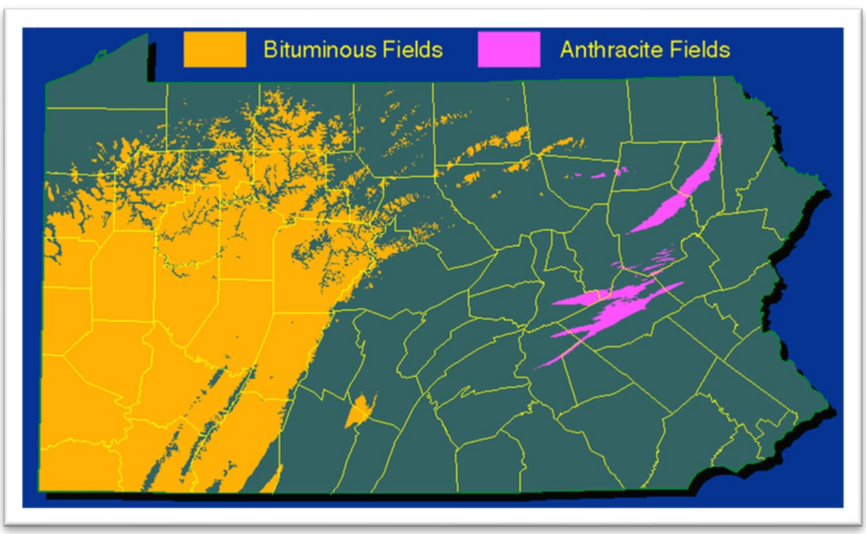
[302] Peralta Ramos, Breede, and Falcone, "Geothermal Heat Recovery From Abandoned Mines," 1.
[303] Peralta Ramos, Breede, and Falcone, "Geothermal Heat Recovery From Abandoned Mines," 8.

Abandoned Coal Mines in Pennsylvania

Siting a Mine Water Geothermal System

Perhaps one reason that mine water energy is not a popular resource in the U.S. is that many regions simply lack the presence of mine pools when compared to Pennsylvania. While often undetectable, Pennsylvania is a national leader in the number of abandoned coal mines.[304] In other areas, however, the legacy of coal mining is plain to see in locations with orange rivers or hills of coal debris. "Abandoned mine lands (AML) are lands and waters adversely impacted by inadequately reclaimed pre-1977 coal mining operations."[305] While the number of mines abandoned throughout the nation has not been exhaustively inventoried, it is estimated to be over 500,000.[306]

Map 4
Pennsylvania Coals
2011



Source: Lehigh University, "Abandoned Coal Mine Drainage Projects in Pennsylvania."

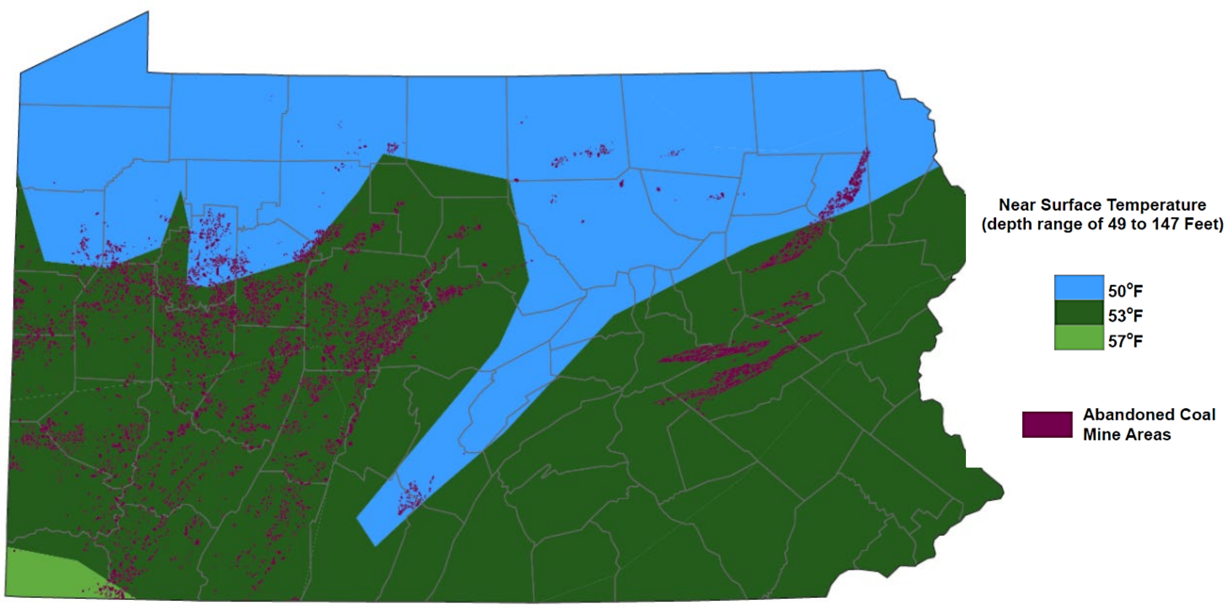
[304] Pennsylvania Department of Environmental Protection, "Shapiro Administration Awards $19.6 Million to Address Largest Inventory of Abandoned Mines in the Nation, Keep Pennsylvanians Safe While Supporting Local Jobs," Pa.gov, December 17, 2024, https://www.pa.gov/agencies/dep/newsroom/2024-12-17-shapiro-administration-awards--19-6-million-to-address-largest-inventory.html.
[305] Pennsylvania Department of Environmental Protection, "Abandoned Mine Land Hazards and Problem Types," PA.gov, accessed July 30, 2025, https://www.pa.gov/agencies/dep/programs-and-services/mining/abandoned-mine-reclamation/aml-program-information/abandoned-mine-land-hazards-and-problem-types.html.
[306] "Abandoned Mine Lands," Bureau of Land Management, December 3, 2024, https://www.blm.gov/programs/aml-environmental-cleanup/aml.

There are over 250,000 acres of abandoned mine lands throughout Pennsylvania.[307] Over $1 billion of health and safety issues are associated with AML within the Commonwealth.[308] According to the Pennsylvania DEP, these problem areas are spread throughout 43 of Pennsylvania's 67 counties. Many of these sites exist in two general regions of the state: throughout western Pennsylvania where bituminous coal was mined and a crescent in the northeast where anthracite coal was mined.

Overview of Pennsylvania Mine Maps

Previous research conducted by the EPA has estimated Pennsylvania is generally favorable to ground source heat pump operations, though it was noted that sites between 50°F and 75°F are preferable. While temperature is important, other characteristics such as mine proximity, well depth, the size of a property, and transmission distance would all need to be considered as part of a scoring criteria for a potential site. Researchers have concluded that mine water energy sites are not uniform in the siting needs and that "additional site-specific technical and economic analysis is required to determine the actual energy potential of these sites."

Map 5
Abandoned Coal Mine Areas in Pennsylvania with Geothermal Heat Pump Siting Potential



Source: Adapted from U.S. EPA, "Abandoned Coal Mine Areas in Pennsylvania with Geothermal Heat Pump Siting Potential."

[307] Pennsylvania Department of Environmental Protection, "PAs Mining Legacy and AML," accessed July 21, 2025, https://www.pa.gov/agencies/dep/programs-and-services/mining/abandoned-mine-reclamation/aml-program-information/pas-mining-legacy-and-aml.
[308] Pennsylvania Department of Environmental Protection, "PAs Mining Legacy and AML."

While knowing where a mine exists is broadly useful for community planning, public safety, insurance purposes, and ecological restoration, more information is needed to show where mine water energy systems can be installed. A widescale accounting for the location and the characteristics of mine pools is needed for development of mine water geothermal systems throughout the state.

The DEP has published several publicly available resources of mine maps:

1. eMapPA shows data points with mine locations and other regulated mining operations.[309]
2. Pennsylvania Mine Map Atlas is a digital compendium of scanned and georeferenced coal mine maps.[310]
3. Pennsylvania Historic Underground Mine Map Inventory System contains a database where users can search and download mine maps and other related mining maps.[311]

The bulk of the work presented in these tools are scans of mine maps, which while useful, are inadequate for the purpose of analyzing mine pool potential by itself. These scans preserve visual information that may be contained within the aging physical maps. In some instances, these scans have been georeferenced so that the map is viewable in correct location within the state. For such an analysis to take place, a mine map must be digitized, which can be a substantial undertaking.[312] However, the existing maps can be used to preliminarily determine whether a mine is present under a particular location and help interested parties consider the first step of whether they are interested in pursuing a mine water energy system. According to State Geologist Gale Blackmer:

> Digitized mine maps are GIS line and polygon layers where the only the exact outlines of the mine openings are represented. Those layers are used in the analysis to find the intersection with the water table and calculate mine pool volumes. The scanned images cannot be used in the analysis.[313]

After a mine map has been scanned and georeferenced, mapping software like ArcGIS is used to trace the boundaries of the mine opening and store them in GIS layers. While technology to automate this process is advancing, currently this stage of the process is considered labor intensive.

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[309] Pennsylvania Department of Environmental Protection, "eMapPA," accessed July 30, 2025, https://gis.dep.pa.gov/emappa/.
[310] Pennsylvania Department of Environmental Protection, "Pennsylvania Mine Maps Atlas," accessed July 30, 2025, https://www.minemaps.psu.edu/.
[311] Pennsylvania Department of Environmental Protection, "Maps," Department of Environmental Protection, accessed July 30, 2025, https://www.pa.gov/agencies/dep/programs-and-services/mining/bureau-of-mining-programs/act-54-yearly-data/maps.
[312] Gale Blackmer e-mail message to Commission Staff, May 21, 2025.
[313] Gale Blackmer e-mail message to Commission Staff, May 21, 2025.

An example of the amount of work that has already been conducted on mapping the mines within the state can be seen in the state's partnership with universities over the last decade. Starting in 2013, DEP in conjunction with Harrisburg University (HU) has worked to scan, georeferenced, and digitize mine maps. By 2015, HU seniors had scanned and inventoried 5,000 coal maps, some of which were over a hundred years old. At that time, over a thousand of the maps had been georeferenced and more than 100 were digitized.[314] By 2018, DEP had granted $1.4 million dollars to HU for five years of work for 40 seniors who had completed 3,000 hours on this project.[315] By 2022, HU students at the Center for Applied Environmental & Geospatial Technology were digitizing maps of the southern anthracite coal field in Schuylkill County.[316]

DEP uses this information to determine which properties are most at risk and may need mine subsidence insurance. According to the DEP this work was accurately and efficiently conducted and led to a better understanding of mine subsidence and other mine-related environmental hazards within the state.[317]

While not exhaustive, this is not to say that efforts to inventory Pennsylvania's mine pools are nonexistent. Mines throughout the Commonwealth contain great volumes of water that slowly filter in and out of mines.[318] For over a decade, the Eastern Pennsylvania Coalition for Abandoned Mine Reclamation (EPCAMR), a nonprofit environmental organization, has worked to create 3D models of mine pools within the state and estimate their volume on behalf of the Susquehanna River Basin Commission. This modeling has uncovered great volumes of water contained within abandoned mines in the anthracite coal mining region. For example, the southern anthracite coal field's Heckscherville Valley mine pools are estimated to contain 6.3 billion gallons of water, while the Rausch Creek mine pools is estimated to contain 2.6 billion gallons. The northern anthracite coal field is thought to contain 161 billion gallons in the Lackawanna Valley and 274 billion gallons in Wyoming Valley.

As EPCAMR is focused on the environmental restoration of areas afflicted with AMD, their reports did not examine the possibility of mine pool-based heating and cooling. They did, however, examine other productive uses that could be found for the pools such as mineral extraction, controlling the release of waters for cleaning them and then holding the water in reserve for drought reduction measures, or to store excess stormwater. Regardless of the beneficial use, one of the barriers identified by EPCAMR staff is the high-water flows rates associated with AMD

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314 Harrisburg University and Albert Sarvis, Post on student mapping initiative, *Facebook*, October 16, 2015, https://www.facebook.com/100069553249787/posts/849587697369664/?_rdr.

315 "HU's Geospatial Technology Center awarded more than $660K grant" Harrisburg University, accessed June 19, 2025, https://www.harrisburgu.edu/news/geospatial-technology-center-awarded-grant/

316 Center for Applied Environmental & Geospatial technology, Portfolio: Mine Mapping Grant, Harrisburgu.edu, accessed June 25, 2025, https://centers.harrisburgu.edu/CAEGT/portfolio/

317 Center for Applied Environmental & Geospatial technology, Keith Previc DEP Testimony, Harrisburgu.edu, accessed June 25, 2025, https://centers.harrisburgu.edu/CAEGT/testimonials/

318 EPCAMR, "3D Mine Pool Mapping," June 2, 2025, https://epcamr.org/home/current-initiatives/technical-assistance/watershed-assessment/mine-pool-mapping-initiative/.

in this region.[319] One such example is the Old Forge borehole, below Scranton which emits an estimated 61 million gallons of AMD a day into the Lackawanna River.[320]

EPCAMR's research has suggested that in the Northeast region of Pennsylvania, the deeper the water, the worse quality it has. To understand local mine pool characteristics at different depths, researchers would need to take samples. EPCAMR has also mapped the complex nature of how seemingly distinct mines are hydraulically connected. The report also offered a prognosis of potential mine pool sites: Brookside mine in the southern anthracite mine field and the West End mine pools were identified to be the safest projects to use for mine pool manipulation because they were below state game lands and had few residential structures nearby.[321]

Alternatively, the Scranton Metropolitan mine pool was estimated to contain 134 billion gallons of water and is considered one of the most difficult for geothermal mine pool purposes, because of the buildings above it and previous subsidence risk.[322] However, these criteria were not established with mine water energy systems in mind when proximity to heat demand is a possible benefit.

Case Study on Feasibility of Mine Water Energy Systems in the UK

The United Kingdom demonstrates the possibilities of using GIS mapping software when determining the feasibility of mine water energy systems. When UK's mining industry was ceased, all remaining mine operators had to turn over maps to the government. At first these maps were used for creating AMD treatment centers. Eventually, these maps found a new useful life as planning tools for mine water geo-exchange systems. These interactive website applications generate interest from potential business partners and determine a broad compatibility of a location and mine-water heat. Overall, these efforts demonstrate what is possible and what a desirable end goal for Pennsylvania mine mapping initiative might look like.

Work conducted by the Mining Remediation Authority (MRA) has helped highlight efforts within the United Kingdom to adopt mine water geo-exchange systems. The organization makes technical documents and maps publicly available which include guidelines for accessing the sites' general suitability for a mine-water system. The MRA provides the public with open access to data

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[319] Robert E Hughes and Michael A Hewitt, "Mosaics, Maps, and Multi-Colliery Hydrogeologic Units: EPCAMR's Efforts to Advance Mine Pool Mapping Models to Address AMD Throughout the Anthracite Region," Presenters (Lewisburg, PA, June 4, 2025), https://static1.squarespace.com/static/61803b18879f384941cdda36/t/68505e68ce63c4135420571e/1750097520886/Hewitt-Hughes+Beneficial+Use+of+Mine+Pools+as+Resources+EPCAMR.pdf.

[320] Lackawanna River Conservation Association, "History of the Lackawanna River," accessed August 4, 2025, https://lrca.org/history.

[321] Michael A. Hewitt and Robert E. Hughes, "Anthracite Mine Pool Mapping for the Southern and Northern Coal Fields," *EPCAMR*, June 2014, https://www.epcamr.org/storage/projects/MinePoolMapping/Northern_&_Southern_Report/NORTHERN_&%20_SOUTHERN_MINE_POOL_REPORT_Final3.pdf.

[322] Hewitt and Hughes, "Anthracite Mine Pool Mapping for the Southern and Northern Coal Fields."

from the MRA has helped generate interest in mine water heat. The organization offers high level screenings for interested parties based on variables including the depth to mine water, suitability of workings, and temperature. So far, they have produced a series of reports on ten cities in Wales and England.[323]

The MRA has partners and a dedicated staff to assist stakeholders in high level feasibility assessments. The MRA offers consultation teams to assist operators with construction or rehabilitation of boreholes. They also have licensing and permitting teams. Overall, the MRA primarily works on advisory services, paperwork, and testing to aid those seeking high levels of screening for potential sites.[324] A flow chart of the processes used by MRA in its evaluation process is included in Appendix D.

In one such document, Mine Water Opportunities Maps for Wales, a number of variables that determine ranking are examined. Currently, the MRA ranks sites by favorability as either 'good', 'possible', 'challenging', or 'no opportunities'. The rankings provide a form of feasibility screening that can show whether further investigation of a site should be performed.

In the MRA's scoring process, there are a few absolute necessities to establishing a mine water system. First, there must be mine workings present near a site, a system of holes in the ground where coal has been removed.[325] Second, the mine must be flooded. Another factor is depth, as mines with seams less than 100 feet below ground level are not considered unless they are only being drilled through to obtain a deeper target.[326] Frequently, the mines selected are newer and may have more accurate and better-preserved documentation than shallower mines which were created long ago. Selecting a proper site can be difficult since the newer mines with the best maps and information about their operations are typically deeper. However, the deeper the mine, the more costly and potentially complex it may be to drill to a target far underground.

The water levels within a mine are a major factor in determining its potential for geo-exchange. The depth of the water has a bearing on the cost of pumping it to the surface, as it requires more energy. Additionally, whether the water level is static and has reached its maximum level or will rise further in the future also influences the decision-making process as this can be a sign that gas is present within a mine.[327]

The structure of the mine also plays an important part in determining its suitability for geo-exchange. For example, overlapping coal seams is a characteristic of a promising site because the MRA is looking for one area to draw water from and another area to reinject it. While single-seam mines that are at least 100 feet below the ground may be workable, such sites are not considered preferential.[328] Similarly, pit mines are challenging to adapt because the coal seams have often

[323] Gareth Farr and Mining Remediation Authority, "Mine Water Heat Opportunities," Webinar (U.K.) February 13, 2025, https://www.youtube.com/watch?v=8m6Pk5aQMq0.
[324]Joanne Eynon and Mining Remediation Authority, "Facilitating Mine Water Heat Schemes Through Access Agreements" Webinar. (UK) February 13, 2025, https://www.youtube.com/watch?v=iWEzm92ZKUQ.
[325] The Coal Authority. "Mine Water Heat Opportunity Maps for Wales: User Guide and Methodology." *Gov.Wales*, July 2024, https://www.gov.wales/mine-water-heat-opportunity-maps-background-and-guidance.
[326] The Coal Authority, "Mine Water Heat Opportunity Maps for Wales: User Guide and Methodology."
[327] The Coal Authority, "Mine Water Heat Opportunity Maps for Wales: User Guide and Methodology."
[328] The Coal Authority, "Mine Water Heat Opportunity Maps for Wales: User Guide and Methodology."

collapsed as part of the mining process.[329] Accordingly, many existing mine water systems use "room and pillar" mines.

In a best case scenario proposed by the MRA, a site would have mine workings at multiple overlapping coal seams that are flooded and approximately 100 to 1,000 feet below ground level.[330] At least one seam should have a water level which is not more than 250 feet below ground level. Meanwhile, mine water sites that are ranked as 'possible' are areas which contain clear obstacles to development. Like good scenarios, these sites may possess multiple flooded overlapping seams. The primary difference is that the depth of the workings and water levels may not be optimal. For example, such sites might include scenarios where mine workings are located deeper but still less than 1,600 feet below ground level. Alternatively, a possible mine might have water levels between 250-330 feet deep or which contain deeper waters that are still rising. Lastly, pit mines which have not collapsed and still have flooded voids that are between 100 and 1,600 feet deep may also be considered as possible sites. The MRA recommends reevaluating mines ranked as possible every two years to determine if conditions within the mine have changed.

The lowest category rated by the MRA is 'challenging,' which is considered unfavorable. These sites include situations where any of a range of conditions might be present including mine workings that are not flooded, those that are too shallow (98 feet below ground) or are too deep (more than 1,640 feet). The ranking also includes water levels that are deeper than 328 feet that have completely recovered. Finally, this classification involves all single seam locations that otherwise meet the necessary depth and water level requirements.

Ultimately, this set of criteria are only the beginning of the process for creating a mine water geo-exchange system in the UK. 'Good' or 'possible' candidates will need to conduct a full feasibility study as part of the next stage of review. This includes criteria such as:

- Presence of a mine water treatment system: pumping water is not allowed to interfere with cleaning polluted mine waters,
- Locations with inconsistent water levels and depths based on local topography,
- Geological features such as openings in the ground that lead to more costly and complex drilling and have a bearing on hydrogeology,
- Age and type of mine workings,
- Gas risk assessment,
- Mine water chemistry that is site specific and variable,
- The amount of risk a developer is willing to undertake,
- Heating and cooling demands of the area that dictate value of the proposed system.[331]

Government ownership of coal mining assets helps to simplify the process of establishing mine water energy within the UK. In the country's regulatory context, a mine water energy system requires both short-term permits and an access agreement providing long term permission. Accordingly, 12-month permits are obtained by an organization for drilling, water level

[329] The Coal Authority, "Mine Water Heat Opportunity Maps for Wales: User Guide and Methodology."
[330] The Coal Authority, "Mine Water Heat Opportunity Maps for Wales: User Guide and Methodology."
[331] The Coal Authority, "Mine Water Heat Opportunity Maps for Wales: User Guide and Methodology."

monitoring, water sampling and mine gas monitoring.[332] Meanwhile access agreements are long-term permissions that are required for system testing and for the operation of such systems.

Examples of when the UK has determined access agreements are needed include pumping water to study the abstraction and discharge rates.[333] These access agreements are transferable to operational phases. Other needed permissions are required from environmental regulators, local planning authorities, and verification that the operator has legal access to the surface where the mine water system will be installed. When applying for access agreements the MRA asks for project information such as the identity of the applicant, details about the surface of the proposed site, and which contractors and drillers would perform the work. The MRA also reviews any technical information on the mine's condition to determine risk to the public. Factors that may impede a project include mine gas, low or high water levels, certain types of water chemistry, ground instability, and whether the mine workings flood to the surface.

Other typical details collected include:

- The rate of water being drawn by the system and from where,
- The rate of water being reinjected into the mine and where,
- The hydrogeological balance of the two locations along with demonstrated pathways between abstract and discharge,
- Water conditions within the mine such as how the water travels underground in the mine, whether it is rising, and levels of gas,
- Monitoring the framework of how owners would oversee their mine water system.

Mine water heat projects require applications to the MRA before testing and before entering the operational phases. This process can take over two years from start to finish. Additional information about the UK application process for mine water energy systems can be found in Appendix E. Unlike the U.K., Pennsylvania does not legally own the abandoned mines located in the state. More about this can be found in a legal review of mine water resources found later in the report. However, the details of the MRA's mine water program demonstrate how a government agency, such as DEP, could establish a review process for evaluating possible sites for mine water systems within Pennsylvania.

West Virginia Feasibility Efforts

Back in the U.S., many states do not have comprehensive inventories of their mine maps. West Virigina, which shares some geological similarities to Pennsylvania due to its close proximity and shared coal mining heritage, has conducted extensive work to learn about their state's geography. The West Virginia Geological and Economic Survey (WVGES) efforts to map the mines and coal seams has been a long effort. What was projected to be a five-year project has

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[332] Joanne Eynon and Mining Remediation Authority, "Facilitating Mine Water Heat Schemes Through Access Agreements" Webinar. (UK) February 13th, 2025, https://www.youtube.com/watch?v=iWEzm92ZKUQ.
[333] Eynon and Mining Remediation Authority, "Facilitating Mine Water Heat Schemes Through Access Agreements."

lasted for 31 years. Currently, the WVGES has identified 117 named coal seams and mapped 86 of them.[334]

In the early stage of the project, one barrier to mapping was the limitations of the confidential structure of private mines. Work progressed more smoothly after agreements were reached to keep mine owners' proprietary information confidential. Today, West Virginia releases much of the information free through online portals like its interactive coal analysis database and other mine information.[335] Of note, it was found that coal in different parts of the state had different characteristics. Northern coal is younger and higher in sulfur; the southern field contains older seams that are lower in sulfur. Water from the southern seams is of such quality that it is a potable water source for municipalities and cities, or to raise trout in. West Virginia has also created a mine pool atlas that details the locations and necessary characteristics needed to begin the assessment. It has been estimated that the Pittsburgh Coal Seam contains 1.36 trillion gallons of water.[336] While the West Virginia Office of Energy has determined that the geography within the state is incompatible with pumped storage hydroelectric systems, it periodically reviews potential sites for mine water heating and cooling.[337]

The mines in West Virginia are often between 55°F and 58°F, which is adequate to operate a heat pump system economically. Such mines are close to the surface but can contain huge reservoirs of water. Many of their mines span across multiple coal seams and close to industrial and government facilities.

Representatives from the WVGES maintain that they are not engineers but provide a high-level screening services for mine water feasibility within the state and can help determine whether a particular location may be suitable. Over time, WVGES has created a process for evaluating a location to estimate initial compatibility for mine water. First, the organization collects relevant criteria about the mine including what seams it connects to, available maps, depth, flooded status, estimated storage capacity, assumed acidity, and the type of mine.[338] It also learns about the proximity to potential customers. Currently, WVGES uses criteria to select the most promising candidates. Among the characteristics examined are:

- Whether the estimated volume is over 100 million gallons of storage;
- Located more than 250 feet from an outcrop and below drainage;
- Feature no down dip portals;
- The presence of structural contours such as dipping, rolling structure, and whether the mine is anticline or syncline;

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[334] James Britton, "Assessing Mine Pool Geothermal Potential in West Virginia Using the WVGS Coal Bed Mapping Project (CBMP) Database," Presentation, *Shamokin Creed.Org* (Lewisburg, PA, June 4, 2025), https://www.shamokincreek.org/s/Britton-Mine-Pool-Geothermal-Potential.pdf.
[335] West Viriginia Geological & Economic Survey, "Interactive Mapping," accessed July 30, 2025, http://ims.wvgs.wvnet.edu/.
[336] Michael C. Korb, "Minepool Geothermal in Pennsylvania."
[337] Britton, "Assessing Mine Pool Geothermal Potential in West Virginia Using the WVGS Coal Bed Mapping Project (CBMP) Database."
[338] Britton, "Assessing Mine Pool Geothermal Potential in West Virginia Using the WVGS Coal Bed Mapping Project (CBMP) Database."

- Availability of high-quality maps;
- Hydraulic isolation from other mines.[339]

During this screening process, WVGES staff compares various types of imaging to learn about surface structures and overburden. While this process is currently labor intensive, one day the task may be possible to automate. WVGES have also worked to create a GIS program to calculate water storage based on the thickness of the seam. The WVGES created a map for schools within one mile of a mine pool. So far, several sites have been evaluated, and each one has encountered a barrier that did not allow a mine water project to proceed. For example, one academy would need a closed loop system because the mine water serves as the school's water supply. Another high school is located near a mine determined to be too deep. WVGES has created 15 reports based on requests. To date, none of these efforts have progressed beyond initial review.

A 2022 Marshall University study sought to identify potential participants within the state that would be suitable candidates for using mine pool water for climate control. As part of the feasibility scenarios researchers collected facility-level energy consumption information for the purpose of calculating potential energy savings when mine water is incorporated into heating and cooling systems. The Marshall study also examined methods of calculating energy savings.[340]

Potential Sites for Mine Water Energy Systems Within the Commonwealth

Increasing public awareness and determining appropriate site selection are two of the largest obstacles to raising the prominence of mine water geothermal within Pennsylvania. Unfortunately, a full regional review, such as performed by the UK or even the type of screening done by West Virignia Geological and Economic Survey, was not possible within the scope of this report. However, JSGC staff reviewed data from the DEP sites with AML points discharging mine water and used mapping software to draw the distances between these waters and available infrastructure locations. Table 10 summarizes the information below, identifying 382 sites located within one mile of mine waters. A complete listing of such buildings can be found in Appendix F of this report. Unsurprisingly, concentrations of public buildings near mines are highest in the southwest and northeast regions of the state where coal mining was the predominant industry. While it is likely that some or possibly most of these sites would be unsuitable for siting a mine water system, such information could be a starting point for discussions concerning where mine water energy systems might be located within the state.

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[339] Britton, "Assessing Mine Pool Geothermal Potential in West Virginia Using the WVGS Coal Bed Mapping Project (CBMP) Database."

[340] Risch, Christine, Andrew Nichols, Mehdi Esmaeilpour, Begley, Richard Begley and Sinaya Dayan. "Mine Pool Geothermal Resources – Phase 1 Engineering Study" (Center for Business & Economic Research, Marshall University, West Virginia, 2022) 2.

It may be advantageous that mine pool geothermal sites are adjacent rather than directly above a mine pool because of subsidence. The farther away it is, however, the less cost effective the technology will be.[341] After a potential location is identified, there must be a siting criterion established, a water chemistry analysis, and consideration of possible effects on surrounding layers of earth. Other potential sites could include record archival facilities, warehouses, and indoor agricultural producers, which could benefit from constant temps.

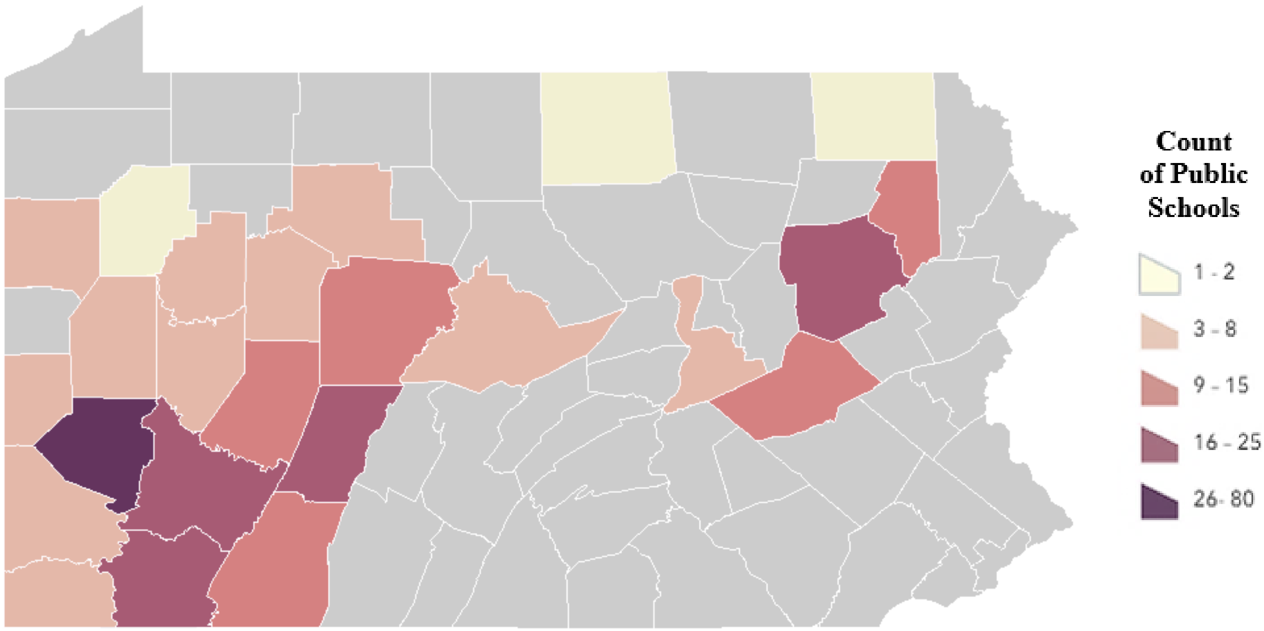
Table 10
Infrastructure Within One Mile of Mine Water Sources by County
Pennsylvania
2025

Counties	School	Higher Education	Hospital	Museum	Corrections	Total
Allegheny	80	6	7	13	1	107
Armstrong	4	--	--	1	--	5
Beaver	5	--	2	1	--	8
Butler	4	1	--	--	--	4
Cambria	25	4	3	3	--	35
Carbon	--	--	--	1	1	2
Centre	3	--	--	--	--	3
Clarion	8	1	1	--	1	11
Clearfield	15	1	1	1	1	19
Elk	3	--	1	--	--	4
Fayette	21	1	1	4	2	29
Greene	3	--	--	--	--	3
Indiana	9	--	--	--	--	9
Jefferson	3	--	--	--	--	3
Lackawanna	14	4	2	4	1	25
Luzerne	25	1	3	--	2	31
Mercer	4	1	1	--	--	6
Northumberland	7	--	--	1	1	8
Schuylkill	13	2	2	--	2	19
Somerset	12	--	1	--	1	14
Susquehanna	2	--	--	--	--	2
Tioga	1	--	--	--	--	1
Venango	1	--	--	--	--	1
Washington	6	--	1	--	--	7
Westmoreland	20	2	2	--	--	24
Grand total	288	24	28	29	13	382

Source: JSGC, DEP AML data.

[341] Kowalski, Kathiann "Ohio Geologists study potential for geothermal in abandoned coal mines" Energy News Network February 9, 2021.

Map 6
Public Schools within One Mile of Mine Water Sources
Pennsylvania
2025



Source: DEP Data, JSGC Spatial Analysis.

Geothermal Mine Mapping Proposal

Commission staff consulted with the Department of Conservation and Natural Resources Bureau of Geological Survey to estimate the amount of work necessary for conducting a statewide analysis of mine pools for suitable geothermal use. DNCR identified three critical components to the task:

1. Regional coal seam maps – These are maps of elevation (depth) and thickness of coal seams which allow the mine maps to be positioned properly in 3D space. Existing coal seam maps are spotty and any digital datasets are in outdated formats. Geologists would compile information on coal seam depth from available sources, make correlations within and between seams, and produce preliminary maps for individual mined coal seams.

2. Regional water table maps – Hydrogeologists will compile information on depth to water and subsurface geology. They will use that information to model the elevation of regional water tables.

3. GIS Analysis
   - Map preparation – Compiling and digitizing mine maps, creating final GIS datasets for mine maps, coal seam maps, and water table maps.
   - Mine pool analysis – Overlaying mine maps and water table maps in 3D space to identify flooded mines and calculate mine pool volumes.

One of the important questions answered during this process is figuring out whether mines are flooded. Detecting whether a mine is flooded is not immediately apparent. First, GIS maps of mines with elevation are created, followed by a model of the water table elevation.[342] Superimposing these data layers allows mappers to determine which parts of the mine are above a water table. In many instances it is a safe assumption that mines below a water table will be flooded, that those intersecting with the water table will be partially flooded, and those above the water table will be dry.[343]

When asked about the suitability of using Bureau of Geological Survey resources to conduct analysis of mines for the suitability of geothermal systems, representatives from the Bureau noted their commitments to other DCNR priorities and that additional contracted staff and appropriations would be needed to undertake this assignment.[344] It was estimated that the most efficient way to create such an analysis would be by employing the expertise of two geologists, two hydrogeologists and two GIS specialists.[345] It was recommend that if these staff were divided into two teams that they could release feasibility reports by region as interim products over the course of a five year duration. It was estimated that the project would cost $500,000 over the five year term of the project.[346] It was suggested that this approach could be extended to inventory the suitability for non-fuel mines containing mine pools within the state that could also be useful resources such as limestone mines, which have been reviewed as a possible resource for cooling data centers.

While mine pool-related energy systems hold promise for areas that contain all of the prerequisite elements detailed in the previous chapters such as flooded mines at the correct depth, within close proximity to heating demand, it is highly probable that the majority of the areas examined by such a surveying effort would lack one or more of these elements. However, conducting this project may contribute to other efforts already undertaken by the Commonwealth including:[347]

- Advancing the Bureau of Geological Survey's goal to produce a 3D geologic model of the state by 2030. This work directly contributes to that goal.
- Understanding competing uses of the subsurface either active or under consideration (e.g., oil and gas production, coal mining, gas storage, carbon storage, hydrogen, geothermal). 3D maps of coal seams and coal mines are important to evaluating appropriate subsurface activities.
- Pressure on Pennsylvania's groundwater resources will only increase over the coming decades. Regional water table maps would be a major contribution to understanding our groundwater.

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342 Gale Blackmer, e-mail message to Commission Staff, May 5, 2025.
343 Gale Blackmer, e-mail message to Commission Staff, May 5, 2025.
344 Gale Blackmer, virtual meeting with Commission Staff, April 16, 2025.
345 Gale Blackmer, e-mail message to Commission Staff, May 21, 2025.
346 Gale Blackmer e-mail message to Commission Staff, May 21, 2025.
347 Gale Blackmer e-mail message to Commission Staff, May 21 2025.

Overall, mine pools can be important for reasons other than geothermal systems. Inventorying the state's mines and mine pools may be a tool that supports a variety of the Commonwealth's objectives.

Best Practices for Mine Water Energy Development

Obstacles to Development

A 2023 review by the USDOE identified many barriers associated with mine water energy systems shown in past studies. Most barriers revolve around issues of designing, permitting, buildings, and operating mine water systems including:

- Extensive site-specific engineering design requirements,
- Economic modeling,
- Management of water chemistry,
- Licensing and permitting,
- Long term sustainability of the system.[348]

Other researchers have identified issues as road blocks to success, such as finding the right expertise and financing, navigating regulations, and generating local interest.[349] It has been suggested that mine pools have not been successful within Pennsylvania because a lack of knowledge about heat pumps and mine pools, a tendency for mines to be located in economically depressed areas that lack necessary investment funds, and stigma against mining.[350]

The USDOE review also noted many of the best practices of successful mine water systems:

- Characterization of mine water chemistry is critical to ensure that problems such as scaling, clogging, and corrosion do not occur.[351]

- It is important to understand the hydrology of the mine and surrounding area, and to conduct thermal-hydrologic-chemical modeling studies to identify potential technical issues to properly evaluate the resource and reduce operational risks[352]

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348 Dobson, Patrick, Gasperikova, Erika, Borglin, Sharon, et al., "U.S. DOE Clean Energy Demonstration Program on Current and Former Mine Land – A Review of Geothermal Energy Case Studies and Opportunities," (2023).
349 Nicolas Maennling and Perrine Toledano, "The Renewable Power of the Mine," SSRN Electronic Journal, January 1, 2018, https://doi.org/10.2139/ssrn.3661616.
350 Michael C. Korb, "Minepool Geothermal in Pennsylvania," 14.
351 David B. Walls et al., "A Review of the Performance of Minewater Heating and Cooling Systems," Energies 14, no. 19 (September 29, 2021): 6215, https://doi.org/10.3390/en14196215.
352 Preene, M., and P. L. Younger. "Can you take the heat?–Geothermal energy in mining." Mining Technology 123, no. 2 (2014): 107-118.

- The condition of the underground workings of abandoned mines may be uncertain, as these features may undergo structural changes after closure.[353]

- Meeting permitting and regulatory requirements on mine land may take significant time and effort, given the complex legal and environmental issues associated with mine land.[354]

- The economics of direct use projects will depend not only on the quality and size of the geothermal resource, but also on the proximity and need for heating, cooling, and/or thermal energy storage near the mine land site.[355]

While many of the case studies and research projects have investigated the thermal potential of abandoned mines, mine water energy systems could also be employed at active sites by the mining industry. Active mines routinely pump water to avoid flooding, and heat pumps added to these systems could allow active mines to replace the heating and cooling needs associated with mining such as in administrative areas. A 2015 study found that mining operations that utilized heat pumps saved approximately $1.17 million a year (USD) and avoided 18.8 tons of released CO2.[356]

UK Mine Water Data Collection

Much of the recent information known about mine water energy systems has come out of the UK as the MRA has focused on promotion, transparency, and data collection related to the technology. Researchers consider each new borehole as an opportunity to collect more data, effectively making it easier to understand the conditions within the mine.[357] While the UK mines are sealed so humans cannot physically enter the underground space, the instrumentation on either the inside or the outside of the casing of the borehole enables large amounts of data to be retrieved. Inside the casing of the boreholes, instrumentation determines the level and the temperature of the water as well as its thermal conductivity. Additional instrumentation on the outside of deep mine casings includes fiber optic cables, temperature gauges and piezometers, a type of instrument which measures water pressure. Scientists examine the fluid between the rocks as well as the pore geometry using borehole magnetic resonance surveys.

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353 Walls et al., "A Review of the Performance of Minewater Heating and Cooling Systems."
354 Walls et al., "A Review of the Performance of Minewater Heating and Cooling Systems."
355 Javier Menéndez et al., "Feasibility Analysis of Using Mine Water From Abandoned Coal Mines in Spain for Heating and Cooling of Buildings," Renewable Energy 146 (July 10, 2019): 1166–76, https://doi.org/10.1016/j.renene.2019.07.054.
356 Lena Patsa et al., "Geothermal Energy in Mining Developments: Synergies and Opportunities Throughout a Mine's Operational Life Cycle" (Melbourne, Australia, April 2015), https://www.researchgate.net/publication/269395965_Geothermal_Energy_in_Mining_Developments_Synergies_and_Opportunities_Throughout_a_Mine's_Operational_Life_Cycle; and JSGC conversion of currency.
357 Fiona Todd and Mining Remediation Authority, "Research and Development in Mine Water Heat," Webinar (UK) February 13th, 2025. https://www.youtube.com/watch?v=m8chfDjtcBo.

To learn more about mine water geothermal systems, the MRA is sponsoring academic research on the subject of open loop mine pool geothermal energy with the goal to develop evidence-based decision making regarding mine water energy systems.[358] One of the complications is understanding the interactions between mine water heat projects drawing from the same mine pool.[359] Better understanding this geohydrology could help drive wider adaptation, which is one reason the MRA sponsors the Living Lab launched in January 2025 at Gateshead to study interaction between geothermal heat systems. Similarly, the mine energy observatory in Glasgow, Scotland, developed by the British Geological Survey in 2020, is another location studying mine water. There, the British Geological Survey has two at-scale demonstrations, one for shallow geothermal technologies and one examining underground thermal energy storage. While observing the mine water at such locations, researchers have noted changes of water level within a mine when they are injecting water.[360] There is also significant variation in temperature gradient that differs throughout the UK.

The MRA presents much of its research through an online portal that is accessible to the public. The portal features information on mine water heat systems such as the equilibrium and pumped temperatures, the locations of discharges, and monitoring points. One of the reasons this system is so transparent is it was part of a grant to make data more accessible and included internal and external stakeholder reviews when the system was designed.[361] Another part of this process was to conduct surveys to estimate demand near abandoned coals mines.

There are many lessons that could be learned from the UK, such as more detailed monitoring of Pennsylvania mine pool temperatures at various depths to help understand the practicality of mine water systems. If new mine water pilot programs are attempted in Pennsylvania, the creation of observational laboratories may help study such systems. Online portals and user engagement initiatives could help design systems around information that matters to the public and make it easier for them to access.

Construction Best Practices

Recent UK research has offered lessons from the implementation of mine water geo-exchange systems. Crucially, the appropriate experts must be consulted if a system is to perform as desired, but gathering the correct group of people can be challenging because of the relative rarity of this type of energy system. One of the difficulties in areas of the world where mining has been phased out is in gathering the input of those knowledgeable about the area. While so-called green energy systems may have different goals, the similarities behind the resource extraction methods remain. While the need for mining and engineering expertise is needed during the drilling phase so that optimal mine areas are accessed, other types of experts are needed to design such systems.[362] "Hydrogeologists should be involved in design of mine water geothermal schemes to

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358 Fiona Todd and Mining Remediation Authority, "Research and Development in Mine Water Heat."
359 Fiona Todd and Mining Remediation Authority, "Research and Development in Mine Water Heat."
360 Fiona Todd and Mining Remediation Authority, "Research and Development in Mine Water Heat."
361 Fiona Todd and Mining Remediation Authority, "Research and Development in Mine Water Heat."
362 Walls et al., "A Review of the Performance of Minewater Heating and Cooling Systems." 18.

avoid issues of well interference and avoid unrealistic expectations of yield."[363] If experienced groundwater engineers are consulted it can lead to more successful outcomes and a higher quality of system.

One way to determine if a site has the necessary conditions, is to drill a hole down to the water and collect data on temperature, basic chemistry, electrical conductivity, and heat with appropriate frequency, precision, and resolution.[364] When working from old mine plans, it may be unreasonable to expect to hit the targeted area of the mine on the first attempt. UK examples demonstrate it can take two to three attempts when drilling into a pillar to access the mine. It was also noted that it can be challenging to predict behavior of mined aquifer before drilling and testing.[365] To some extent, risk and uncertainty are part of these designs; some problems, however, can be anticipated. When possible, it is preferable to avoid mines with exposed or open sections as air and water mixing together is more likely to lead to iron oxidation (rust) that can clog a system.[366]

Construction materials of the well, pipeline, sensors, and heat exchangers must be appropriate to the mine water in question. While traditional open-loop geothermal systems are recommended to be used with clear water, in a mine water system this is not always possible. Scaling and clogging of the systems are common. However, some issues with mine water systems can be prevented by monitoring conditions within the mine such as a loss of pressure in the system. Despite efforts, mine water geothermal systems can be charactered as high maintenance and may need the following actions:

- Emptying and washing filters,
- Chemical flushing of heat exchangers and pipelines,
- Replacement and calibration of sensors,
- Work on boreholes to maintain necessary pressure.[367]

A downside of the maintenance necessary for a mine water energy system, is it may limit adoption to those with the expertise and funding to sustain them. Larger mine-water geothermal systems who sell heat to buyers or have high maintenance budgets may be preferable. [368]

One of the crucial tasks when creating a mine water system is creating access to the mine pool, first to gather information and later as part of the production or resource well. A recent UK study analyzed 564 boreholes across Great Britain to assess the accuracy of drilling into mine voids.[369] The result was much higher than conventional wisdom in the mining industry had led officials to

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[363] Banks, David et al. "Conceptual Modelling of Two Large-Scale Mine Water Geothermal Energy Schemes: Felling, Gateshead, UK." *International journal of environmental research and public health* vol. 19, 3 1643. January 31, 2022, doi:10.3390/ijerph19031643.
[364] Walls et al., "A Review of the Performance of Minewater Heating and Cooling Systems." 4.
[365] Walls et al., "A Review of the Performance of Minewater Heating and Cooling Systems." 17.
[366] Walls et al., "A Review of the Performance of Minewater Heating and Cooling Systems." 22.
[367] Walls et al., "A Review of the Performance of Minewater Heating and Cooling Systems," 25.
[368] Walls et al., "A Review of the Performance of Minewater Heating and Cooling Systems," 25.
[369] L.M. Wyatt et al., "Drilling Into Coal Mine Workings; Overview and Experience From Britain's Coalfields," Quarterly Journal of Engineering Geology and Hydrogeology 58, no. 3 (June 2025), 2 https://doi.org/10.1144/qjegh2025-016,

believe. Approximately 75 percent of attempts to drill down hit mine voids, which were higher than the assumed success rates or those documented in prior studies.[370]

The rate of success depends on the characteristics of the target. Boreholes designed to hit underground roadways succeed 77 percent of the time.[371] The study also noted that 85 percent of these boreholes were suitable for their original intended purpose, which is useful given that some shafts within the ground degrade over time. Success was linked to selecting an appropriate target and having proper planning and design. Conversely, failure attempts were sometimes linked to failures in the design or construction phases.

Paradoxically, deeper mine targets can be easier to hit than shallow ones, 97 percent compared to 66 percent.[372] This is because newer mines are deeper and have better documentation that can be used as guidance when drilling into a mine. The study noted other insights like boreholes designed to monitor mine water do not need to target mine voids or workings. [373] There are many possible risks that could lead to failure include: inaccurate mine plans, a poor target is chosen underground partly because it may be the only target available on the site.

For example, incomplete information may lead to engineers designing the wrong type of borehole, while improper assessment of mining hydrogeology can result in a dry borehole or a depleted water body. Errors during the construction can include the drill deviating from their expected target and missing, hitting parts of the mine that were unintended, a lack of experience drilling into mines, and incorrect construction of the well casing.

Economic Impact Analysis

Examining the cost of a mine water system can be difficult to generalize due to factors relating to size of the system and site conditions. In 2021, West Virigina identified the cost of existing mine water energy systems as between \$150,000 to \$750,000 with an average estimated payback time of 5.3 years for a combined heating and cooling system.[374]

There are programs within the state which could be used to fund geothermal systems. Rise PA is a \$396 million statewide decarbonization grant program. The program has several tracks aimed at different sizes of businesses. In the small- to mid-sized track manufacturers with under 500 employees that undertake projects between \$50,000 - \$1,000,000 can receive grants up to 50 percent of the project cost. Medium and large-scale tracks are also offered at higher amounts. The award tracks are summarized in Table 11.

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[370] Wyatt et al., "Drilling Into Coal Mine Workings; Overview and Experience From Britain's Coalfields," 12.
[371] Wyatt et al., "Drilling Into Coal Mine Workings; Overview and Experience From Britain's Coalfields," 12.
[372] Wyatt et al., "Drilling Into Coal Mine Workings; Overview and Experience From Britain's Coalfields," 12.
[373] Wyatt et al., "Drilling Into Coal Mine Workings; Overview and Experience From Britain's Coalfields," 12.
[374] Christine Risch and William Sheils, "Mine Pool Geothermal: Opportunities in West Virginia," Marshall University Center for Business and Economic Research, September 2021, https://www.marshall.edu/cber/files/2021/11/2021_09_Minepool_Geothermal_Opportunities_in_WV.pdf.

Table 11
Funding Amounts for RISE PA Award Tracks
2025

Award Track	Total Funding	Base Grant Percentage	Minimum Single Base Grant Award	Maximum Single Base Grant Award
Small-scale	$40,000,000	50%	$25,000	$74,999
			75,000	149,999
			150,000	500,000
Medium-scale	100,000,000	30	130,000	20,000,000
Large-scale	220,000,000	30	20,000,001	110,000,000

Source: PA DEP, "Rise PA Grant Program Guidance: Medium-and Large-Scale Award Track Applicants," *DEP Greenport*, January 2025, 2.

Eligible activities for the Rise PA program include technologies that reduce greenhouse gas and support electrification. The full program criteria are listed in "Rise PA Grant Program Guidance: Medium-And Large-Scale Award Track Applicants." Below are some of the criteria which may be the most applicable to geothermal technologies:

- Electrification technologies that could be used with geothermal like low carbon process heat, as well as heat pumps.[375]

- Energy efficient technologies such as thermal storage and industrial heat pumps are also listed.[376]

- The terms of the program would also ostensibly support on-site generation of renewable energy inclusive of geothermal electrical production through methods such as EGS, geothermal well reuse, or co-production generators.[377]

It is also likely that some applications using mine water energy systems could include abandoned mine land or brownfield remediation efforts which may increase the amount of tax credits available. Furthermore, the Community Benefit Bonus and Fair Labor Bonus can raise the amount of a grant awarded by 10 percent each. Medium and large scale projects could also apply for a six percent bonus for Greenhouse Gas Emission Reduction Bonus which is available for

[375] Pennsylvania Department of Environmental Protection, "Rise PA Grant Program Guidance: Medium-and Large-Scale Award Track Applicants," DEP Greenport, January 2025, 5, https://greenport.pa.gov/elibrary/GetDocument?docId=8926418&DocName=RISE%20PA%20GRANT%20PROGRAM%20GUIDANCE:%20MEDIUM-AND-LARGE-SCALE%20AWARD%20TRACK%20APPLICANTS.PDF.
[376] Pennsylvania Department of Environmental Protection, "Rise PA Grant Program Guidance: Medium-and Large-Scale Award Track Applicants," 6.
[377] Pennsylvania Department of Environmental Protection, "Rise PA Grant Program Guidance: Medium-and Large-Scale Award Track Applicants," 6.

projects which reduces annual greenhouse gas emissions by 20 percent.[378] This may be relevant to the heat pump-based projects and geothermal due to their proven track records of emission reduction.

Despite inclusive provisions noted above within the RISE PA program, geothermal electrical production may be an impossibility for small and medium businesses at this time due to the current cost of geothermal energy production and its level of maturity within Pennsylvania. Direct use geothermal systems which utilize hot water or steam may have the most potential in industrial applications at this scale, and such activity is not explicitly encouraged by this program. Similarly, geothermal heat pumps would not qualify as fuel switching under the current provisions when replacing existing carbon-based fuel sources. Amending the program to encourage the full spectrum of beneficial geothermal uses could increase its adoption within Pennsylvania.

Environmental Impacts of Mine Water Energy Systems

Mine water energy systems have unique needs when compared to other geothermal systems. Environmental effects of these systems have not been studied in detail, however previous mine water systems within the state have operated without incidents of mine water spilling or subsidence. It has been documented that pumping water within a mine can change the quality of the water.[379] The possible environmental effects would depend on the conditions with a particular mine pool. Many of the systems identified used heat exchangers paired with loops of clean water to avoid bringing mine water to the surface or putting strain on a heat pump. Reinjection wells were common in these systems designs, except in cases where the water was being treated for AMD. The less oxygen in a flooded mine, the lower the risk of rust. Site specific study is necessary to ensure that open-loop systems would not affect nearby groundwater.

Qualified engineers should be consulted when planning an open loop system near a mine to avoid sink holes. Mine pool researcher Andreana Madera-Martorell has stated that mine pool geothermal sites are best located adjacent rather than directly on top of a mine water pool to avoid subsidence. In Europe, satellite technologies have been pioneered as one way of detecting subsidence over time.[380]

Currently, DEP recommends closed-loop systems as one way to minimize potentially dangerous effects of geothermal.[381] DEP could determine what practices might be employed in open-loop versions of this technology could confer the most benefit in a cost-effective way while still protecting the environment.

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[378] Pennsylvania Department of Environmental Protection, "Rise PA Grant Program Guidance: Medium-and Large-Scale Award Track Applicants," 2.
[379] Kwon, Koo-Sang & Park, Youngyun & Yun, Sang & Lee, Jin-Yong. (2013). Environmental impacts of open loop geothermal system on groundwater.
[380] Han Claringbould et al., "A Pragmatic Approach to Monitoring Geohazards at Geothermal Operations," GRC Transactions 47 (2023), https://publications.mygeoenergynow.org/grc/1034781.pdf.
[381] Michael C. Korb, "Minepool Geothermal in Pennsylvania," 3.

State Funding Sources

Energy green banks are a highly recommended solution for geothermal systems as they help spread out the cost of development. In Pennsylvania, the Green Energy Loan Fund administered by the Energy Development Authority is one such program that could benefit geothermal projects. The loan amounts range from $100,000 to $2,500,000 and interest rates are typically between 3.5-4.5 percent.[382] Mine water systems seem compatible with the core mission of this program and could fulfill the requirements to reduce annual energy costs by 25 percent.

The Appalachian Regional Commission is another potential source of funding. Its 2024 annual strategy report lists projects that impact jobs, build out infrastructure, and create smart grids.[383] One of the goals of the program includes advancements of energy efficient infrastructure. There is a significant overlap between counties within this region and potential sites for mine pool geothermal. For example, this funding might be used to start a heat pump installation company.

Federal Funding Opportunities

At the time of this report, the U.S. Dept. of Energy provides a range of incentives and tax breaks that could be used in geothermal systems. While the future of federal investment in clean energy technologies is difficult to forecast because of a realignment of federal government priorities aimed at scaling back wind and solar initiatives, at this time initiatives to promote geothermal energy are still in effect.[384] As of July 2025, the Energy Infrastructure Reinvestment (EIR 1706) loan program has been retooled to support "Energy Dominance Financing," which aims to provide loan guarantees for energy projects which include:

- retool, repower, repurpose or replace energy infrastructure that has ceased operations;
- enable operating energy infrastructure to increase capacity or output; or
- support or enable the provision of known or forecastable electric supply at time intervals necessary to maintain or enhance grid reliability or other system adequacy needs.[385]

The Inflation Reduction Act included several incentives for geothermal technologies. Among these is a 30 percent Investment Tax Credit which explicitly called out geothermal heat pumps and direct use applications. [386] The program also details a 10 percent bonus tax credit for

[382] Reinvestment Fund, "Pennsylvania Green Energy Loan Fund — Reinvestment Fund," March 25, 2022, https://www.reinvestment.com/gelf/.
[383] PA Department of Community & Economic Development, "Appalachian Regional Commission (ARC)," July 10, 2025, https://dced.pa.gov/programs/appalachian-regional-commission-arc/.
[384] Jeremy Grossman, "Local Impacts From Congress' One, Big, Beautiful Bill," National League of Cities, July 14, 2025, https://www.nlc.org/article/2025/07/11/local-impacts-from-congress-one-big-beautiful-bill/.
[385] Hunton Andrews Kurth LLP, "Department of Energy Loan Guarantee Program Update: New Energy Dominance Financing Mechanism," Hunton Andrews Kurth, July 17, 2025, https://www.hunton.com/insights/legal/department-of-energy-loan-guarantee-program-update-new-energy-dominance-financing-mechanism.
[386] "Summary of Inflation Reduction Act Provisions Related to Renewable Energy," US EPA, January 28, 2025, https://www.epa.gov/green-power-markets/summary-inflation-reduction-act-provisions-related-renewable-energy.

energy communities, domestic material content, low-income areas.[387] The Renewable Electricity Production Tax Credit was also available, which may benefit electricity producing geothermal technologies, such as EGS, but not geothermal heat pumps. These programs were phased out and replaced by the Clean Electricity Investment Credit, which focuses on emission reduction with a technology-neutral approach. The Clean Electricity Investment Credit has a six percent base level that can be raised through meeting prevailing wage and apprenticeship requirements, domestic material content requirements, and siting facilities in an energy community.[388] This program will start to phase out in 2032. For residential heat pump systems, a 30 percent tax credit for geothermal heat pumps is also expiring December 31, 2025.[389] Other potential sources of federal funding that could be examined include the USDA Rural Energy for America program and the USDA Electric Infrastructure Loan and Guarantee Program.

Many of the mine water energy systems shown in this report were the result of investment in public funding across a variety of government levels. To date, many private companies seem unwilling to bear the potential liability and uncertainties regarding mine water energy systems. In the future, there may be potential for public-private partnership opportunities if these risks are mitigated.

Whether it makes sense to adopt a geothermal heat pump system can be a decision dependent on local energy costs. One study estimated that the cost of electricity, to be economical, must be less than natural gas divided by 3.33.[390] These conditions appear to be present in Pennsylvania.[391] Buildings which install solar panels can also be highly compatible with geothermal heating and cooling systems, as they supply electricity needed to power the systems during the day helping to lower the costs even further. The primary downsides of such a combined solar and geothermal system are higher upfront capital costs (if such systems are not being constructed in phases) and enough space on the roof or adjacent land would be needed to place the solar panels. Sealing the building may be important to prevent energy leaks, and determining the size of the proposed system needed to accurately meet energy needs is important.

Residential Building Scale

A mine water heating and cooling system is unlikely to be a viable solution for most individual homes. While the fundamentals of installing a GSHP are simple, such as a large drill to make a well, a heat exchanger, tubing, and a pump, executing the task can be difficult. The tradeoff for the systems simplicity in design is the complexity of the site-specific environmental needs. Differences in geology and water quality at each site means that it is unlikely that conditions present at each home could be accounted for. Furthermore, there is some evidence that multiple

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387 "Summary of Inflation Reduction Act Provisions Related to Renewable Energy," US EPA.

388 U.S. Internal Revenue Service, "Clean Electricity Investment Credit," May 29, 2025, https://www.irs.gov/credits-deductions/clean-electricity-investment-credit.

389 "What to Know About Expiring Energy Tax Credits," NAHB, July 10, 2025, https://www.nahb.org/blog/2025/07/expiring-energy-tax-credits.

390 Edward Peace Louie, "Writing A Community Guidebook for Evaluating Low-Grade Geothermal Energy from Flooded Underground Mines for Heating and Cooling Buildings" (2015), https://doi.org/10.37099/mtu.dc.etds/922.

391 JSGC Staff Calculations using data from US EIA, found that natural gas in PA was 3.6 times more expensive in April of 2025.

systems present in the same area risk interfering with each other.[392] Based on the current body of case studies available, it may be preferable for the Commonwealth to encourage the development of larger mine pool geothermal systems that serve large spaces or more than one building. However, this will require greater degrees of local planning and project coordination along with new development or retrofits.

For areas without mines, closed-loop geo-exchange should be considered on a case-by-case basis. For some homeowners ground source heat pumps will remain unaffordable as heating and cooling systems are frequently replaced upon failure of the previous system, often with in kind or with the most affordable option.[393] Depending on the economics of the project, available yard space, and homeowner needs, geo-exchange will not be the optimal choice.

Regardless of the type of system, there is currently no way to identify how many geothermal systems have been installed in homes across Pennsylvania. Creating a registry could help collect data on this subject and spread public awareness of geothermal heat pump adoption. Creating such a list improves the potential to incentivize the replacement of aging heating infrastructure with efficient heat pump technology where geographical opportunities permit.

Large Building Scale

Many of the geo-exchange systems identified by our case studies were larger buildings, such as those found in schools, industry warehouses, and hospitals. For example, Seattle schools who have adopted geo-exchange systems saved between 30-77 percent on annual energy uses.[394] It is probable that Pennsylvania schools with aging heating and cooling infrastructure could save money on operating costs by replacing these with more efficient systems. The following example is intended to demonstrate the potential cost savings of mine water energy systems, if they were to be adopted within Pennsylvania schools. For example, a 1,000-student high school is estimated to have 173,730 square feet of space on average. Such a school spends up to $149,500 a year on energy, 74 percent of which is tied to heating both the space and water within the building. [395] As noted earlier, a German school built in 1903 that installed a mine water energy system was able to reduce its annual energy output by 66.7 percent. In our example school, that would have annual savings of $99,716.

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[392] Alexandra Sweeney et al., "The Need to Regulate Thermal Interference Between Mine Water Geothermal Systems: A UK Perspective," *Quarterly Journal of Engineering Geology and Hydrogeology*, March 26, 2025, https://doi.org/10.1144/qjegh2024-185.
[393] Reid Frazier and The Allegheny Front, "In Pa., Heat Pumps Could Be a Climate Change Solution. But Contractors and Customers Would Need to Buy in," WITF, May 30, 2025, https://www.witf.org/2023/01/20/in-the-modest-heat-pump-a-climate-solution/.
[394] NREL (2025). Geothermal Heat Pump Case Study: Seattle Public Schools. National Renewable Energy Laboratory (NREL). https://www.nrel.gov/docs/fy25osti/91401.pdf.
[395] Colby Ezell, "Average School Electricity Bill: How Much Energy Do Schools Use?," P3 Cost Analysts, February 5, 2024, https://www.costanalysts.com/average-school-electric-bill/.

Using ArcGIS software, JSGC staff identified 24 counties that had at least one school within a mile of AML water sources. [396] In total, 288 schools were identified near mine waters, which is approximately nine percent of public schools in the state. In the bituminous region, Allegheny County had 80 schools within one mile of mine water sources, the largest in the state by far. Counties surrounding Allegheny also had many schools near mine water sources albeit at much lower levels. In the anthracite region, Luzerne County has 25 schools near mine water sources.

Based on the average energy cost savings of installing a geothermal system above in our example building, the Commonwealth could see a total annual savings of $28.7 million a year in energy costs if all sites adopted mine water systems. It is likely that many of the locations reviewed would be unsuitable for installing mine water systems for a variety of reasons. However, even if only five percent of the schools proved feasible with mine water energy systems, that could still save the Commonwealth $1.4 million annually for the next thirty years.

In actuality, the cost savings could be far different as Pennsylvania schools are a variety of sizes, and little is currently known about the heat capacity of the individual mine pools compared to the demand at a school. However, researchers have created tools to estimate mine pool capacity.[397] Once mine pool size is known, more accurate estimates of cost savings could be generated by reviewing the energy expenditures and facility records of the identified schools.

Additionally, as it is common for grades of school buildings to be located in close proximity, to each other, in some instances several buildings could potentially be served by the same mine water geothermal system if the mine pool were of sufficient size, which could lead to greater efficiencies. Geothermal heat pumps are considered a highly compatible technology with photovoltaic solar panels. If mine water energy systems or other types of heat pumps were combined with Pennsylvania's "Solar for Schools" grant program, even greater operational savings could likely be achieved.

One sobering caution is that to date, West Virigina's efforts to screen for the collocation of mine water heating and cooling and schools have not born fruit. However, they are still developing a screening process and have not yet exhausted many of the possibilities within their state. It is recommended that Pennsylvania collaborate with West Virginia to develop tools to better screen for mine water energy sites.

District Scale

Even Spring Hill in Nova Scotia, which has had mine water systems in place for decades has experienced difficulty in creating a district level system, possibility due to the necessary capital expenditures. This demonstrates that the presence of mine pools, the necessary practical knowledge, and experience with small scale implementations may not be enough to guarantee success at a larger district scale. Beyond Nova Scotia, further study of European projects may provide new insights into how to pursue the development of these technologies. The largest mine

[396] JSGC staff spatial analysis using DEP AML data, 2025.
[397] Edward Peace Louie, "Writing A Community Guidebook for Evaluating Low-Grade Geothermal Energy From Flooded Underground Mines for Heating And Cooling Buildings" (2015), https://doi.org/10.37099/mtu.dc.etds/922.

water systems identified in this review were UK's Gateshead. At this level geothermal may be better thought of as a sustainable development strategy than a cost-saving one.

Overall, Pennsylvania is likely many years away from implementing mine water energy at a district level. The most promising course of action could be to screen the largest cities and industrial sites near mine pools. Based on the actions taken in the UK, millions of dollars of public investment and decades of research may be needed before a project on the scale Gateshead could be replicated in Pennsylvania.

Energy Companies and Utilities

Similar to closed-loop geothermal systems, gas companies would need state authorization to sell heat created by mine water energy systems.[398] However, JSGC was unable to find evidence that any existing utility within the Commonwealth was actively pursuing this course of action. The cities of Wilkes-Barre and Scranton once pursued a mine water district heat system, which never materialized.[399] Philadelphia Gas Works examined a geothermal network; however it is still pursuing feasibility studies rather than a pilot. Overall, Pennsylvania is currently not close to achieving utility scale district heating in its largest population centers. It is recommended that the Commonwealth focus on developing mine water energy systems at large building and multi-building scale within the state and use these as opportunities to educate and build coalitions that could grow confidence in building large-scale applications.

[398] Apt et al., "The Future of Geothermal," 104.
[399] Michael C. Korb, "Minepool Geothermal in Pennsylvania." presentation at 2012 PA AML Conference New Frontiers in Reclamation August 2-4, 2012.

GEOTHERMAL COOLING OF DATA CENTERS

Overview

With the growth of artificial intelligence technologies (AI), demand for power from data centers has skyrocketed. Estimates from Goldman Sachs Research predict that global power demand will increase by 50 percent by 2027 and by an incredible 165 percent by 2030, compared to 2023.[400] A report from the Electric Power Research Institute helps to explain this phenomenon, indicating that AI models are generally more energy-intensive than the other applications that have driven data center growth in previous years, such as data retrieval, streaming, and communications.[401] Specifically, the report notes that "at 2.9 watt-hours per ChatGPT request, AI queries are estimated to require 10 times the electricity of traditional Google queries, which use about 0.3 watt-hours each; and emerging, computation-intensive capabilities such as image, audio, and video generation have no precedent."[402] With such significant global growth in demand for power, large technology companies are scrambling to find locations and infrastructure to keep up. Meeting demand, however, can be difficult to achieve, especially when considering costs and environmental concerns.

Data centers require enormous amounts of power and water to function. The cooling of data center infrastructure is a significant part of this demand, accounting for up to 40 percent of total energy consumption and 50 percent of CO_2 emissions.[403] The use of geothermal cooling technologies to cool data centers has great potential to support the future growth of data centers. There are two primary types of geothermal cooling. The first utilizes a subsurface of less than 70°F, allowing for naturally cooled fluid to be used directly.[404] Specifically, these conditions could be created using shallow aquifers and abandoned mines. The second type of geothermal cooling requires a subsurface temperature of greater than 180°F, using absorption chillers to transform hot fluids into cold refrigerants.[405] Either way, geothermal cooling systems, when integrated with gas-powered data centers, have a wide range of benefits.

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[400] "AI to drive 165% increase in data center power demand by 2030," *Goldman Sachs*, February 4, 2025, accessed July 24, 2025, https://www.goldmansachs.com/insights/articles/ai-to-drive-165-increase-in-data-center-power-demand-by-2030.
[401] "Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy," EPRI, May 28, 2024, https://www.epri.com/research/products/3002028905, 2.
[402] "Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy," 2.
[403] Jay Apt, Max Clark, Carlee Joe-Wong, et al., "The Future of Geothermal Energy in Pennsylvania: Leveraging the Commonwealth's Legacy of Energy Leadership," *Penn State Center for Energy Law and Policy*, 2025, https://celp.psu.edu/wp-content/uploads/2025/02/Pennsylvania-Report.pdf, i.
[404] Apt et al., "The Future of Geothermal Energy in Pennsylvania," ii.
[405] Apt et al., "The Future of Geothermal Energy in Pennsylvania," ii.

Energy efficiency is among these benefits. One contributor to energy efficiency is reduced energy consumption. Research indicates that geothermal cooling systems can create up to 30 or 40 percent reductions in energy consumption for data centers.[406] Another aspect of the efficiency of geothermal cooling is reduced water consumption. Research suggests that geothermal cooling, specifically when implemented as a closed-loop system, can decrease a data center's water consumption.[407] Possibly the most significant factor aiding the efficiency of data centers with geothermal cooling systems is their advanced, efficient system design. When data centers are powered by natural gas, geothermal cooling can utilize the waste heat, redirecting it for subsurface energy storage.[408] The stored excess energy can be utilized during periods of intense demand. Geothermal cooling can also create significant cost savings for data centers; recent studies suggest annual cost savings of up to $1 million for a standard data center.[409] Compared with a traditional HVAC system, geothermal cooling reduces energy costs by up to 30 percent.[410] Efficiency certainly helps with cost savings. Finally, geothermal cooling is environmentally friendly, enabling data centers to reduce their carbon footprint. CO_2 emissions can decrease by up to 50 percent when geothermal cooling systems are included.[411]

Pennsylvania Data Centers

Pennsylvania is a promising location for data centers exploring geothermal cooling solutions. In 2023, Pennsylvania was among the fifteen states with the highest data center demands, sitting at tenth place.[412] These top fifteen states carried approximately eighty percent of the U.S. data center load during 2023.[413] In 2023, 3.2 percent of Pennsylvania's total electricity consumption was used by data centers; however, this percentage is projected to grow up to 7.5 percent by 2030 under a higher-growth scenario.[414]

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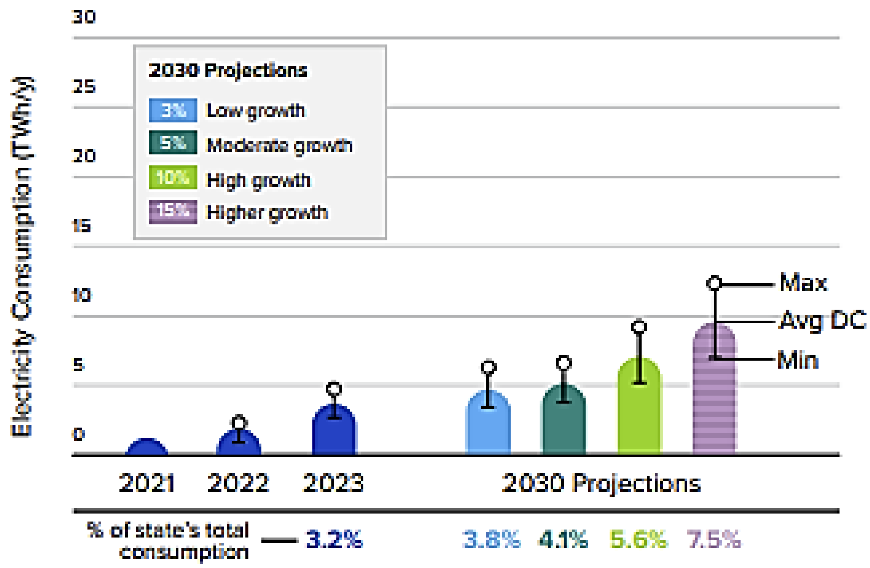
406 Apt et al., "The Future of Geothermal Energy in Pennsylvania," ii.
407 Apt et al., "The Future of Geothermal Energy in Pennsylvania," iii.
408 Apt et al., "The Future of Geothermal Energy in Pennsylvania," iii.
409 Apt et al., "The Future of Geothermal Energy in Pennsylvania," iii.
410 Apt et al., "The Future of Geothermal Energy in Pennsylvania," iii.
411 Apt et al., "The Future of Geothermal Energy in Pennsylvania," iii.
412 "Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy," 24.
413 "Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy," 24.
414 "Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy," 26.

Figure 20
Projected Electricity Consumption
in Pennsylvania Data Centers
2024



Source: Electric Power Research Institute.

Pennsylvania's energy resources, infrastructure, and geological conditions make it an excellent place to combine data center infrastructure with geothermal technologies.

Pennsylvania is already a leader in natural gas. As data centers are rising in popularity, companies can take advantage of Pennsylvania's legacy of energy production. A recent industry report noted that Pennsylvania was "renowned for its abundant natural gas reservoirs and production, enjoys a near-perfect nexus of energy resources and infrastructure for building new gigawatt-scale data centers powered by natural gas and cooled with geothermal."[415]

In addition to Pennsylvania's natural gas resources and infrastructure, the Commonwealth is also home to valuable thermal resources. It is estimate that there are approximately 700 GWs of thermal resources within 13,000 feet of the surface in the state that is available for cooling solutions.[416] With a standard 200 MW data center requiring an estimated 80 MWs for cooling, Pennsylvania has more than enough thermal potential to cool hundreds of data centers.[417] It is important to note that not all of this thermal energy is immediately recoverable, but it is promising for future development. When combining Pennsylvania's abundant natural gas infrastructure with its thermal potential for cooling, it is possible to reduce costs at existing centers or build larger data centers while barely increasing power use.[418]

[415] Apt et al., "The Future of Geothermal Energy in Pennsylvania," i.
[416] Apt et al., "The Future of Geothermal Energy in Pennsylvania," i.
[417] Apt et al., "The Future of Geothermal Energy in Pennsylvania," i.
[418] Apt et al., "The Future of Geothermal Energy in Pennsylvania," i.

There has been recent investment in natural gas and data center infrastructure throughout Pennsylvania in an effort to help the state lead in energy, innovation, and the development of AI. On July 15, 2025, participants at the Pennsylvania Energy and Innovation Summit announced a total of $90 billion in investment projects, including $25 billion for natural gas power generation in the northeastern region of the Commonwealth.[419] PPL and Blackstone Investment announced this $25 billion investment in data center and infrastructure development in Northeast Pennsylvania, estimating that 60 GWs of potential data center projects are in the process of being developed.[420] While this specific investment targets natural gas infrastructure, it could be further supported by geothermal cooling solutions to boost efficiency, provide cost savings, and reduce CO_2 emissions.

Iron Mountain Case Study

One center that is already using geothermal cooling technology is the Iron Mountain Data Centers in Boyers, Pennsylvania. The geothermal cooling system is located 200 feet underground in a former limestone mine, with a 35-acre water reservoir that maintains constant temperatures and water levels year round.[421] The data center was built near this part of the mine to take advantage of constant low ambient temperatures and the close proximity of the lake for geothermal cooling purposes.[422] The geothermal cooling system is made up of three main parts: reservoir pumps, heat exchanges, and building loop data center pumps.[423] The cooling process occurs as "the pump works by lifting the water into a heat exchanger where it receives the heat from the data center and rejects it when the warm water from the heat exchanger returns to the reservoir."[424] One benefit of the reservoir is that it allows for unlimited backup thermal storage without the limits of traditional backup generators.[425] Iron Mountain does not require an overly complex system for geothermal cooling, but the site had a 34 percent decrease in its total energy use with the geothermal cooling system.[426] Further, the simplicity of the variable flow pump design provides reliability and lower maintenance costs for the system as a whole.[427]

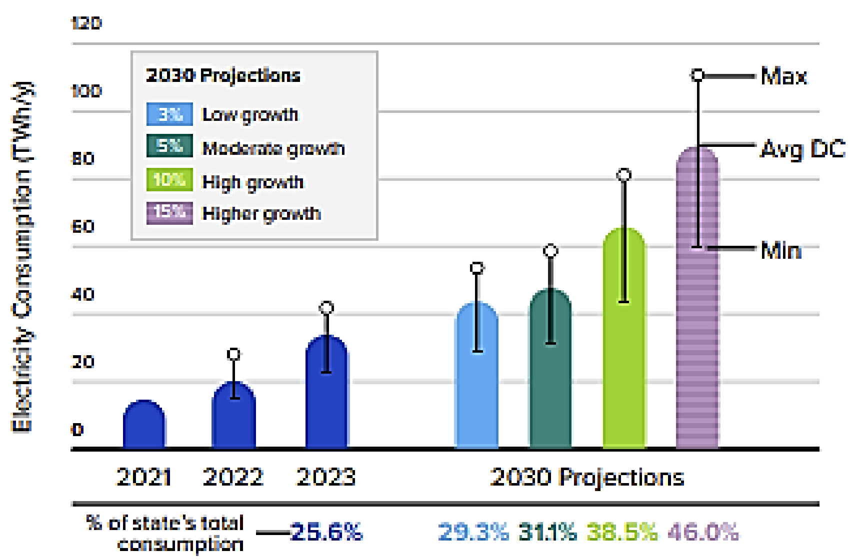
Virginia Data Center Case Study

While Pennsylvania was within the top ten states carrying the national data center load in 2023, Virginia was the state with the highest data center demand.[428] Virginia has the largest concentration of data centers in the world, with many of them in Northern Virginia serving the

[419] "Liam Mayo, "Billions coming to PA for natural gas, data center development," River Reporter, July 21, 2025, accessed July 24, 2025, https://riverreporter.com/stories/billions-coming-to-pa-for-natural-gas-data-center-development,208178.
[420] Mayo, "Billions coming to PA for natural gas."
[421] "Iron Mountain Data Centers: Geothermal Cooling System," *Better Buildings, U.S. Department of Energy*, accessed July 24, 2025, https://betterbuildingssolutioncenter.energy.gov/showcase-projects/iron-mountain-data-centers-geothermal-cooling-system#:~:text=Solutions,level%20and%20temperature%20year-round.
[422] "Iron Mountain Data Centers."
[423] "Iron Mountain Data Centers."
[424] "Iron Mountain Data Centers."
[425] Apt et al., "The Future of Geothermal in Pennsylvania," ii.
[426] Apt et al., "The Future of Geothermal in Pennsylvania," ii.
[427] "Iron Mountain Data Centers."
[428] "Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy," 5.

Department of Defense.[429] In 2023, Virginia had a staggering 25.6 percent of its total electricity consumption come from its data centers, with this percentage projected to grow up to 46 percent by 2030 under a higher-growth scenario.[430]

Figure 21
Projected Electricity Consumption in Virginia Data Centers
2024



Source: Electric Power Research Institute.

The Project Oasis feasibility study has specifically identified Southwest Virginia as a promising location for data centers to further expand and be paired with geothermal technology, utilizing billions of gallons of water from underground mines to save energy and costs.[431] The 2020 study identified this region specifically because of land availability, unique geothermal cooling opportunities, and workforce readiness.[432] It included an economic analysis, estimating that the creation of a large data center in the region would create over 2,000 construction jobs, 40 direct and 59 additional permanent jobs, $233 million in economic activity during construction, and over $50 million in economic activity every year once operations were begun.[433] Project Oasis identified a total of 10 sites for different-sized data centers, with three sites having geothermal cooling potential. Two sites could utilize 51°F mine water, and a third had underground space with a consistent temperature of 55°F.[434]

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[429] Will Payne, "Data Center Ridge: 1-Gigawatt Data Center and Clean Energy Generation Strategy in Southwest Virginia's Coalfields," *U.S. Department of Energy Office of Fossil Energy and Carbon Management*, November 14, 2024, https://netl.doe.gov/sites/default/files/netl-file/Payne_CBW24.pdf.
[430] "Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy," 26.
[431] "Project Oasis," Invest SWVA, 2022, accessed July 24, 2025, https://www.investswva.org/project-oasis.
[432] "Project Oasis," Invest SWVA, 2022.
[433] "Project Oasis," Invest SWVA, 2022.
[434] "Project Oasis," Invest SWVA, 2022.

Project Oasis provided an initial study on data centers and their potential to be paired with geothermal technology in Virginia. A recent application of the concepts tested in Project Oasis is demonstrated in Data Center Ridge, a 450-acre site development project intended "to be the catalyst for the most sustainable and energy efficient data center cluster in the world."[435] The Energy DELTA Lab, a nonprofit organization managing energy-ready sites throughout Virginia, has developed an Oasis Closed-Loop Mine-Based Water Cooling System alongside engineers within the mining and geothermal industries to be applied in the Data Center Ridge.[436] The project is incredibly large. Analysis from DELTA Labs suggests that the Oasis system can reduce electric and water costs by $1 million annually for a 36-megawatt data center, and Data Center Ridge is anticipated to have a capacity almost thirty times that of the standard 36-megawatt centers.[437] The campus has the potential to house one-gigawatt data centers, accessing nearly 10 billion gallons of cool underground water.[438]

The large-scale development of geothermal cooling technologies alongside the exploding data centers of Virginia provides a helpful example for Pennsylvania to consider when thinking about the application of these technologies within Pennsylvania itself. While it is not necessary to create every project at such a large scale, Virginia provides an example of just how much energy and money can be saved by employing geothermal cooling technologies made available by water found in abandoned mines to cool growing data centers.

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[435] "Energy DELTA Lab," Energy DELTA Lab, 2023, accessed July 24, 2025, https://www.energydeltalab.org/about.
[436] Payne, "Data Center Ridge."
[437] Payne, "Data Center Ridge."
[438] "Energy DELTA Lab," Energy DELTA Lab, 2023.

PENNSYLVANIA LAW IMPACTING GEOTHERMAL ACTIVITIES

Geothermal Property Rights in Pennsylvania

Pennsylvania's law governing property rights was established in the courts and is part of the common law. Statutory law can and does address extraction, restoration and reclamation, worker safety, and several other aspects of resource use and removal but does not usually address ownership.

The owner of a parcel of land is considered to own the air above, the surface, and the subsurface to the Earth's core. The landowner may divide the property vertically and sell or lease various resources in the subsurface property. The resources can be divided into two types – immobile and fugitive. Immobile resources include soil, rocks, coal and other metallic minerals. Fugitive resources include wind and subsurface oil, gas, and water. Generally, fugitive resources are in a state of fluidity, be they liquid or gaseous, and may spread under the surface of adjacent landowners' tracts. The landowner owns the right to that resource but does not fully actualize that ownership until the resource is brought under his control via extraction (known as the ownership in place rule). If the resource being extracted migrates to an adjacent landowners' property, that adjacent person has the right to capture the resource and make it his own property. [439]

Subsurface rights can be sold or leased in whole or in part. They can be delineated into smaller portions and can further be divided into types of resources. Pennsylvania follows the Dunham Rule, which provides for the proposition that a transfer of mineral rights must be specific, and generally only applies to immobile resources, and not to gas and oil resources. The transfer document must explicitly address the transfer of oil and gas rights along with other mineral rights.[440] When asked to determine ownership of other resources trapped in an immobile resource, the Pennsylvania Supreme Court distinguished between coalbed gas and other natural gases. It declared that coalbed gas trapped in coal pores (holes) belonged to the owners of the coal deposit but later noted that the owner of shale rock with natural gas trapped in the shale was not necessarily the owner of the gas.[441] Coalbed gas was treated as part of the coal deposit, as the product was a non-commercially exploitable valueless waste product of the coal mining operation.[442]

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[439] Hannah Wiseman, "Underground Property Rights in Pennsylvania: Understanding Surface Ownership, Mineral Ownership and Pore Space," *Penn State Center for Energy Law and Policy*, December 2022. https://celp.psu.edu/wp-content/uploads/2022/12/Summary-of-Underground-Property-Rights-in-Pennsylvania_CELP-for-posting.pdf

[440] The recent case of *Comerford Family Limited Partnership v. Ainbinder et al*., Pa. Super., No. 849 MDA 2022 (non-precedential decision November 14, 2024) reaffirmed the applicability of the Dunham Rule.

[441] Wiseman, 4-5.

[442] *Butler v. Charles Powers Estate*, 65 A.3d 885 (Pa. April 24, 2013).

This differentiation could come into play in determining the ownership of heat, steam, or water resources. If these items are a waste by-product of oil and gas drilling, they could be found to be included as part of an oil and gas lease or reservation. If they are the product of a system that accesses heat, steam or water independent of, and not ancillary to, mineral or oil and gas operations, they would initially be considered the property of the landowner under the Dunham Rule, unless specifically conveyed to another.

Pores within rock are another subcategory of subsurface property where ownership is important, particularly with respect to geothermal energy development. Existing geothermal energy technologies do not generally impact pore space as the resources are not trapped within such spaces. Two of these technologies involve either:

- natural hot aquifers in porous rock formations (for conventional hydrothermal geothermal); or
- sedimentary aquifers (direct heating).

A third technology, ground source heat pumps, use shallow ground temperature stability to heat and cool buildings in almost any geological area. These function as an alternative HVAC system and are the most common use of geothermal energy sources.

Ownership of subsurface pore space becomes an issue in implementing some emerging geothermal technologies, including Engineered Geothermal Systems (EGS), which uses hydraulic fracturing to create artificial permeability for heat extraction. Essentially, the process releases heat by recirculating fluid through fractures in hot rock. Another proposed method is known as Sedimentary Geothermal Systems (SGS), which uses sedimentary rock formations that may contain hot water in pores. With these two techniques, ownership of pores would be crucial. Under the Dunham Rule, access to the thermal energy in the pores would belong to the landowner or his lessee, if he specifically conveyed the right to the pore space to the lessee. In 2024, Pennsylvania codified this position in statutory law, declaring:

> Section 4. Ownership of pore space.
>
> (a) General rule.--The ownership of all pore space in all strata below the surface lands and waters of this Commonwealth shall be vested in the surface property interest owner above the pore space.
>
> (b) Conveyance.--A conveyance of the surface ownership of real property shall be a conveyance of the pore space in all strata below the surface of the real property unless the ownership interest in the pore space previously has been expressly excepted and reserved, conveyed or otherwise severed from the surface ownership. The ownership of pore space in strata may be conveyed in the manner provided by law for the transfer of real property interests. No agreement conveying minerals, including coal, oil and gas, or other interests underlying the surface shall act to convey pore space in the stratum unless the agreement expressly includes conveyance of the pore space.[443]

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[443] Act of July 17, 2024 (P.L.933, No. 87), known as the Carbon Capture and Sequestration Act (CCSA). 32 P.S. § 696.1 et. seq..

Under these provisions, coal, oil, and gas subsurface uses, including the surface space necessary to development of the coal, oil, and gas, is dominant over pore space use, regardless of whether the pore space is owned by the surface property interest owner or is owned separately. Existing pore space leases agreements are grandfathered in by the act.[444]

The question has been raised as to the existence of laws or regulations governing open-loop geothermal systems that utilize mine water/mine pool resources. The short answer is: it depends. Some of the factors include who is considered the owner of the water and how the water is returned to the ground (e.g., through the well, a recharge well, or surface discharge).

Ownership of Pennsylvania's Water

The Pennsylvania Constitution includes an environmental rights amendment that is foundational for all uses of the Commonwealth's public natural resources.

> § 27. Natural resources and the public estate.
> The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people.[445]

Any energy development, including geothermal energy, that makes use of natural resources is subject to this protective trust. Thus, in the final analysis, the Commonwealth has the ultimate responsibility for protecting Pennsylvania's environment.

Ownership rights can be distinguished between surface water and groundwater through common law doctrines (rules that have evolved by the court system via case law and are not statutory). For purposes of this report, it is assumed that mine water is groundwater and not surface water. Ownership of surface water is determined by the riparian rights doctrine, which generally assigns surface water ownership to the landowner whose property abuts the water. Groundwater ownership is governed by the American Rule (aka the Reasonable Use Rule):

> Under this rule, landowners may withdraw percolating groundwater from beneath their property for any "natural and ordinary" use without regard for neighboring users. Natural and ordinary uses encompass virtually any water use, as long as the use occurs on the landowner's property. Uses occurring off-site are "unreasonable" and "unlawful."
> * * *
> Some courts have found the offending user liable for damages when the withdrawal interferes with other users. There is also legal precedent stating that in order for the user to be liable for damages, the withdrawal must be "malicious" or "negligent." A "malicious" withdrawal is done with intent to harm one's neighbors, while an

[444] CCSA § 4(d)(2) and (d)(3). 32 P.S. § 696.4(d)(2) and (d)(3).
[445] Article I, Section 27, Pennsylvania Constitution.
https://ldpc6.legis.state.pa.us/cfdocs/legis/LI/consCheck.cfm?txtType=HTM&ttl=0.

> owner who makes a "negligent" withdrawal has failed to exercise care when there was a duty to do so and the impact of the withdrawal on other water users could be reasonably anticipated.
> * * *
> Its provisions usually mean that those with the deepest wells and most powerful pumps get the most water. Landowners are thereby given the incentive to drill ever-deeper wells and use ever-more powerful pumps, as long as the water use qualifies as natural and ordinary.[446]

These doctrines can be interpreted to mean that as long as a landowner makes reasonable use of water resources on their property, the use of geothermal systems is in their discretion. If the withdrawal and return of the water does not impact the property owner's neighbors, they generally can do what they want with the water. An additional wrinkle in the claims of ownership occurs when there is a lease or reservation of mineral rights. Mine pool water ownership has not been the subject of litigation specifically; its ownership is not absolutely clear in mineral rights situations. Pennsylvania law is well settled in that mineral rights reservations or leases must specifically identify an immobile resource and are essentially limited to coal and other soil, rocks, and metallic minerals. Oil and gas interests must be specifically transferred and are not considered part of "mineral rights." However, coalbed gas, while not solid, is considered part of the coal deposit and is treated as the property of coal owner, as the product of a non-commercially exploitable, valueless waste product of the coal mining operation. Disputes over ownership of mine pool water may be subject to this analysis in determining whether the water belongs to the landowner or the holder of the mineral rights to the coal. Similarly pore space, or the gaps within subsurface strata, where mine pool water may accumulate, has be statutorily declared to belong to the surface landowner unless it has been specifically conveyed otherwise.[447]

Pennsylvania's ownership doctrines relating to subsurface property rights and water rights need to be considered before a geothermal production begins, and a complete title search and opinion of counsel as the rights to mine pool water of the various potential interested owners or lessees is an important first step.

Ownership doctrines, however, are not the final word in this analysis. While the person with property rights to the water can remove underground mine water as the owner, what the owner does with that water can bring their activities under government scrutiny and regulation.

Clean Streams

The Clean Streams Law is the definitive statute governing pollution of the waters of the Commonwealth from a variety of activities, including mining. The statute's official title describes

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[446] Access and Allocation of Water in Pennsylvania," PennState Extension, updated December 17, 2007, https://extension.psu.edu/access-and-allocation-of-water-in-pennsylvania. See also, Robert T. Caccese, Esq., "An Overview of Pennsylvania Water Law," The Spring Creek Watershed Atlas, updated December 16, 2022, https://www.springcreekwatershedatlas.org/post/2018/01/16/an-overview-of-pennsylvania-water-law.
[447] See "Geothermal Property Rights in Pennsylvania," infra.

its purposes, including "regulating the impact of mining upon water quality, supply and quantity, . . ."[448]

The relevant definitions include:

> "Mine" shall be construed to mean any coal mine, clay mine or other facility from which minerals are extracted from the earth including coal refuse disposal areas and coal collieries, coal breakers and other coal processing operations.
>
> "Pollution" shall be construed to mean contamination of any waters of the Commonwealth such as will create or is likely to create a nuisance or to render such waters harmful, detrimental or injurious to public health, safety or welfare, or to domestic, municipal, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life, including but not limited to such contamination by alteration of the physical, chemical or biological properties of such waters, or change in temperature, taste, color or odor thereof, or the discharge of any liquid, gaseous, radioactive, solid or other substances into such waters. The department shall determine when a discharge constitutes pollution, as herein defined, and shall establish standards whereby and wherefrom it can be ascertained and determined whether any such discharge does or does not constitute pollution as herein defined.
>
> "Waters of the Commonwealth" shall be construed to include any and all rivers, streams, creeks, rivulets, impoundments, ditches, water courses, storm sewers, lakes, dammed water, ponds, springs and all other bodies or channels of conveyance of surface and underground water, or parts thereof, whether natural or artificial, within or on the boundaries of this Commonwealth[449]

The statute was amended in 1965 and 1980 to strengthen its provisions relating to mining operations and discharges. The statute requires a mine operator interested in operating a mine or allowing discharge from a mine into the waters of the Commonwealth to obtain a permit from the Department of Environmental Protection. Operating of a mine includes "preparatory work in connection with the opening or reopening of a mine, refuse disposal, backfilling, sealing, and other closing procedures, and *any other work done on land or water in connection with the mine*. (emphasis added) . . . The operation of any mine or the allowing of any discharge without a permit or contrary to the terms or conditions of a permit or contrary to the rules and regulations of the department, is hereby declared to be a nuisance."[450] Additionally, the part of the definition of "pollution" that refers to "change in temperature, taste, color or odor thereof" may have implications for geothermal uses if the water, when returned to the Earth, is not in the same condition as when extracted, which would certainly be the case if the water had been treated to remove heavy metals and sulfates, as discussed below relating to fracking.

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[448] The act of June 22, 1937 (P.L. 1987, No. 394), referred to as the Clean Streams Law, as amended by the act of August 23, 1965 (P.L. 312, No. 194) and the act of October 10, 1980 (P.L. 894, No. 157). 35 P.S. § 691.1 et seq.
[449] Section 1, the Clean Streams Law; 35 P.S. § 691.1.
[450] Section 315, the Clean Streams Law; 35 P.S. § 691.315.

Mine pool water can be considered a type of "waters of the Commonwealth" under the definitional phrase "and all other bodies or channels of conveyance of surface and underground water, or parts thereof, whether natural or artificial." Accessing these waters requires accessing the mine, and the methods used to do so could be considered a mining operation that requires a mining permit. Additionally, to the extent the activities to access the water involve significant earth disturbance, a permit may be required. A National Pollution Discharge Elimination System (NPDES) permit may also be required if the activities could potentially impact stormwater runoff. Depending on the nature of the proposed geothermal system, other permits could also be required.[451]

Mine Water and Hydraulic Fracturing

The use of mine pool water for natural gas fracking can serve as a partial analogy for the use of mine pool water in geothermal systems. In 2015, the Pennsylvania General Assembly enacted the Treated Mine Water Act, which authorized the use of treated mine water for oil and gas development. The statute requires the operator of an active or closed coal mine to obtain a permit to treat mine pool or mine drainage water, so that the treated water can be used as a substitute for fresh water for fracking purposes. The statute provides immunity for the mine operator for damages arising out of the use of the water, and immunity for the oil and gas development from responsibility for treatment or abatement of the acquisition or use of the water. The statute maintains the liability of either party for unlawful spills or release of the water. Mine operators must meet three conditions to claim the immunity: the treated mine water must be used for use outside of the boundaries of the permitted mining activity site, the treated water is for oil or gas well development, and the mine operator is not the same person as the person using the treated water.[452]

Water removed directly from the mine without treatment generally cannot be used untreated for hydraulic fracking or other industrial uses. Mine pool water frequently leads to acid mine drainage and contains both heavy metals and sulfates that can make it incompatible with fracking fluid chemistry and can leave heavy metal deposits and iron scale buildup in equipment. For similar reasons, untreated water may be problematic for some geothermal systems.[453]

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[451] Pennsylvania Department of Environmental Protection, "A Citizen's Guide To The Mining Permit Application Process," revised July 2025, http://www.depgreenport.state.pa.us/elibrary/PDFProvider.ashx?action=PDFStream&docID=1473348&revision=0&docName=A+CITIZEN%26%2339%3BS+GUIDE+TO+THE+MINING+PERMIT+APPLICATION+PROCESS&nativeExt=pdf.

[452] Act of October 8, 2015 (P.L. 186, No. 47), known as the Treated Mine Water Act; 58 P.S. §§ 1101-1105. Staff found no litigation under this act interpreting or expanding upon it rules.

[453] Carolyn Guju Kotsol, Winner Water Services, "New PA Law Puts Mine Water to Work," *Water Online,* November 10, 2015. https://www.wateronline.com/doc/new-pa-law-puts-mine-water-to-work-0001 and Jodi Weigand, "Mine drainage treatment system shows promise with fracking waste in Clinton Twp.," *TribLive.* May 10, 2015, https://archive.triblive.com/news/mine-drainage-treatment-system-shows-promise-with-fracking-waste-in-clinton-twp/.

Recycling the water (e.g., returning it to its source) can also be an activity that will likely require permits under NPDES and the Clean Streams Law. Return of the used water via the original mine, a recharge well, or surface discharge can have multiple effects. Potential chemical and bacterial contaminants may enter the water during its extraction and return, resulting in potential pollutant releases. These same processes may also alter the soil surrounding the mine pool.

> A properly designed recharge well will recharge as much as the pumping capacity. The problem lies in recharge water quality and turbidity.
>
> Any silt carried by water into a recharge well is filtered out and tends to clog the aquifer surrounding the well. Similarly, recharge water may also contain bacteria that can form growths on the well screen and the surrounding formation, thereby reducing the effective flow area. Chemical constituents of the recharge water may differ sufficiently from the normal groundwater to cause undesirable chemical reactions, i.e., ion exchange in aquifers containing sizable fractions of silt and clay. These factors all act to reduce recharge rates and, as a result, well recharging has been limited to areas where local conditions and experience have shown the practicality of the method.[454]

In conclusion, installation of geothermal systems that use mine pool water will likely need to obtain environmental protection permits depending on the specific circumstances of each project and each mine pool to be accessed. Before any work begins, there should be a clear resolution of the ownership rights to the mine pool water. While the method of extraction may not need pre-approval or permits depending on the level of activity needed to access the water, how the water is used in the system and how it is to be returned to the subsurface may also require specific permits.

Redeveloping Abandoned Mine Land in Pennsylvania

As early as 1945, Pennsylvania had enacted legislation to reclaim and restore abandoned mine lands.[455] Originally intended to address bituminous coal open pit mining, the act was amended in 1986 to include anthracite deep mines.[456] In 1968, the General Assembly authorized an initial bond issue of $500 million, $200 million of it dedicated to abandoned mine reclamation and mine drainage abatement within the Commonwealth.[457] In 1971, the General Assembly amended the 1945 act to expand its coverage to bituminous coal, anthracite coal, and metallic and

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[454] "Principals of Induce Infiltration and Artificial Recharge," National Ground Water Association, NGWA, accessed July 12, 2025. https://www.ngwa.org/what-is-groundwater/About-groundwater/principles-of-induced-infiltration-and-artificial-recharge.
[455] Act of May 31, 1945 (P.L.1198, No.418), known as the Surfacing Mining Conservation and Reclamation Act; 52 P.S. § 1396.1 et seq.
[456] Act of December 12, 1986 (P.L.1570, No.171).
[457] Act of January 19, 1968 (1967 P.L.996, No.443), known as the Land and Water Conservation and Reclamation Act; 32 P.S. 5101 et seq.

nonmetallic minerals and renamed the act.[458] This recitation of statutes serves to illustrate Pennsylvania's commitment to mine lands reclamation long before the federal government became involved in the process. In 1977, Congress enacted the federal Surface Mining Control and Reclamation Act of 1977 (SMCRA).[459] The U.S. Department of the Interior Office of Surface Mining Reclamation and Enforcement (OSMRE) administers the abandoned mine land (AML) program created under the SMCRA, which provides grants to states for conservation and reclamation activities. With the passage of the SMCRA, Pennsylvania established its Bureau of Abandoned Mine Reclamation to receive and administer funds available under the AML. In 1980, Pennsylvania amended the 1968 statute to expand coverage to sealing deep mines, and to assign federal dollars received under the SMCRA to the Department of Environmental Protection for abandoned mine reclamation.[460] In 1982, Pennsylvania was granted primacy approval by the federal Office of Surface Mining, which allows Pennsylvania to administer the SMCRA funding the Commonwealth receives. While most of Pennsylvania's AML projects have involved environmental rehabilitation and abating hazardous conditions potentially threatening public safety at abandoned mine sites,[461] energy development is a possibility, although abandoned mines are defined differently under federal and state laws.

Under the federal SMCRA, eligible land and waters include those which were mined for coal or which were affected by such mining, wastebanks, coal processing, or other coal mining processes and left or abandoned in either an un-reclaimed or inadequately reclaimed condition prior to August 3, 1977, and for which there is no continuing reclamation responsibility. However, lands and water damaged by coal mining operations after that date and on or before November 5, 1990, may also be eligible for reclamation if they meet the requirements specified in [this regulation].[462]

Under Pennsylvania's SMCRA,

> "Abandoned" shall mean any operation where no mineral has been produced or overburden removed for a period of six (6) months, verified by monthly reports submitted to the department by the operator and by inspections made by the department, unless an operator within thirty (30) days after receipt of notification by the secretary terming an operation abandoned submits sufficient evidence to the secretary that the operation is in fact not abandoned and submits a timetable satisfactory to the secretary regarding plans for the reactivation of the operation.

Developing solar energy facilities on abandoned mine lands is under consideration in Pennsylvania. A 2024 report prepared for the Pennsylvania Department of Environmental Protection recommended that the Commonwealth establish a goal of 9,000 acres or 1,500 MW of

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[458] Act of November 30, 1971 (P.L.554, No. 147).
[459] Public Law 95-87, 30 U.S.C. § 1201 et seq.
[460] Act of October 10, 1980 (P.L.921, No.158).
[461] Pa. Department of Environmental Protection, "Pennsylvania's Award Winning Reclamation Projects," accessed July 21, 2025 https://www.pa.gov/agencies/dep/programs-and-services/mining/abandoned-mine-reclamation/program-accomplishments/pas-award-winning-reclamation-projects.
[462] 30 C.F.R. §700.5.

solar energy on previously mined lands site by 2032.[463] A proposal to reclaim abandoned mine lands to build a 400-megawatt solar energy generating facility in Girad and Goshen Townships in Clearfield County, Pennsylvania was approved for phase one of the development (initial planning, design and community benefit activities) by the U.S. Department of Energy. The results of the initial phase would be used to help determine if the DOE would authorize federal funding for subsequent project phases.[464] On July 12, 2025, DEP issued a DEP encroachment permit addressing stream and wetland impacts for the project.[465]

While the energy policy of the Trump Administration has retracted support from solar and wind projects as well as electric vehicles, they U.S. Department of Energy has endorsed the development of geothermal energy.[466] The DOE has approved phase one of a proposed project to construct and operate a pumped storage hydroelectric generating facility in Bell County, Kentucky on former mine lands.[467]

Pennsylvania Government Support of Geothermal Systems

Within Pennsylvania state government, the executive branch agencies could play a crucial role in the development of geothermal, geo-exchange, and mine water energy systems.

Department of Conservation and Natural Resources (DCNR)

As detailed in a previous section of this report, the Bureau of Geological Survey within DCNR could work to determine which sites have potential for mine water systems. As this work is finished, the Bureau could publish this information to generate interest from those in academia and industry in developing mine water energy systems. For example, an inventory of mine water resources could aid regional development planning.

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463 LaBella Associates, "Assessment of Solar Development On Previously Impacted Mine Lands In Pennsylvania,.88, May 7, 2024, https://greenport.pa.gov/elibrary/GetDocument?docId=8421405&DocName=ASSESSMENT%20OF%20SOLAR%20DEVELOPMENT%20ON%20PREVIOUSLY%20IMPACTED%20MINE%20LANDS%20IN%20PENNSYLVANIA.PDF.

464 U.S. Department of Energy, Office of Clean Energy Demonstrations, National Environmental Policy Act (NEPA) Determination, Award No. DE_CD0000113 https://www.energy.gov/sites/default/files/2025-04/CX-033550.pdf.

465 "DEP Approves Permit For 400 MW, 2,716 Acre Mineral Basin Solar Energy Project On Abandoned Mine Land In Clearfield County," Pa Environmental Digest, July 14, 2025. http://www.paenvironmentdigest.com/newsletter/default.asp?NewsletterArticleID=63420&SubjectID=.

466 U.S. Department of Energy, Press Release, "Secretary Wright Acts to 'Unleash Golden Era of American Energy Dominance," February 5, 2025. https://www.energy.gov/articles/secretary-wright-acts-unleash-golden-era-american-energy-dominance.

467 U.S. Department of Energy, Office of Clean Energy Demonstrations, National Environmental Policy Act (NEPA) Determination, Award No.DE-CD000114, https://www.energy.gov/sites/default/files/2025-04/CX-033533.pdf, and Tina Casey, "$81 Million for Gigantic Energy Storage Showcase in Kentucky," *CleanTechnic*a, November 6, 2024, https://cleantechnica.com/2024/11/06/81-million-for-gigantic-energy-storage-showcase-in-kentucky/.

Environmental Regulation
and the Department of Environmental Protection (DEP)

Environmental laws governing geothermal energy involve interaction between state and federal agencies with overlapping responsibilities. The U.S. Environmental Protection Agency (EPA) is the federal agency that will have the largest bearing on the development of geothermal systems, including mine water-based geothermal systems. It administers the underground injection control (UIC) program, which began in 1984 under the Safe Drinking Water Act to protect drinking water from subsurface injections.[468] There are six classifications of wells under this program. Two of these classes are relevant to this study:

- Class II wells include oil and gas related injections, including disposal of oil and gas wastewater, enhanced hydrocarbon recovery, and liquid hydrocarbon storage.

- Class V wells include the injection of non-hazardous fluids into or above underground sources of drinking water, stormwater drainage wells, septic system leach fields, agricultural drainage wells, aquifer storage and recovery wells, and geothermal electric power wells. Open-loop geothermal systems such as those which would reinject mine water into the ground are regarded as class five.

While the EPA may currently be responsible for regulating the reinjection of geothermal fluids and mine water, it should be noted that states can apply for primary jurisdiction under a number of federal laws. For example, Pennsylvania already assumed primary jurisdiction over surface coal mining and reclamation in the Clean Streams Law in 1980.[469] There are provisions in the regulations under the federal Clean Water Act that allow States to apply for primary enforcement of underground injection control programs.[470] The state program must meet minimum federal standards and can add their own additional provisions.

At the time of writing this report, the Pennsylvania DEP is considering applying for primacy over Class II and V wells.[471] If DEP were to apply and their application was approved, Pennsylvania could have greater control over the development of geothermal resources within the state and determine the pace of its development. This change could be implemented through state legislation mandating DEP to pursue this primacy status. The statutes noted above and related regulations provide DEP with authority to issues permits, conduct oversight and compliance inspections, develop regulations, and enforce them.[472] When a violation occurs, DEP possesses the authority to enforce laws via administrative orders, civil penalties, permit denial, and criminal referral.[473]

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[468] The act of May 1, 1984 (P.L. 206, No. 43), known as the Safe Drinking Water Act; 35 P.S. § 721.1.
[469] The Clean Streams Law, § 612; 35 P.S., § 691.612.
[470] The requirements and procedures are set forth in 40 C.F.R. Parts 144 and 145.
[471] Klapkowski, "Testimony of Deputy Secretary Kurt Klapkowski," 9.
[472] The Clean Streams Law; 35 P. S. § 691.1 et. seq..
[473] The Clean Streams Law, Article VI; 35 P. S. §§ 691.601-691.613.

However, it should be noted that even with the authority to enforce the law, compliance can be difficult to ensure. Over 16,000 natural gas violations were noted in a five-year review DEP conducted between 2017 through 2021.[474] If the state were to take an increased role and presence in regulating geothermal systems, staffing levels in the appropriate state offices should be increased to handle those additional duties. Additionally, the time it takes to develop new environmental review regulations is estimated to be a minimum of two to three years in Pennsylvania.[475]

Finally, DEP has spearheaded efforts to develop an engineered geothermal system within Utica shale gas wells through a pilot program.[476] The department could do so with mine water geothermal as well, on a larger scale than was attempted in the past, if an appropriate site was chosen. DEP could also review active Acid Mine Drainage treatment sites and future treatment sites for opportunities to include heat pumps in the designs of these facilities.

Department of Community & Economic Development (DCED)

Several programs co-administered by DCED could help fund the development of geothermal applications. DCED could perform a review of existing state incentives and their potential for geothermal businesses, ground source heat pumps, and mine water energy systems and host this information on their website.

DCED administers the 'Renewable Energy Program: Geothermal and Wind Projects' under the direction of the Commonwealth Financing Authority. This program includes loans for job creation related to clean energy projects, guaranteed loans, and grants for feasibility studies.[477] The grant limit was $1,000,000 or 30 percent of a project's total cost. Grants for planning and feasibility could cover 50 percent of total cost or $175,000. This program features a matching dollar investment from its applicants.

While the 2018 iteration of the renewable energy program explicitly mentioned mine water systems, program documentation only listed closed-loop geothermal systems as eligible.[478] Even if such language was not intended to be exclusionary, going forward, programs promoting geothermal energy should explicitly comment on the eligibility of open-loop designs. A restriction on open-loop designs would rule out many of the configurations of mine water geothermal designs detailed in this report. If the DEP were to assume primacy and begin regulating injection wells,

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[474] Department of Environmental Protection, "Governor's Lapsing Statement Report" (Harrisburg, PA, December 29, 2022), https://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/Governor's_Lapsing_Statement_Report_2022-12-29.pdf.
[475] Air Quality Technical Advisory Committee, "The Regulatory Process and Proposals for Reform," Slide show, August 15, 2019, https://files.dep.state.pa.us/Air/AirQuality/AQPortalFiles/Advisory%20Committees/Air%20Quality%20Technical%20Advisory%20Committee/2019/8-15-13/ELF_2019.pdf.
[476] Utica Shale is a geological formation extending throughout the majority of PA. It can be up to 7,000 feet deeper than the Marcellus Shale formation; see also Klapkowski, "Testimony of Deputy Secretary Kurt Klapkowski," 1.
[477] Pennsylvania Department of Community and Economic Development, "Renewable Energy Program: Geothermal and Wind Projects," January 2018, accessed July 31, 2025, https://dced.pa.gov/renewable-energy-program-rep-geothermal-wind-projects-guidelines/?wpdmdl=81668.
[478] Pennsylvania Department of Community and Economic Development, "Renewable Energy Program: Geothermal and Wind Projects."

they could undertake a review of open-loop systems and adjust this program to balance environmental concerns over water safety with the decreased costs and higher efficiencies inherent in open-loop system designs. The Mining Remediation Authority's review process from the UK demonstrates how mine water regulations can be permissive of open loops while providing necessary protection for ground water sources.

In January 2020 the Alternative and Clean Energy Program was created using authority from the Alternative Energy Investment Act of 2008.[479] DEP and DCED co-administer the program, and the Commonwealth Financing Authority directs it. Businesses, economic development corporations, and political subdivisions are eligible to apply for loans and grants to develop clean and alternative energy within the Commonwealth. The program offers both loans and grants for two types of activities. The first is job creation in manufacturing clean energy equipment or components within three years of approval. The second activity is financing clean energy projects more directly by providing loans up to $5 million (or 50 percent of total project cost) and grants of up to $2 million (or 30 percent of total project cost). There is a dollar per dollar match requirement as well.

A review of the Alternative and Clean Energy program found several limitations to applying geothermal projects within the provisions of this program. Perhaps the largest limitation of the Alternative and Clean Energy program for this purpose is that its definition of geothermal energy is shared with the Alternative Energy Portfolio Standards Act of 2004. This law defines geothermal energy narrowly as electricity production, meaning that only higher temperature thermal resources may be considered eligible by this program.[480] Similarly, geothermal heating and cooling systems would also be ineligible for funding projects that involve switching fuel from a non-renewable energy source to a clean one. For example, a project replacing a steam boiler with a geothermal heating and cooling system would not qualify based on the description.[481]

While the program guidelines contain alternative language surrounding installation of equipment to "facilitate or improve energy conservation or energy efficiency" it is uncertain to what degrees geothermal heat pumps could be used under this provision as many of the costs pertaining to these such as drilling may fall outside the interpretation of installation.[482] Another part of the program outlines costs relating to construction and renovation of high-performance buildings which could include geothermal heat pumps, but employing this technology in isolation would be unlikely to qualify for obtaining such certifications as they frequently depend on many scoring criteria. For example, when Swarthmore College pursued a high-performance building certification, they needed a solar energy contract to qualify. Similarly, LEED does not consider geothermal heat pumps to be a form of onsite renewable energy.[483]

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[479] The act of July 9, 2008 (P.L.1813, No. 1, Spec. Sess.) known as the Alternative Energy Investment Act; 73 P.S. § 1649.101 et seq.
[480] The act of November 30, 2004 (P.L. 1672, No. 213), known as the Alternative Energy Portfolio Standards Act of 2004; 73 P.S. § 1648.1 et seq.
[481] Pennsylvania Department of Community & Economic Development, "Alternative and Clean Energy: Program Guidelines," January 2020, accessed July 31, 2025, https://dced.pa.gov/download/alternative-clean-energy-program-ace-guidelines/?wpdmdl=81859.
[482] Pennsylvania Department of Community & Economic Development, "Alternative and Clean Energy: Program Guidelines."
[483] U.S. Green Building Council, "USGBC," accessed July 31, 2025,

When designing future renewable energy programs, DCED could incorporate mine water as one aspect of their scoring criteria for determining which grants are funded. This could aid well-designed mine water projects in securing state administered funding. Pennsylvania could also establish a grant program specifically for mine water energy systems if they wish to spur research or development of this technology.

Working with DEP, the Governor's Center for Local Government Services in DCED could also aid the development of model ordinances for local communities that provide the right balance between support for responsible open-loop geothermal design and common-sense requirements to protect the environment and preserve health and safety. An example of what such measures could look like is found later in this chapter in the local government section detailing Bucks County's geothermal regulations.

Department of Labor and Industry (L&I)

Promoting geothermal and geo-exchange technologies could help stimulate job creation within the Commonwealth. These systems require jobs relating to water and geological testing, drilling wells, building distribution infrastructure, and maintaining geothermal equipment. While clean energy programs have sometimes been characterized as opposed to resource extraction jobs, in the instance of geothermal technology there is a high overlap in the types of skills needed. Adding clean energy jobs can help diversify the type of work available and provide more job security. L&I could continue to promote job training, apprenticeships, and career education to support the growth of the geothermal industry within the Commonwealth. Programs such as PA Career Link could be used to connect oil and gas workers with clean energy projects.

Department of Agriculture

The Pennsylvania Department of Agriculture could explore direct use applications of geothermal technologies in conjunction with agriculture and agribusinesses common in Pennsylvania. One of the more promising uses is the development of greenhouses heated and cooled by mine water or converted oil and gas infrastructure.[484] Manufacturing needs that are below 212°F have the most potential to be used in conjuncture with mine pool energy. In Pennsylvania, these industries include food, beverage, dairy, plastic production, greenhouses, and sugar processing facilities. *The Future of Geothermal Energy in Pennsylvania: Leveraging the Commonwealth's Legacy of Energy Leadership* report by Penn State University and the federally funded Project Innerspace examines the potential for such direct use opportunities based on the geothermal gradient and prominent industries throughout the state.

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https://www.usgbc.org/education/sessions/geothermal-systems-10679668.

[484] Weiyun Hua, "Challenges and Opportunities for Recycling Geothermal Energy From Abandoned Mine Lands for Greenhouses and Agricultural Applications," Recorded Presentation, *Shamokin Creek.Org* (Lewisburg, PA, June 4, 2025).

Other Stakeholders

One challenge characteristic of the development of mine water systems is bringing the right people together and aligning their goals: environmentalists, building designers, union leaders, infrastructure workers, mining and drilling occupations, geologists, hydrogeologists, economic redevelopment experts, science and engineering researchers, and HVAC maintenance workers are all needed to develop mine water energy systems to prominence. If such a group were assembled, its members would need to educate the public and build support for opportunities for mine reuse. Setting clear and achievable goals to work toward may aid this work. However, because geothermal is heavily tied to particular regions, non-governmental organizations such as regional economic organizations in areas of the state with a history of mining might have an advantage in bringing the right experts together to target region-specific solutions.

Local Governments

Local governments have the potential to play a significant role in determining the eligibility of mine water systems through local zoning or ordinances in the Commonwealth. Throughout southern parts of the state, ordinances exist that could impact the development of geothermal systems. York County circulated a model ordinance which banned open-loop systems.[485] The Delaware Valley Planning Authority has circulated information to educate local governments on geothermal systems.[486] However, this organization cautions that zoning ordinances may be an inappropriate place to regulate geothermal uses since by some definitions, geothermal would not be considered a "land use." In 2011, the Borough of Quarryville in Lancaster County adopted an ordinance prohibiting open-use systems within the borough.[487]

Not all local government efforts to regulate geothermal systems are prohibitive. In 2025, West Goshin Township in Chester County created an ordinance requiring that any closed-loop geothermal systems be at least 10 feet from building foundations and property lines.[488] It also required open-loop systems to be 30 feet from building foundations. The ordinance also details higher setback requirements for commercial geothermal systems.

Out of all the local governments reviewed, the Bucks County Department of Health had the most detailed regulations pertaining to geothermal systems, while still permitting open-loop types. The county requires that companies drilling, altering, or installing geothermal systems must have a license from DCNR. Similarly, geothermal system installers should have DCNR approval

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[485] York County Planning Commission, "Geothermal Heating System Model Ordinance," 2019, accessed July 31, 2025, https://www.ycpc.org/DocumentCenter/View/300/Model-Geothermal-Heating-Systems-Ordinance-PDF.
[486] Delaware Valley Regional Planning Commission, "Renewable Energy Ordinance Framework - Geothermal," November 30, 2012, accessed August 4, 2025, https://www.dvrpc.org/energyclimate/modelordinance/geothermal/.
[487] Borough of Quarryville, Penn. Ordinances ch 217, §217-3 (2011).
[488] West Goshin Township, Penn. Ordinances ch. 84, §84-57.16 (2025).
https://www.westgoshen.org/DocumentCenter/View/1809/Ordinance-No-1-2025---Zoning-Ordinance-Amendment-Geothermal-Wells.

or be accredited by the International Ground Source Heat Pump Association.[489] The county requirements for open-loop geothermal wells include the following provisions:

a. Best Management Practices shall be used to prevent aquifer contamination. Return wells shall be drilled into the same aquifer as the withdraw well to prevent introduction of contaminants from one aquifer to another. If this is not possible, the water quality of both the withdrawal well and return well shall be tested and the withdraw well aquifer cannot be of lesser quality (as determined by the Department), than the return well aquifer. To prevent thermal degradation, the withdraw and return wells must be a minimum of 50 feet apart.

b. Only PA DCNR approved well drillers using PA DCNR approved well drilling rigs shall drill the withdraw and return flow wells for this type of system.

c. Return flow wells shall be designed and screen lengths doubled. Extended pump testing of 12-24 hours shall be done to determine the hydraulic characteristics of the well, and a blind flange shall be installed to allow for emergency surface discharge of water. Any emergency surface discharge shall conform to applicable state regulations.

d. Surface discharge of water from an open loop system to a surface water body may require a National Pollutant Discharge Elimination System (NPDES) permit. The person requesting a geothermal permit from the Department is required to submit proof of an NPDES permit or exemption with any application.

e. An EPA reporting requirement exists for injection of water to a return well for groundwater heat pump systems.

f. Under no circumstances may additives of any kind be placed in this type of geothermal system to enhance heat transfer or reduce freezing points of the circulating water.

Adoption of these guidelines could help serve as a model for other local governments seeking to expand geothermal technologies, especially in regions of the state that wish to establish mine water systems.

While the above localities do contain coal mines and would have no direct impact on mine water energy development, they are examples of the types of regulations local governments might choose to enact. It appears that widespread local government action to curtail the use of open-loop geothermal systems is not present within the Commonwealth at the time of this report. Therefore, a careful review of local government ordinances should be conducted at the outset of mine water geothermal planning.

[489] Bucks County "Bucks County Department of Health Rules and Regulations Governing All Wells and their Construction Specifications," August 17, 2024, https://www.buckscounty.gov/DocumentCenter/View/2097/Rules-and-Regulations-Governing-Individual-Residential-Water-Supply-Systems-and-Construction-Specifications-PDF.

Role of Academic Institutions

Pennsylvania academic institutions have led large-scale conversions to geothermal heating and cooling systems. While Swarthmore College and Marywood University are successes highlighted earlier in this report, there are others taking advantage of geothermal. Allegheny College in Meadville installed a geo-exchange system in 2006 and has expanded it through several phases.[490] West Chester University heats and cools half of its building with geo-exchange system.[491] More campuses will likely look to geothermal energy for as long as they pursue carbon reduction initiatives. However, not every proposed geothermal project within the state has received funding. For example, in 2023 Saint Vincent College was reportedly in consideration for a $1 million US DOE grant to replace part of the campus' heating and cooling needs with a mine water energy system; the application, unfortunately, was ultimately not selected.[492] A geothermal mine water feasibility study for the University of Pittsburgh Johnstown Campus was a finalist in the Pitt Sustainability Challenge, but not selected for a $300,000 prize.[493] These projects and their search for alternative funding sources may nonetheless inform others seeking to adopt mine-water energy systems.

Colleges and universities in Pennsylvania could help develop and research mine pool technologies in the Commonwealth and aid in the development of mine water energy pilot projects. Like the UK, Pennsylvania government could work with universities to establish and develop geothermal observatories. These centers could spur more research into geothermal technologies as many colleges across the Commonwealth are located in places convenient to study mine pools. In Joint State staff's screening of college campuses in close proximity to mine water sources, 24 campuses were identified. Three of these sites, Marywood University, Pitt's Johnstown Campus, and St. Vincent College were independently verified. If mine water energy systems were built on college campuses, they could also be studied in greater detail, and the institutions could help act as ambassadors for mine water energy systems. As at Swarthmore, the institutions could promote their geo-exchange systems to educate students, distribute informational materials online, and provide tours for stakeholders. Such efforts could also advance non-energy uses, as academic research is also advancing in the study of critical mineral resource recovery.[494]

Finally, the Pennsylvania State University Extension has advocated for the creation of a geothermal energy plan like the Pennsylvania Solar Plan.[495] Adoption of such a plan in conjunction with concrete goals to measure, advance, and promote geothermal systems could help stakeholders find common ground and more effectively pool their efforts and resources.

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[490] Brown, Jake Lee, Brian Cameron Mercer, and Anna M Maziarz. 2010. Geothermal Energy: A Feasibility Study On the Application of Ground Source Heat Pumps. : Worcester Polytechnic Institute,42.
[491] West Chester University, "The Geothermal Exchange System and the Decommissioning of WCU's Coal Plant," wcupa.edu, March 2022, accessed July 31, 2025, https://www.wcupa.edu/sciences-mathematics/anthropologySociology/museum/earthDayVirtualExhibition/geothermal.aspx.
[492] JSGC Staff telephone conversation with Michael Korb, August 29, 2024.
[493] "UPJ Geothermal Tunnels Feasibility Study," Pitt Sustainability Challenge, October 2023, accessed July 31, 2025, https://www.pittsustainabilitychallenge.org/finalists/university-of-pittsburgh-johnstown.
[494] Mohammad Rezaee, "Selective Recovery of Multi-Critical Minerals From Acid Mine Drainage," Presenter (Lewisburg, PA, June 5, 2025), https://www.shamokincreek.org/s/Rezaee-Presentation.pdf.
[495] Joseph Conklin, "Geothermal Energy and Agriculture in Pennsylvania," June 24, 2025, https://extension.psu.edu/geothermal-energy-and-agriculture-in-pennsylvania.

Legislative Considerations

Historically, Pennsylvania has produced none of its electricity from geothermal energy sources.[496] Emerging technologies like engineered geothermal and geothermal co-production at oil and gas wells detailed earlier in this report may make geothermal electrical production viable within the Commonwealth for the first time in its history.

Increasing Geothermal Electricity Production

As noted in the section on DCED energy policies, Pennsylvania's statutory definition of geothermal energy systems may be too narrow to encompass the range of productive uses the technology can provide. Geothermal programs within the Commonwealth are tied to language found in the Alternative Energy Portfolio Standards Act of 2004 which states: "Geothermal energy, which shall mean electricity produced by extracting hot water or steam from geothermal reserves in the earth's crust and supplied to steam turbines that drive generators to produce electricity."[497] One limitation of this definition is its narrow focus on electricity. An updated definition could focus on underground heat resources rather than the specific output of the system."[498]

Geothermal resources are incredibly nuanced. In addition to the distinguishing between mineral and surface rights, which was discussed earlier, geothermal ownership could also relate to water rights or be *sui generis*, neither a water nor a mineral resource. There are also a wide variety of definitions to specify what is included under the word geothermal, whether that be by temperature or by the various types of heat, steam, fluids, brine, and byproducts associated with geothermal energy. The many possible ownership structures and definitions for geothermal resources make it important that states that wish to develop or update geothermal resource definitions carefully consider factors such as temperature thresholds, the specificity of what is encompassed within the geothermal right, and the language necessary for clear and concise definitions.

Many existing state definitions for geothermal resources use minimum temperature thresholds to define what is included as a geothermal resource.[499] A review of state definitions form the National Renewable Energy Laboratory found that the lower end of these thresholds start between 86° to 104°F. One advantage of a lower threshold is that it can encompass direct-use geothermal applications.[500] South Carolina is an example of a state with a lower minimum temperature threshold, defining geothermal resources as heat at temperatures greater than 104°F.[501]

[496] U.S. Energy Information Administration "Pennsylvania: State Profile and Energy Estimates," accessed August 1, 2025, https://www.eia.gov/state/?sid=PA#tabs-4.
[497] Alternative Energy Portfolio Standards Act of 2004, § 2; 73 P.S. §1648.2.
[498] Apt et al., "The Future of Geothermal in Pennsylvania," 102.
[499] Aaron Levine, Faith Martinez Smith, and Heather Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," September 1, 2023, https://doi.org/10.2172/2000950, 4.
[500] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 4.
[501] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 5.

On the upper end of these thresholds are those near 212 degrees Fahrenheit. This may be accurate, as research indicates that the "minimum required fluid temperature to make electricity cost-competitively is approximately 100°C" and "the vast majority of geothermal fluid temperatures used for electricity production at power plants around the world fall in the range of 100° to 300°C".[502] This range is equivalent to 212° to 572°F. However, one issue with adopting a higher temperature thresholds is that they may exclude certain geothermal electricity generation and direct-use applications from the geothermal definition, making the excluded resources subject to additional regulations.[503] Further, higher minimum temperature thresholds may be limiting in the scenario that there are advances in technology that could allow for efficient geothermal electricity generation at lower temperatures.[504] Alaska is a good example of a state with a higher minimum temperature threshold, defining geothermal resources as being greater than 248°F.[505]

Sometimes, the definitions mention water rights related to temperature thresholds. For example, Idaho defines groundwater at or above 212°F as a geothermal resource, but states that below the threshold, the resource is considered a water right.[506] Such a definition could require additional authorization for those looking to use any cooler water in the reservoir for geothermal resource development.

The specificity of what is encompassed within the geothermal right, like temperature thresholds, can also vary by state. Some geothermal resource definitions can be very specific, while others are broad in their definition of what is included within the right to extract geothermal resources, whether that be heat, brine, fluid, steam, and/or other byproducts.[507] It is important that definitions are specific about what exactly is part of geothermal rights granted for resource extraction. It is important that these definitions and rights are consistent with other mineral extraction laws in the area.[508]

Another important consideration relating to the specificity of what is encompassed within the geothermal right is whether terminology includes or excludes certain technologies, such as EGS or closed-loop systems. Language that references the resource's heat helps ensure that the broadest scope of technologies is included, with terminology such as "heat of the earth" or "geothermal heat" being preferable to "geothermal reservoir."[509] EGS and closed-loop systems utilize heat from the subsurface rather than fluids, so this mindful use of terminology is important for ensuring technology inclusivity.[510] Nevada's definition is a good example of well-used terminology, and it references "the natural heat of the earth" when defining geothermal resources.[511]

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[502] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 4-5.
[503] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations." 4.
[504] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations." 4.
[505] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 5.
[506] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 5.
[507] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 6.
[508] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 6.
[509] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 6.
[510] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 7.
[511] Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 7.

Not only are preferred definitions clear about what is encompassed within geothermal, but they are also clear and concise in order to aid comprehension and avoid multiple interpretations. Sometimes, "clarifying phrases" do more harm than good, requiring further information and additional definitions to aid understanding.

Oregon offers an excellent definition of geothermal resources that is specific about what is encompasses within the geothermal right, while being clear and easy to understand:

> "Geothermal resources" means "the natural heat of the earth, the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or that may be extracted from, the natural heat, and all minerals in solution or others products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, exclusive of helium or of oil, hydrocarbon gas or other hydrocarbon substances, but including, specifically:
>
> (a) All products of geothermal processes, including indigenous steam, hot water and hot brines;
> (b) Steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations;
> (c) Heat or other associated energy found in geothermal formations; and
> (d) Any by-product derived from them.[512]

Beyond updating definitions, there are examples of policies that could increase geothermal development within Pennsylvania including Carbon Cap and Trade, greenhouse gas emissions limits, and updated energy portfolio requirements. However, such policies should be made in consultation with the energy industry and other stakeholders. A substantial limitation on past geothermal policy efforts, such as the Renewable Standards Portfolio Act, incentivized a type of geothermal energy production that was not feasible in Pennsylvania. Enacting legislation that requires target goals for geothermal electricity production may help spur the development of deep and engineered geothermal systems. Meanwhile, policies that penalize greenhouse gas emissions could promote development of geothermal heating.

Looking further to the future, balance between state priorities regarding energy growth may be difficult to achieve. One of the greatest strengths of geothermal energy production is its low rate of carbon emissions. Energy deregulation policies have benefited Pennsylvanians in many ways by providing affordable energy to consumers. However, these policy decisions do not factor in the environmental and health costs of emissions tied to generating electricity from fossil fuels. By treating this cost as an externality, one of the greatest strengths of geothermal energy production will not be reflected in its price. Similarly, policies which focus on energy production from sources that produce with high-capacity rating, also referred to as baseload energy sources, could benefit geothermal over other intermittent renewable energy sources.

512 Levine, Smith, and Buchanan, "Topics and Considerations for Developing State Geothermal Regulations," 8.

While the above policies are likely to spur geothermal development, they may need to be considered with the state's energy profile as a whole to determine the impact on the broader energy market within the Commonwealth.

Mine water energy systems and geo-exchange systems could play a greater role in clean energy development within the state. Through the adoption of definitions that more fully distinguish between current geothermal and geo-exchange technologies, the state legislature could increase the clarity and direction of the state energy policy. While often promoted under a broad geothermal umbrella, these technologies can have differing uses, societal benefits, materials, costs, and environmental risks. Although an inclusive geothermal label may be helpful in marketing such technologies, policy makers would benefit from clear and current definitions that encourage industry development. It should also be recognized that there is also possibility for geothermal and geo-exchange technologies to be used in conjunction.

Policies designed to promote energy efficient energy use are also likely to benefit geo-exchange. Additionally, potential exists to develop synergy between photovoltaic solar panels and geo-exchange to further decrease heating and cooling costs. Supporting smart grid infrastructure choices in Pennsylvania cities allows new sources of energy to be incorporated as needed. Efforts aimed at increasing electrification could increase the adoption of geothermal heat pumps as heating and cooling needs make up a substantial amount of homeowner energy usage within the Commonwealth.

Stable and long-term energy policies designed to limit carbon emissions could help increase investment in geo-exchange. As noted previously, geothermal resources take time to develop and focusing on developing short term incentives may see little use. In a majority of the countries and U.S. states surveyed implementing geothermal systems, carbon reduction strategies played a direct role increasing the relevance of geothermal technology through not just public investment but also sending strong market signals about the future direction of the energy market over the next 25 to 50 years.

While some states have begun to regulate geothermal energy production, and thermal energy networks, currently mine water heating and cooling systems are almost unheard of domestically. It is important to note that Pennsylvania does not currently have another model within the country to emulate when it comes to development. To date, no other state has successfully developed a mine water energy program. Most states lack mines in conjunction with the necessary heat demand and infrastructure to make such projects feasible. Pennsylvania and some of its direct neighbors may be uniquely situated due to our heritage of industrial development near mining centers.

Out of all the states surveyed, West Viriginia has done the most to position themselves for the development of mine water geothermal. Despite this, their efforts have not yet produced any successes, demonstrating that progress of this technology may be slow. When possible, Pennsylvania should collaborate with neighboring states to advance the body of knowledge relating to mine water energy systems in places with similar geology. Across the country, closed-loop geo-exchange systems are becoming more common due to efficiency and low carbon heating and cooling, however mine water energy systems have yet to find a similar niche.

As our society thinks more critically about energy usage, we may need to reassess the policy distinctions between heating and energy sources. In traditional buildings from the 20th century, heating and cooling needs were frequently provided with external electricity sources combined with on-site generation of heating. In recent decades, this system has been upended in high efficiency buildings that combine energy efficient appliances in conjunction with locally generated renewable energy sources. However, this decarbonization strategy can lead to a narrowing of focus on electricity generation alone and may inadvertently minimize the role that heat generation from clean sources like geothermal could serve. Currently, 62 percent of Pennsylvania's electricity is generated from burning fossil fuels.[513] Pursuing electrification without greater focus on saving energy and reducing greenhouse gases practices can create gaps in policy that may lead to unintended consequences.

Promoting geothermal heat pumps could lead to a more direct reduction in greenhouse gases in the near term. While a geo-exchange system like Swarthmore's is nowhere near the scale of a power plant in how it affects the power usage of a given area, it is also a much larger and substantial piece of infrastructure than a typical energy-saving home appliance. Funding and technical support for pieces of energy-saving infrastructure which supply multiple buildings with heat at lower operating costs and with fewer emissions should be encouraged when economically viable.

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[513] U.S. Energy Information Administration, "Pennsylvania Profile" 2025 https://www.eia.gov/state/?sid=PA#tabs-4.

FINDINGS AND RECOMMENDATIONS

As noted throughout the report, various types of geothermal systems have significant differences in their characteristics, which have an impact on system costs, functions, designs, and siting requirements. As a result of this variation, different legislative actions may be applicable for each type of geothermal system. The following is a summary of findings and recommendations for each type of geothermal technology included in the report.

Geothermal Energy Production

Findings

- Conventional geothermal systems were long considered impractical in Pennsylvania because of the unfavorable temperature gradient and earth which lacked the water or channels necessary to produce steam. To date none of Pennsylvania's electricity is provided by geothermal generation.

- A landmark report on "The Future of Geothermal Energy in Pennsylvania" was released in spring 2025 by Project Innerspace and Pennsylvania State University and provided the first truly in-depth examination of our Commonwealth's geothermal potential.

- In recent years, oil and gas techniques to fracture earth could significantly increase the number of locations where geothermal power plants can be sited. It is possible that all of Pennsylvania's electric needs could eventually be met by geothermal power production.

Recommendations

- **Define the legal ownership and usage rights for potential geothermal assets, specifically for abandoned wells.**

- **The definition of geothermal in the Alternate Energy Standards Portfolio Act should be amended so that geothermal resources are not defined solely by electrical generation abilities but also the heat they produce.**

- **If the state applied for primacy from the EPA, Pennsylvania could have more power to develop a geothermal regulatory system in DEP based on the authority granted to it in Clean Stream Laws.**

Oil and Gas Reuse and Co-Production

Findings

- Pennsylvania has created a pilot program for a geothermal generator at a low performing gas well, which could spur electricity development in state for the first time. Co-production methods to turn wasted heat from oil and gas wells into electricity or productive heat are also being developed within the state.

- Estimates suggest that there are anywhere between 200,000 to 750,000 abandoned wells throughout the Commonwealth.

- The skills needed to construct geothermal systems and those associated with oil and gas have high levels of overlap and could be a source of jobs within the state. Sixty-one percent of total oil and gas jobs have a high relevance to the geothermal sector, and 13 percent of moderate relevance.

Recommendations

- **Provide funding and incentives for well reuse pilot projects and further development, such as state grants, tax incentives, and low-interest loans.**

- **Support the conversion of oil and gas wells into geothermal assets by offering liability protections and streamlined permitting processes to developers retrofitting orphaned wells for their transition to geothermal technologies.**

Geothermal Heating and Cooling

Findings

- Geothermal heat pumps use stable underground temperatures as a method of heating and cooling that has the potential to save Pennsylvanians approximately 46 percent on their annual energy costs.

- Because of upfront expense, a limited number of providers, and a lack of knowledge, the market penetration of geothermal heat pumps has been limited to date.

- Pennsylvania's education institutions, such as Swarthmore College, have led the state in construction of high efficiency campus buildings that employ geo-exchange technologies that circulate fluids in pipes buried underground to provide low-cost heating and cooling and produce 90 percent less carbon emissions than traditional systems.

Findings

- For institutions that can afford to spread out the costs, geo-exchange systems could be a strategic investment when replacing aging infrastructure such as steam boilers. Adoption of geo-exchange in government buildings could save Pennsylvania a substantial amount of money in operating costs but possibly come at a high initial cost.

- Some Pennsylvania cities are investigating use of geo-exchange on a district scale. These are called thermal energy networks. However, gas utilities need legislative permission to sell heat instead of only gas and for this activity to be regulated by the PUC.

- Thermal Energy Networks (TENs) can smooth electricity demand patterns and use the ground as a source of heat and as a thermal battery to achieve an estimated rate of efficiency that is five to six times higher than traditional heating sources. TENs systems are also two to four times more efficient than air source heat pumps.

- TENs have the potential to offset 62.4 million metric tons of greenhouse gas emissions in the northeast region of the country. Government intervention is likely necessary to reach this potential, as it has been estimated that TENs would achieve only 10 percent of its potential with market forces alone.

- As with geothermal electricity production, adopting TENs could bring more jobs to oil and gas workers as there is a higher overlap between the skills required to sustain the two industries.

- TENs have high upfront costs, with retrofit and replacement estimates being over $3 million per mile of pipeline and varying by geographic location; however, the high costs of maintaining aging fossil fuel infrastructure make the installation of TENs a natural next step for gas utilities looking to pivot and realize long-term cost savings.

- Philadelphia Gas Works studied the adoption of creating a TENs pilot but opted for more research instead because of obstacles of navigating a complex regulatory structure which involved the Philadelphia Facilities Management Corporation, Philadelphia Gas Commission, and PUC.

Recommendations

- **To overcome regulatory challenges and clarify ambiguities, legislation is necessary to allow gas utilities to build, own, and operate TENs.**

- **To overcome financial challenges in promoting the development of geothermal TENs, incentives should be established for pilot projects to test the specific feasibility and costs of geothermal TENs in the state.**

- **Legislation for TENs pilots should contain provisions related to emission standards, other energy standards, job creation, and protection against stranded gas infrastructure assets.**

- **Setting statewide carbon reduction goals could encourage the adoption of geothermal by creating consistent policy and giving energy companies time to plan around them.**

- **Tracking GSHP and geo-exchange system adoption within the state and providing additional educational resources may also help spur development.**

Mine Water Energy Systems

Findings

- Over a million buildings in Pennsylvania are built over abandoned mines. Mines exist in most counties although they are concentrated in northeast and southwest of the state.

- Mine water-based heating and cooling systems have been used in Pennsylvania since the mid-20th century. These systems employ heat pumps to extract heat from ambient temperatures of underground water in flooded mines as a source and heat sink.

- Because of their simplicity, mine water systems are frequently less expensive to construct and have greater efficiencies than closed loop geothermal. They can be scaled to community wide use.

- To date, few mine water energy systems have been constructed across Pennsylvania because of siting requirements, regulatory uncertainty, lack of knowledge, environmental concerns, limited capital, and concerns about safety.

Findings

- Currently, Marywood University, an academic institution built above an old colliery, has the only mine water cooling system in operation in Pennsylvania.

- Throughout Europe, mine water systems are being built more frequently and at larger scales than past efforts, in part because those countries are setting policies to lower carbon emissions and promoting a switch to electricity-based heating and cooling systems.

- The Mijnwater project from Heerlen, Netherlands serves as an example of fifth-generation district heating and cooling that uses water from abandoned coal mines to contribute to a 65 percent reduction in CO2 emissions for the heating and cooling of buildings in the region.

- Despite significant cost saving potential, the necessary economic pressure to research and invest in mine water systems may not be present in Pennsylvania at this time. Conditions may not be favorable until the private sector has a stronger motive to invest in low carbon energy systems, or alternatively the prices of fossil fuel increase. Liability concerns over subsidence and mine water usage may also deter private investment.

- For over 25 years, West Viriginia has inventoried the pools within its mines and more recently has begun efforts to site mine water systems within the state. Recent examinations to site mine water energy systems there have not progressed beyond a theoretical stage.

- Previous pilot efforts for mine water energy systems in Pennsylvania, such as the Kingston Recreation Center, failed to spur greater adoption of geothermal technologies.

- Local governments have the potential to limit mine water systems based on zoning and ordinances, however so far regulation has occurred in areas without mines.

- Initial screening efforts have identified 288 public schools across 24 Pennsylvania counties that are within one mile of a mine water source.

- If mine water systems were successfully developed at only five percent of these sites, the state could have the potential to save $1.4 million annually on heating and cooling costs. Additional site-specific screening capability and technical assistance to public building managers would be needed to determine the viability of these sites.

Mine Water Energy Systems (continued)

<u>Recommendations</u>

- **Mine water systems should be built over sites with clear ownership rights, such as an active mine, or by an owner of a site with both the surface and mineral rights. Potential exists to redevelop abandoned mines in the future.**

- **New mine water pilot projects should be combined with instrumentation capabilities, reporting requirements, partnership with researchers, and sustained advocacy efforts.**

- **For an additional appropriation of $500,000, DCNR's Bureau of Geological Survey could accelerate the process of mapping and modeling mine waters over a 5-year time period. This could play a greater role in promoting regional mine water development. It would also advance other state objectives such as identifying sources of critical minerals and aiding environmental clean-up efforts.**

- **Another possible use of heat pumps systems is positioning them within active mine water treatment plants to help fund efforts to clean Pennsylvania's rivers and streams from abandoned mine land (AML) damage. Further review of existing and planned sites is needed.**

- **The General Assembly could pass legislation like West Virginia's HB4003 of 2022 to enable organizations that study or clean mine water to benefit from critical minerals.**

- **More effort is needed to bring together a knowledgeable group of experts, such miners, geologists, hydro geologists, engineers, and community planners that could drive mine water energy development within the state.**

Mine Water Cooled Data Centers

<u>Findings</u>

- Fueled by the growth of AI, global power demand is forecasted to increase by 50 percent by 2027 and 165 percent by 2030, compared to 2023.

- Data centers require enormous amounts of power and water to function, with cooling making up 40 percent of total energy consumption and 50 percent of CO_2 emissions.

Findings

- In southeastern Virginia, recent efforts have focused on redeveloping AML lands to host data centers cooled with mine water. It is estimated that using mine water could help save $1 million annually on a 36 MW data center. The Center Ridge Project is working to scale up the system for a larger center.

- As of this report, no investigation of using mine water from AML sites for data centers within Pennsylvania has been recorded. This could be an area of future exploration.

- Using geothermal cooling technologies in data centers can reduce their energy consumption by up to 30 to 40 percent, reduce CO2 emissions by up to 50 percent, and provide annual cost savings of up to $1 million for a standard data center.

- Pennsylvania is the state with the tenth highest data center demand, which is projected to grow from 3.2 percent up to a high of 7.5 percent by 2030.

- The Commonwealth is home to valuable thermal resources, with an estimated 700 gigawatts of thermal resources within 13,000 feet of the surface available for cooling. A standard 200 MW data center requiring an estimated 80 MWs for cooling, Pennsylvania has enough thermal potential to cool hundreds of data centers.

- Pennsylvania's Iron Mountain Data Center uses a geothermal cooling system built near a former limestone mine, which uses the underground water for cooling and has helped the data centers achieve a 34 percent decrease in total energy use.

Recommendations

- **Provide funding and incentives for the construction of geothermal cooling systems to conserve energy used by the growing number of data centers within the state.**

APPENDICES

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APPENDIX A

2023 House Resolution 185

PRIOR PRINTER'S NO. 1932 PRINTER'S NO. 2307

THE GENERAL ASSEMBLY OF PENNSYLVANIA

HOUSE RESOLUTION

No. 185 Session of 2023

INTRODUCED BY WEBSTER, KAUFER, CEPEDA-FREYTIZ, DONAHUE, PIELLI, DELLOSO, FREEMAN, McANDREW, PROBST, ROZZI, MADDEN, BRENNAN, SANCHEZ, STEELE, CIRESI, OTTEN, HILL-EVANS AND T. DAVIS, AUGUST 29, 2023

AS AMENDED, HOUSE OF REPRESENTATIVES, NOVEMBER 14, 2023

A RESOLUTION

Directing the Joint State Government Commission to conduct a study on the feasibility of using geothermal energy technologies that utilize abandoned mining locations and operations in this Commonwealth and issue a report of its findings and recommendations to the House of Representatives.

WHEREAS, In the former coal mines located in the United Kingdom, abandoned mines which once fueled the Industrial Revolution are now being retrofitted to utilize new technology; and

WHEREAS, The objective behind retrofitting abandoned coal mines is to generate an alternative source of heat in a cost-effective manner to offset rate impacts; and

WHEREAS, Former mining sites often flood and the water must be subsequently pumped out and cleaned to prevent contamination of drinking supplies at an eventual cost to consumers or taxpayers; and

WHEREAS, Through the application of heat pumps, the floodwater temperature, which is already warmed in the mines deep underground, could be further increased and piped into homes and other structures to serve as a constant source of heat; and

WHEREAS, This process would produce almost no carbon while harnessing a steady stream of cheap and reliable heating and minimizing costs; and

WHEREAS, Multiple plans of a similar nature are in development outside of the United States; and

WHEREAS, In addition to producing energy, these plans would create an industry of technicians and engineers which will be needed to build and service this new geothermal infrastructure; and

WHEREAS, Since many former mining communities were built in close proximity to where the coal was mined, there is a substantial possibility for these residents to benefit from the creation of a new geothermal energy industry; and

WHEREAS, The power-producing legacy of more than 100 years of mining could continue in a manner that has a positive impact economically and environmentally for generations to come; and

WHEREAS, THIS COMMONWEALTH HAS CONSIDERABLE INFRASTRUCTURE <-- AND A SIGNIFICANTLY TRAINED WORKFORCE THAT MAY BE EMPLOYED IN THE GEOTHERMAL SECTOR; AND

WHEREAS, Refocusing attention and retrofitting this Commonwealth's abandoned coal mines for the purpose of geothermal energy could be transformative for the production of low-cost, zero carbon energy in former mining communities; therefore be it

RESOLVED, That the House of Representatives direct the Joint State Government Commission to conduct a study on the feasibility of using geothermal energy technologies that utilize abandoned mining locations and operations in this Commonwealth, including the costs to ratepayers of public utilities, and issue a report of its findings and recommendations to the House of Representatives; and be it further

RESOLVED, That the study:

(1) identify and examine potential efforts and procedures, measures, statutes and management responsibilities of State agencies, public utilities, nongovernmental organizations and academic institutions to assist in determining the feasibility of utilizing abandoned coal mines for the purpose of geothermal energy with a particular focus on the impact to consumers in this Commonwealth;

(2) conduct an economic impact analysis regarding the widespread utilization of abandoned coal mines for the purposes of geothermal energy in this Commonwealth in varying degrees of scale and cost-effective deployment;

(3) identify possible best practices regarding the development of the necessary infrastructure to support the widespread use of abandoned mines for the production of geothermal energy;

(4) identify and examine potential environmental impacts regarding the development of abandoned mining locations; ~~and~~ <--

(5) IDENTIFY THE BENEFITS AND CHALLENGES OF DEVELOPING <-- THERMAL UTILITIES, INCLUDING WITH THE USE OF EXISTING INFRASTRUCTURE;

~~(5)~~ (6) identify financial mechanisms or potential cost- <-- effective deployment throughout private entities and options for the development of a Statewide mine geothermal energy program and related infrastructure in this Commonwealth; AND <--

(7) IDENTIFY AND EVALUATE:

(I) OTHER POTENTIAL USE CASES OF GEOTHERMAL DEPLOYMENT IN PENNSYLVANIA, INCLUDING, BUT NOT LIMITED TO:

(A) RECONFIGURATION OF ABANDONED OIL AND GAS WELLS FOR GEOTHERMAL PRODUCTION; AND

(B) USE OF GEOTHERMAL HEAT FOR DISTRICT HEATING AND FOR COMMERCIAL AND INDUSTRIAL APPLICATIONS; AND

(II) ANY TECHNICAL, REGULATORY OR STATUTORY LIMITATIONS TO THE APPLICATIONS UNDER SUBPARAGRAPH (I);

and be it further

RESOLVED, That the Joint State Government Commission consult with stakeholders that:

(1) have organizational missions and expertise regarding consumer affairs, the economy, electricity generation and distribution, GAS OR THERMAL DISTRIBUTION, the infrastructure <-- and operations of public utilities, the environment, the health and safety of Commonwealth residents, mining, water quality issues and both rural and urban affairs;

(2) collect data on the benefits that retrofitting abandoned coal mines for the utilization of geothermal energy may have regarding consumer impacts, the economy, electricity generation and distribution, the environment, the health and safety of Commonwealth residents, mining, water quality issues and both rural and urban affairs; and

(3) have knowledge of issues relevant to the study;

and be it further

RESOLVED, That the Joint State Government Commission prepare a report of its findings and recommendations and submit the report to the House of Representatives no later than 18 months after the adoption of this resolution.

Pennsylvania Schools Near Gas Wells 2025				
Name	**City**	**Zip**	**County**	**Number of wells within 1 mile**
William Penn El Sch	Monongahela	15063	Allegheny	11
Armstrong JSHS	Kittanning	16201	Armstrong	2
Lenape El Sch	Ford City	16226	Armstrong	4
Lenape Technical School	Ford City	16226	Armstrong	3
South Buffalo El Sch	Freeport	16229	Armstrong	1
Highland MS	Beaver Falls	15010	Beaver	1
Lincoln Park Performing Arts CS	Midland	15059	Beaver	1
Midland El/MS	Midland	15059	Beaver	2
Pennsylvania Cyber CS	Midland	15059	Beaver	1
Western Beaver Co JSHS	Industry	15052	Beaver	2
Morrow El Sch	Towanda	18848	Bradford	2
Northern Tier Career Center	Towanda	18848	Bradford	2
SRU El Sch*	East Smithfield	18817	Bradford	6
Towanda Area El Sch	Towanda	18848	Bradford	1
Towanda Area JSHS	Towanda	18848	Bradford	2
W R Croman Primary Sch	Troy	16947	Bradford	4
Wyalusing Valley El Sch	Wyalusing	18853	Bradford	5
Wyalusing Valley JSHS	Wyalusing	18853	Bradford	5
Connoquenessing El Sch	Renfrew	16053	Butler	3
Dassa McKinney El Sch	West Sunbury	16061	Butler	4
Knoch HS	Saxonburg	16056	Butler	8
Knoch Intermediate El Sch	Saxonburg	16056	Butler	7
Knoch MS	Saxonburg	16056	Butler	7
Knoch Primary Sch	Saxonburg	16056	Butler	7
Mars Area Centennial Sch	Mars	16046	Butler	3
Mars Area MS	Mars	16046	Butler	3
Mars Area SHS	Mars	16046	Butler	3
McQuistion El Sch	Butler	16001	Butler	13
Moraine El Sch	Prospect	16052	Butler	4
Ryan Gloyer MS	Harmony	16037	Butler	5
Seneca Valley HS	Harmony	16037	Butler	5
Summit Township El Sch*	Butler	16002	Butler	17
Western Secure Treatment Unit	Emlenton	16373	Butler	2
Albert Gallatin North MS	McClellandtown	15458	Fayette	8
Belle Vernon Area MS	Belle Vernon	15012	Fayette	2
Brownsville Area El Sch	Brownsville	15417	Fayette	2
Brownsville Area HS	Brownsville	15417	Fayette	2
Brownsville Area MS	Brownsville	15417	Fayette	2
Bullskin El Sch	Connellsville	15425	Fayette	2

Pennsylvania Schools Near Gas Wells 2025				
Name	**City**	**Zip**	**County**	**Number of wells within 1 mile**
Dunbar Twp El Sch	Connellsville	15425	Fayette	2
Franklin Sch	Vanderbilt	15486	Fayette	1
Marclay Sch	Markleysburg	15459	Fayette	1
Marion El Sch	Belle Vernon	15012	Fayette	3
Masontown El Sch	Masontown	15461	Fayette	2
West Crawford El Sch	Connellsville	15425	Fayette	2
Carmichaels Area El Ctr	Carmichaels	15320	Greene	7
Carmichaels Area HS	Carmichaels	15320	Greene	7
Carmichaels Area MS	Carmichaels	15320	Greene	7
Greene County Career and Technology Center	Waynesburg	15370	Greene	3
Jefferson-Morgan El Sch	Jefferson	15344	Greene	13
Jefferson-Morgan MS/HS	Jefferson	15344	Greene	1
Waynesburg Central El School	Waynesburg	15370	Greene	3
Waynesburg Central JSHS	Waynesburg	15370	Greene	3
West Greene El Ctr	Waynesburg	15370	Greene	9
West Greene JSHS	Waynesburg	15370	Greene	9
Mohawk El Sch	New Castle	16102	Lawrence	1
Mohawk JHS	New Castle	16102	Lawrence	1
Mohawk SHS	New Castle	16102	Lawrence	1
Carl G Renn El Sch	Lairdsville	17742	Lycoming	6
Loyalsock Valley El Sch	Montoursville	17754	Lycoming	8
Mercer County Career Center	Mercer	16137	Mercer	2
Susquehanna County Career and Technology Center	Springville	18844	Susquehanna	11
Elk Lake El Sch	Springville	18844	Susquehanna	11
Elk Lake JSHS	Springville	18844	Susquehanna	11
Lathrop Street El Sch	Montrose	18801	Susquehanna	10
Mountain View El Sch	Kingsley	18826	Susquehanna	9
Mountain View JSHS	Kingsley	18826	Susquehanna	10
Blossburg El Sch	Blossburg	16912	Tioga	6
Wellsboro Area HS	Wellsboro	16901	Tioga	4
Allison Park El Sch	Houston	15342	Washington	8
Avella Area JSHS	Avella	15312	Washington	29
Avella El Center	Avella	15312	Washington	21
Bethlehem-Center El Sch*	Fredericktown	15333	Washington	4
Bethlehem-Center JSHS	Fredericktown	15333	Washington	5
Bethlehem-Center MS	Fredericktown	15333	Washington	5
Burgettstown El Ctr	Burgettstown	15021	Washington	16
Burgettstown MS/HS	Burgettstown	15021	Washington	14
Fort Cherry El Ctr	Mc Donald	15057	Washington	18
Fort Cherry JSHS	Mc Donald	15057	Washington	18
McGuffey HS	Claysville	15323	Washington	8
McGuffey MS	Claysville	15323	Washington	8
Muse El Sch	Muse	15350	Washington	4
Trinity MS	Washington	15301	Washington	13
Trinity North El Sch	Washington	15301	Washington	4
Trinity SHS	Washington	15301	Washington	7
Trinity South El Sch	Washington	15301	Washington	17

Pennsylvania Schools Near Gas Wells 2025				
Name	**City**	**Zip**	**County**	**Number of wells within 1 mile**
Trinity West El Sch	Washington	15301	Washington	7
Western Area CTC (of Washington County)*	Canonsburg	15317	Washington	17
Wylandville El Sch	Eighty Four	15330	Washington	9
Grandview El Sch	Derry	15627	Westmoreland	2
H W Good El Sch	Herminie	15637	Westmoreland	10
Kiski Area South Primary Sch	Export	15632	Westmoreland	15
West Hempfield MS	Irwin	15642	Westmoreland	6
West Newton El Sch	West Newton	15089	Westmoreland	4
Yough SHS	Herminie	15637	Westmoreland	21

*Schools within .3 miles of an active gas well.

Source: JSGC Analysis; “Oil and Gas Conventional Well Locations,” by DEP, 2025; and “Public School Location Data,” National Center for Education Statistics, 2025.

APPENDIX C

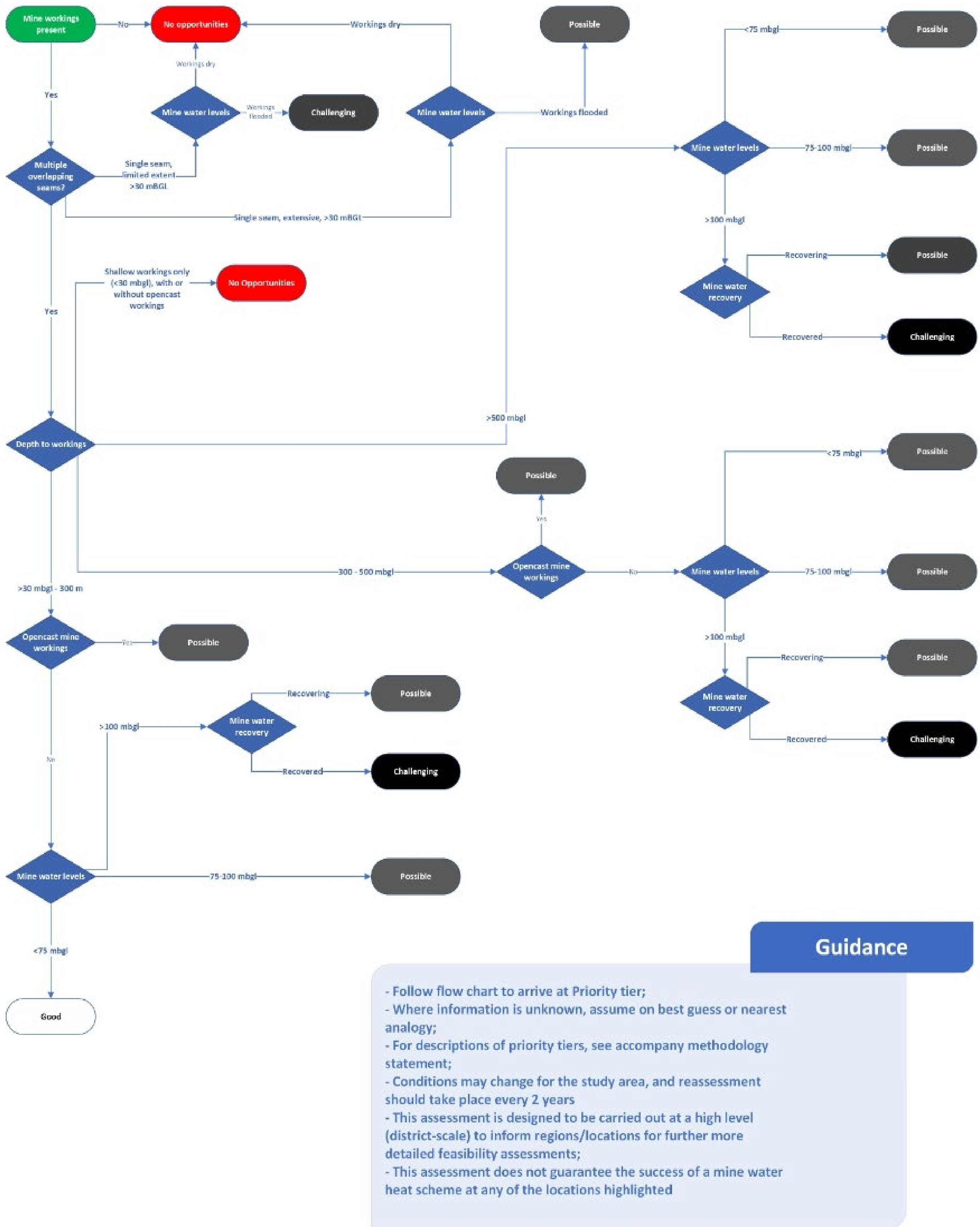
Pennsylvania DEP Assessment of Geothermal Technologies

Pennsylvania DEP Assessment of Geothermal Technologies 2025								
Title	**Definition**	**Attributes**	**Potential in PA**	**Reuse of Infrastructure**	**Considerations**	**System Depth (feet)**	**Groundwater Contact**	**Product**
Closed-Loop Borehole Heat Exchangers	Sealed system that circulated fluid in either vertical or horizontal loop	One of the most common types of geothermal systems in residential and commercial	Yes	Yes Oil and Gas wells	Requires cemented casings, uses include: district heating, greenhouses, and modular thermal storage	100-500+ (Vertical); 6-10 Horizonal Trench	No	Heating, Cooling
Open-Loop Systems	Groundwater from well or surface used as heat exchange fluid that is returned to the ground	Useful in places with abundant groundwater, DEP is cautious due to water regulations and limited sources	Limited	Not ideal for oil and gas, mines due to formation of scaling, contaminants, and regulatory constraints	DEP recommends fluid chemistry, flow rate, and isolation zones are documented and approved	Variable based on water depth	Yes	Heating, Cooling
Hybrid Systems	Geothermal paired with traditional HVAC or other types of Geothermal loops	Can reduce peak demand or recovering installation costs more rapidly	Yes, commercial retrofits or large facilities with seasonal heat load	Well suited for oil and gas well with a variable flow rate or subsurface, enables wells to be used that may not be viable on their own, optimize heat recovery and assist in phasing out fossil fuel with retrofits	Complicated to engineer, efficient capital costs, build in redundancy and reliability, incentivized by federal and state policy, but monitor dependent	Variable	Possible	Heating, electric from non geothermal systems (solar)
Binary Cycle Power Plants	Power plant uses moderate-temp geothermal fluids 185-374 F to heat secondary fluid with a low boiling point, which vaporized and spins a turbine	Allows electric generation without boiling water temperatures. Fluid does not touch turbine	High due to PA's low to moderate geothermal gradient.	Repurpose deep unconventional Utica shale wells. Can be installed at the surface with heat exchanges connected to wellhead circulation	Best option for producing electricity at PA temperature grade. Requires wells with integrity and insulation. Costs estimated to be $6 Million	2000+	--	Electric

Pennsylvania DEP Assessment of Geothermal Technologies 2025								
Title	**Definition**	**Attributes**	**Potential in PA**	**Reuse of Infrastructure**	**Considerations**	**System Depth (feet)**	**Groundwater Contact**	**Product**
Co-Production Systems	Simulation extraction of geothermal heat and hydrocarbons such as oil and gas from the same well	Uses water produced from oil & gas operations. Can extend the productive life of old wells	Strongly potential for reuse of infrastructure. Aligns with state efforts to reduce liability of abandoned wells.	Ideal for low and marginally producing wells or fields with water cut, potentially compatible with binary cycle power plants if water is over 185 F	Management of scaling, corrosion and water treatment, requires existing liquid separation infrastructure, applicable in enhanced recovery or depleted fields	Variable	--	Heating, electric potential at higher temps
Source: Adapted from "Testimony of Deputy Secretary Kurt Klapkowski," May 7, 2025.								

Opportunity Mapping Flowchart
Coal Authority, 2024

Opportunity Mapping Flowchart
Coal Authority, 2024



Guidance on Mine Water Heat Access Agreement Application Process Timeline for Schemes in England

The following timeline has been prepared by combining Mining Remediation Authority and Environment Agency requirements for proposed mine water heat schemes in England. A summary of the key milestones and estimated timescales is provided for each stage. Some of the activities will be undertaken in parallel with overlapping timescales, this has been taken into account for the total working days calculated for each stage. The timescales specified are estimates, based on average timescales taken by schemes who have already been through the process. Timescales could be shorter or longer, depending on the complexity of the scheme or the efficiency of site works. NOTE: The term 'applicant' is used by the Mining Remediation Authority until a mine water heat access agreement is entered into. Once this agreement is in place the term 'Operator' is used.

1. Stage 1 - Pre-construction of boreholes - Activity	**Working days**
Pre-application enquiries	30
Applicant to submit a completed application form for a permit for the purpose of a mine water heat scheme to the Mining Remediation Authority	1
Applicant to submit a completed WR32 groundwater investigation consent form to the Environment Agency	1
Environment Agency to assess WR32 and advise the applicant of the extent of the water feature survey	10
Mining Remediation Authority processes the application for a permit for the purpose of a mine water heat scheme	30
Applicant to undertake an initial water feature survey	65
Applicant to submit the initial water feature survey and updated hydrogeological conceptual model to the Environment Agency	1
Environment Agency to undertake technical assessment and draft groundwater investigation consent	30
Environment Agency to issue groundwater investigation consent to applicant, granting permission to drill boreholes and undertake well clearance	1
Mining Remediation Authority issues permits for the purpose of a mine water heat scheme	1
Total working days for stage 1	138

2. Stage 2 - Construction of boreholes and potential initial yield test - Activity	Working days
Applicant drills exploration and final boreholes	132
Total working days for stage 2	132

3. Stage 3 - Testing the boreholes and system - Activity	Working days
Applicant to request to vary groundwater investigation consent, allowing for pumping tests to be undertaken	1
Applicant to apply to the Environment Agency for an environmental permit or register an exemption for the discharge or re-injection activity	90
Applicant to submit a completed application form and supporting documents for a mine water heat access agreement to the Mining Remediation Authority	1
Environment Agency to assess the request to vary the groundwater investigation consent	30
Mining Remediation Authority completes initial review of application	5
Environment Agency to issue groundwater investigation consent variation to the applicant, granting permissions for pumping tests and system testing	1
Environment Agency to issue an environmental permit for discharge or notify applicant of exemption registration	1
Applicant to send a copy of the groundwater investigation consent to the Mining Remediation Authority	1
Mining Remediation Authority completes a stage 1 technical assurance process of the application and terms of the mine water heat access agreement agreed with the Operator	30
Mining Remediation Authority and applicant enter into mine water heat access agreement which incorporates Mining Remediation Authority permits	5
Data licence issued	1
Applicant to notify the Environment Agency of the pumping test programme at least 5 working days before the start of the pumping tests	6
Operator to notify the Mining Remediation Authority of the pumping test programme at least 10 working days before the start of the pumping tests	10
Applicant to undertake pumping tests, monitoring and data analysis	132
Total working days for stage 3	192

4. Stage 4 - Pre-operational phase - Activity	Working days
Applicant to submit application for an abstraction licence to the Environment Agency	1
Applicant to submit an application for a new environmental permit, or an application to vary an existing permit, to the Environment Agency, if required	1
Operator to submit a completed application form and supporting documents to vary the mine water heat access agreement to the operational phase to the Mining Remediation Authority	1
Mining Remediation Authority to review the application and notify the Operator if it is complete or advise what further information is required	10
Environment Agency to process, advertise and assess abstraction licence and environmental permit applications	122
Environment Agency to issue applicant with licence and permit where acceptable	1
Mining Remediation Authority completes a stage 2 technical assurance process of the application and terms of the mine water heat access agreement agreed with the Operator	123
Operator to send Mining Remediation Authority copies of the abstraction licence and environmental permit issued by the Environment Agency	7

4. Stage 4 - Pre-operational phase - Activity	Working days
Mining Remediation Authority and Operator enter into an operational phase mine water heat access agreement	1
Total working days for stage 4	132

Total overall activity	Total overall working days
Complete stages 1 to 4	529

5. Stage 5 - Operational phase includes
Long term mine water heat operation
Decommissioning or abandonment of scheme

Source: Mining Remediation Authority, *Guidance, Mine water heat access agreement application process timeline for schemes in England*, December 13, 2024, https://www.gov.uk/government/publications/mine-water-heat-access-agreement/mine-water-heat-access-agreement-application-process-timeline-for-schemes-in-england.

APPENDIX F

Public Schools Near Mine Water Sources				
Name	**City**	**ZIP**	**County**	**Mines within One Mile**
Baker El Sch	Pittsburgh	15241	Allegheny	1
Barrett El Sch	Homestead	15120	Allegheny	1
Carlynton JSHS	Carnegie	15106	Allegheny	12
Carnegie El Sch	Carnegie	15106	Allegheny	3
Chartiers Valley HS	Bridgeville	15017	Allegheny	2
Chartiers Valley Intrmd School	Pittsburgh	15220	Allegheny	3
Chartiers Valley MS	Bridgeville	15017	Allegheny	2
Chartiers Valley Primary Sch	Bridgeville	15017	Allegheny	3
Clara Barton El Sch	West Mifflin	15122	Allegheny	1
Curtisville Pri Ctr	Tarentum	15084	Allegheny	1
David B. Oliver Citywide Academy	Pittsburgh	15212	Allegheny	1
Dickson Prep STEAM Academy	Swissvale	15218	Allegheny	1
Donaldson Elem Sch	Oakdale	15071	Allegheny	14
Dr Cleveland Steward Jr El Sch	Monroeville	15146	Allegheny	2
East Allegheny JSHS	North Versailles	15137	Allegheny	2
Edgewood El STEAM Academy	Pittsburgh	15218	Allegheny	1
Evergreen El Sch	Monroeville	15146	Allegheny	1
Forbes Road Career and Technology Center	Monroeville	15146	Allegheny	5
Fred L Aiken El Sch	Pittsburgh	15220	Allegheny	1
Gateway MS	Monroeville	15146	Allegheny	2
Gateway SHS	Monroeville	15146	Allegheny	2
Gill Hall El Sch	Jefferson Hills	15025	Allegheny	1
Highlands El Sch	Tarentum	15084	Allegheny	1
Jefferson Hills Intermediate Sch	Jefferson Hills	15025	Allegheny	5
Life Male STEAM Academy CS	Pittsburgh	15235	Allegheny	6
Linton MS	Pittsburgh	15235	Allegheny	1
Logan El Sch	North Versailles	15137	Allegheny	2
McKee El Sch	Oakdale	15071	Allegheny	28
Montour El Sch	McKees Rocks	15136	Allegheny	12
Montour HS	Mc Kees Rocks	15136	Allegheny	8
Moss Side MS	Monroeville	15146	Allegheny	2
O'Block El Sch	Pittsburgh	15239	Allegheny	6
Parkway West Career and Technology Center	Oakdale	15071	Allegheny	7
Penn Hills CS of Entrepreneurship	Pittsburgh	15235	Allegheny	5
Penn Hills El Sch	Pittsburgh	15235	Allegheny	5
Penn Hills SHS	Pittsburgh	15235	Allegheny	9
Pittsburgh Allderdice HS	Pittsburgh	15217	Allegheny	2
Pittsburgh Allegheny 6-8	Pittsburgh	15212	Allegheny	1
Pittsburgh Allegheny K-5	Pittsburgh	15212	Allegheny	1
Pittsburgh Arlington K-8	Pittsburgh	15210	Allegheny	1
Pittsburgh Banksville K-5	Pittsburgh	15216	Allegheny	2
Pittsburgh Beechwood K-5	Pittsburgh	15216	Allegheny	4
Pittsburgh Brashear HS	Pittsburgh	15216	Allegheny	4
Pittsburgh Carmalt K-8	Pittsburgh	15226	Allegheny	3
Pittsburgh Carrick HS	Pittsburgh	15210	Allegheny	2
Pittsburgh Classical 6-8	Pittsburgh	15220	Allegheny	2
Pittsburgh Colfax K-8	Pittsburgh	15217	Allegheny	2
Pittsburgh Concord K-5	Pittsburgh	15210	Allegheny	2

Public Schools Near Mine Water Sources				
Name	City	ZIP	County	Mines within One Mile
Pittsburgh Grandview K-5	Pittsburgh	15210	Allegheny	2
Pittsburgh Greenfield K-8	Pittsburgh	15207	Allegheny	2
Pittsburgh King K-8	Pittsburgh	15212	Allegheny	1
Pittsburgh Minadeo K-5	Pittsburgh	15217	Allegheny	2
Pittsburgh Pioneer	Pittsburgh	15226	Allegheny	5
Pittsburgh Schiller 6-8	Pittsburgh	15212	Allegheny	1
Pittsburgh South Brook 6-8	Pittsburgh	15226	Allegheny	4
Pittsburgh South Hills 6-8	Pittsburgh	15216	Allegheny	3
Pittsburgh Spring Hill K-5	Pittsburgh	15212	Allegheny	1
Pittsburgh West Liberty K-5	Pittsburgh	15226	Allegheny	4
Pittsburgh Westwood K-5	Pittsburgh	15205	Allegheny	2
Pivik El Sch	Plum	15239	Allegheny	1
Propel CS-Braddock Hills	Pittsburgh	15221	Allegheny	4
Propel CS-East	Turtle Creek	15145	Allegheny	7
Propel CS-Homestead	Homestead	15120	Allegheny	1
Propel CS-Montour	Pittsburgh	15205	Allegheny	11
Propel CS-Northside	Pittsburgh	15212	Allegheny	1
South Fayette El Sch	McDonald	15057	Allegheny	3
South Fayette HS	McDonald	15057	Allegheny	3
South Fayette Intermediate Sch	McDonald	15057	Allegheny	3
South Fayette MS	McDonald	15057	Allegheny	3
Thomas Jefferson HS	Jefferson Hills	15025	Allegheny	4
Turner Intermediate Sch	Wilkinsburg	15221	Allegheny	10
Turtle Creek EL STEAM Academy	Turtle Creek	15145	Allegheny	3
Twin Rivers El Sch	McKeesport	15132	Allegheny	2
West Allegheny MS	Imperial	15126	Allegheny	3
West Allegheny SHS	Imperial	15126	Allegheny	2
Westinghouse Arts Academy CS	Wilmerding	15148	Allegheny	6
Wilkins El STEAM Academy	Pittsburgh	15235	Allegheny	3
Wilson Elementary School	Imperial	15126	Allegheny	1
Woodland Hills HS	Pittsburgh	15221	Allegheny	4
Young Scholars of Western Pennsylvania CS	Pittsburgh	15234	Allegheny	1
Armstrong JSHS	Kittanning	16201	Armstrong	1
Elderton El Sch	Elderton	15736	Armstrong	1
Shannock Valley El Sch	Rural Valley	16249	Armstrong	8
West Shamokin JSHS	Rural Valley	16249	Armstrong	5
Beaver Falls Area SHS	Beaver Falls	15010	Beaver	1
Beaver Falls MS	Beaver Falls	15010	Beaver	1
Central El Sch	Beaver Falls	15010	Beaver	1
New Brighton Area MS	New Brighton	15066	Beaver	1
Patterson Primary Sch	Beaver Falls	15010	Beaver	2
Moniteau JSHS	West Sunbury	16061	Butler	3
Slippery Rock Area El Sch	Slippery Rock	16057	Butler	2
Slippery Rock Area HS	Slippery Rock	16057	Butler	2
Slippery Rock Area MS	Slippery Rock	16057	Butler	2
Admiral Peary Area Vocational-Technical School	Ebensburg	15931	Cambria	1
Blacklick Valley El Ctr	Nanty Glo	15943	Cambria	4
Blacklick Valley JSHS	Nanty Glo	15943	Cambria	10

Public Schools Near Mine Water Sources				
Name	**City**	**ZIP**	**County**	**Mines within One Mile**
Cambria El Sch	Ebensburg	15931	Cambria	1
Cambria Heights El Sch	Carrolltown	15722	Cambria	1
Central Cambria HS	Ebensburg	15931	Cambria	1
Central Cambria MS	Ebensburg	15931	Cambria	1
Ferndale Area JSHS	Johnstown	15905	Cambria	7
Ferndale El Sch	Johnstown	15905	Cambria	6
Forest Hills El Sch	Sidman	15955	Cambria	1
Forest Hills JSHS	Sidman	15955	Cambria	1
Greater Johnstown MS	Johnstown	15902	Cambria	11
Greater Johnstown School District's Cyber Academy	Johnstown	15902	Cambria	11
Greater Johnstown SHS	Johnstown	15902	Cambria	12
Northern Cambria El Sch	Northern Cambria	15714	Cambria	6
Northern Cambria HS	Northern Cambria	15714	Cambria	9
Northern Cambria MS	Northern Cambria	15714	Cambria	6
Penn Cambria HS	Cresson	16630	Cambria	3
Penn Cambria Intrmd Sch	Lilly	15938	Cambria	8
Penn Cambria MS	Gallitzin	16641	Cambria	1
Penn Cambria Pre-Primary	Cresson	16630	Cambria	3
Penn Cambria Primary Sch	Lilly	15938	Cambria	3
Portage Area El Sch	Portage	15946	Cambria	8
Portage Area JSHS	Portage	15946	Cambria	6
Westmont Hilltop JSHS	Johnstown	15905	Cambria	1
Mountaintop Area El Sch	Snow Shoe	16874	Centre	1
Philipsburg El Sch	Philipsburg	16866	Centre	18
Philipsburg-Osceola Area HS	Philipsburg	16866	Centre	8
Clarion Career Center	Shippenville	16254	Clarion	2
Clarion-Limestone Area JSHS	Strattanville	16258	Clarion	11
Clarion-Limestone El Sch	Strattanville	16258	Clarion	11
North Clarion Co El Sch	Tionesta	16353	Clarion	6
North Clarion Co JSHS	Tionesta	16353	Clarion	6
Redbank Valley HS	New Bethlehem	16242	Clarion	1
Redbank Valley Primary School	New Bethlehem	16242	Clarion	1
Sligo El Sch	Sligo	16255	Clarion	6
Clearfield Area El Sch	Clearfield	16830	Clearfield	1
Clearfield Area JSHS	Clearfield	16830	Clearfield	1
Clearfield Career & Technology Center	Clearfield	16830	Clearfield	1
DuBois Area MS	DuBois	15801	Clearfield	1
DuBois Area SHS	DuBois	15801	Clearfield	1
Juniata El Sch	DuBois	15801	Clearfield	1
Moshannon Valley El Sch	Houtzdale	16651	Clearfield	3
Moshannon Valley JSHS	Houtzdale	16651	Clearfield	2
Oklahoma El Sch	DuBois	15801	Clearfield	1
Osceola Mills El Sch	Osceola Mills	16666	Clearfield	6
Philipsburg-Osceola Area MS	Philipsburg	16866	Clearfield	11
Wasson Avenue El Sch	DuBois	15801	Clearfield	3
West Branch Area El Sch	Morrisdale	16858	Clearfield	4
West Branch Area HS	Morrisdale	16858	Clearfield	4
West Branch MS	Morrisdale	16858	Clearfield	4

Public Schools Near Mine Water Sources				
Name	**City**	**ZIP**	**County**	**Mines within One Mile**
Bennetts Valley El Sch	Weedville	15868	Elk	7
South St Marys Street El Sch	Saint Marys	15857	Elk	1
St Marys Area MS	Saint Marys	15857	Elk	1
Albert Gallatin Area SHS	Uniontown	15401	Fayette	8
Albert Gallatin South MS	Point Marion	15474	Fayette	14
Belle Vernon Area MS	Belle Vernon	15012	Fayette	2
Ben Franklin Sch	Uniontown	15401	Fayette	1
Clark El Sch	Uniontown	15401	Fayette	4
Connellsville Area MS	Connellsville	15425	Fayette	1
Connellsville Area SHS	Connellsville	15425	Fayette	1
Fayette Career & Technical Institute	Uniontown	15401	Fayette	2
Frazier El Sch	Perryopolis	15473	Fayette	1
Frazier HS	Perryopolis	15473	Fayette	1
Frazier MS	Perryopolis	15473	Fayette	1
Friendship Hill El Sch	Point Marion	15474	Fayette	12
Hatfield El Sch	Uniontown	15401	Fayette	2
Lafayette El Sch	Uniontown	15401	Fayette	4
Lafayette MS	Uniontown	15401	Fayette	4
Marion El Sch	Belle Vernon	15012	Fayette	2
Masontown El Sch	Masontown	15461	Fayette	1
Smithfield El Sch	Smithfield	15479	Fayette	20
Springfield El Sch	Normalville	15469	Fayette	1
Uniontown Area SHS	Uniontown	15401	Fayette	2
West Crawford El Sch	Connellsville	15425	Fayette	1
Bobtown El Sch	Bobtown	15315	Greene	7
Jefferson-Morgan El Sch	Jefferson	15344	Greene	1
Jefferson-Morgan MS/HS	Jefferson	15344	Greene	1
Blairsville El Sch	Blairsville	15717	Indiana	5
Homer-Center El Sch	Homer City	15748	Indiana	5
Homer-Center JSHS	Homer City	15748	Indiana	7
Marion Center Area JR/SR HS	Marion Center	15759	Indiana	2
River Valley HS	Blairsville	15717	Indiana	5
River Valley MS	Blairsville	15717	Indiana	5
United El Sch	Armagh	15920	Indiana	3
United JSHS	Armagh	15920	Indiana	3
W.A. McCreery El Sch	Marion Center	15759	Indiana	2
Brockway Area Elementary Sch	Brockway	15824	Jefferson	2
Brockway Area JSHS	Brockway	15824	Jefferson	2
C G Johnson El Sch	Reynoldsville	15851	Jefferson	2
Carbondale Area JSHS	Carbondale	18407	Lackawanna	4
Carbondale El Sch	Carbondale	18407	Lackawanna	2
Career Technology Center of Lackawanna	Scranton	18508	Lackawanna	3
Dunmore El Ctr	Dunmore	18512	Lackawanna	2
Dunmore JSHS	Dunmore	18512	Lackawanna	2
Fell CS	Simpson	18407	Lackawanna	4
Howard Gardner Multiple Intelligence CS	Scranton	18505	Lackawanna	1
John G Whittier #2	Scranton	18505	Lackawanna	1
McNichols Plaza	Scranton	18505	Lackawanna	1

Public Schools Near Mine Water Sources				
Name	**City**	**ZIP**	**County**	**Mines within One Mile**
Robert Morris #27	Scranton	18509	Lackawanna	1
Valley View El Ctr	Peckville	18452	Lackawanna	1
Valley View HS	Archbald	18403	Lackawanna	1
Valley View MS	Archbald	18403	Lackawanna	1
William Prescott #38	Scranton	18510	Lackawanna	1
Dana El Ctr	Forty Fort	18704	Luzerne	2
Daniel J Flood El Sch	Wilkes Barre	18705	Luzerne	1
Dr David W Kistler El Sch	Wilkes Barre	18702	Luzerne	1
Drums El/MS	Drums	18222	Luzerne	1
Freeland El/MS	Freeland	18224	Luzerne	2
GNA El Ctr	Nanticoke	18634	Luzerne	7
Greater Nanticoke Area Ed Ctr	Nanticoke	18634	Luzerne	7
Greater Nanticoke Area SHS	Nanticoke	18634	Luzerne	6
Hanover Area JSHS	Hanover Township	18706	Luzerne	6
Hanover Area Memorial El Sch	Hanover Township	18706	Luzerne	2
Hanover Green El Sch	Hanover Township	18706	Luzerne	3
Kennedy Early Childhood Center	Nanticoke	18634	Luzerne	6
Lee Park El Sch	Hanover Township	18706	Luzerne	2
Lyndwood El Sch	Hanover Township	18706	Luzerne	2
Pittston Area MS	Pittston	18640	Luzerne	3
Pittston City Intrmd Ctr	Pittston	18640	Luzerne	3
Solomon/Plains El Sch	Plains	18705	Luzerne	4
Solomon/Plains MS	Plains	18705	Luzerne	4
Wilkes-Barre Area Career & Technical Center	Wilkes-Barre	18705	Luzerne	3
Wilkes-Barre Area HS	Plains	18705	Luzerne	1
Wilkes-Barre Area SD STEM Academy	Plains	18705	Luzerne	1
Wolfpack Early Learning Academy	Wilkes-Barre	18702	Luzerne	1
Wyoming Area Intermediate Ctr	West Pittston	18643	Luzerne	3
Wyoming Area Kindergarten Ctr	Exeter	18643	Luzerne	1
Wyoming Area Sec Ctr	Exeter	18643	Luzerne	1
Case Avenue El Sch	Sharon	16146	Mercer	1
Musser El Sch	Sharon	16146	Mercer	1
Sharon HS	Sharon	16146	Mercer	1
Sharon MS	Sharon	16146	Mercer	1
Line Mountain El Sch	Trevorton	17881	Northumberland	3
Mount Carmel Area El Sch	Mount Carmel	17851	Northumberland	1
Northumberland Career and Technology Center	Coal Township	17866	Northumberland	5
Shamokin Area El Sch	Coal Township	17866	Northumberland	5
Shamokin Area HS	Shamokin	17866	Northumberland	5
Shamokin Area Intermediate Sch	Coal Township	17866	Northumberland	5
Shamokin Area MS	Shamokin	17866	Northumberland	5
Clarke El Ctr	Pottsville	17901	Schuylkill	1
Early Childhood Edu Ctr	Pottsville	17901	Schuylkill	1
Gillingham Charter School	Pottsville	17901	Schuylkill	12
Lengel MS	Pottsville	17901	Schuylkill	5
Minersville Area El Ctr	Minersville	17954	Schuylkill	1
Minersville Area JSHS	Minersville	17954	Schuylkill	1
Saint Clair Area El/MS	Saint Clair	17970	Schuylkill	4

Public Schools Near Mine Water Sources				
Name	**City**	**ZIP**	**County**	**Mines within One Mile**
Schuylkill Technology Centers-South Campus	Mar Lin	17951	Schuylkill	3
Shenandoah Valley El Sch	Shenandoah	17976	Schuylkill	1
Shenandoah Valley JSHS	Shenandoah	17976	Schuylkill	1
Tamaqua Area MS	Tamaqua	18252	Schuylkill	10
Tamaqua Area SHS	Tamaqua	18252	Schuylkill	9
Tamaqua El Sch	Tamaqua	18252	Schuylkill	8
Berlin Brothersvalley El Sch	Berlin	15530	Somerset	1
Berlin Brothersvalley MS	Berlin	15530	Somerset	1
Berlin Brothersvalley SHS	Berlin	15530	Somerset	1
Cairnbrook El Sch	Cairnbrook	15924	Somerset	4
Meyersdale Area El Sch	Meyersdale	15552	Somerset	14
Meyersdale Area HS	Meyersdale	15552	Somerset	14
Meyersdale Area MS	Meyersdale	15552	Somerset	13
North Star East MS	Stoystown	15563	Somerset	14
Rockwood Area El Sch	Rockwood	15557	Somerset	1
Rockwood Area JSHS	Rockwood	15557	Somerset	1
Shade JSHS	Cairnbrook	15924	Somerset	4
Windber El Sch	Windber	15963	Somerset	3
Forest City Regional El Sch	Forest City	18421	Susquehanna	2
Forest City Regional HS	Forest City	18421	Susquehanna	2
Blossburg El Sch	Blossburg	16912	Tioga	6
Victory El Sch	Harrisville	16038	Venango	4
Burgettstown El Ctr	Burgettstown	15021	Washington	2
Burgettstown MS/HS	Burgettstown	15021	Washington	2
Cecil Intrmd Sch	Mc Donald	15057	Washington	1
Fort Cherry JSHS	Mc Donald	15057	Washington	1
Ringgold El Sch North	Finleyville	15332	Washington	4
Western Area CTC (of Washington)	Canonsburg	15317	Washington	1
Amos K Hutchinson El Sch	Greensburg	15601	Westmoreland	1
Baggaley El Sch	Latrobe	15650	Westmoreland	1
Dr Robert Ketterer CS Inc	Latrobe	15650	Westmoreland	5
H W Good El Sch	Herminie	15637	Westmoreland	1
Hahntown El Sch	North Huntingdon	15642	Westmoreland	1
Kiski Area East Primary Sch	Vandergrift	15690	Westmoreland	3
Kiski Area HS	Vandergrift	15690	Westmoreland	3
Kiski Area IHS	Vandergrift	15690	Westmoreland	3
Latrobe El Sch	Latrobe	15650	Westmoreland	3
Martin Sch	New Kensington	15068	Westmoreland	2
Metzgar El Sch	New Alexandria	15670	Westmoreland	3
Monessen El Ctr	Monessen	15062	Westmoreland	1
Monessen MS	Monessen	15062	Westmoreland	1
Monessen SHS	Monessen	15062	Westmoreland	1
Norwin HS	North Huntingdon	15642	Westmoreland	1
Sheridan Terrace El Sch	North Huntingdon	15642	Westmoreland	6
Southmoreland Primary Center	Alverton	15612	Westmoreland	8
Southmoreland SHS	Alverton	15612	Westmoreland	10
Stewartsville El Sch	North Huntingdon	15642	Westmoreland	2
Yough SHS	Herminie	15637	Westmoreland	3

Public Schools Near Mine Water Sources				
Name	**City**	**ZIP**	**County**	**Mines within One Mile**
Source: JSGC Analysis; "AML Inventory Sites," DEP, 2025; "Public School Locations," National Center for Education Statistics, 2025.				

Post Secondary Education Institutions Near Mine Water Sources

Higher Education	City	County	Mine Water Sites within One Mile	Area of Campus in Square Kilometers
Community College of Allegheny County	Pittsburgh	Allegheny	1	10.89
Community College of Allegheny County - Boyce Campus	Monroeville	Allegheny	13	10.4
Community College of Allegheny County - South Campus	West Mifflin	Allegheny	1	11.41
Pittsburgh Technical College	Oakdale	Allegheny	27	11.22
Rosedale Technical College	Pittsburgh	Allegheny	14	9
Waynesburg University - Monroeville Center	Pittsburgh	Allegheny	6	8.54
Slippery Rock University of Pennsylvania	Slippery Rock	Butler	12	18.5
Mount Aloysius College	Cresson	Cambria	1	12.31
Pennsylvania Highlands Community College	Johnstown	Cambria	1	9.36
Pennsylvania Highlands Community College - Ebensburg Center	Ebensburg	Cambria	1	8.72
University Of Pittsburgh-Johnstown	Johnstown	Cambria	1	14.36
Clarion University of Pennsylvania	Clarion	Clarion	2	12.31
Pennsylvania State University-Penn State Dubois	Dubois	Clearfield	1	10.28
Pennsylvania State University-Penn State Fayette - Eberly	Lemont Furnace	Fayette	1	12.23
Johnson College	Scranton	Lackawanna	3	8.74
Marywood University	Scranton	Lackawanna	4	13.76
Pennsylvania State University - Penn State Scranton	Dunmore	Lackawanna	3	10.72
University Of Scranton	Scranton	Lackawanna	1	11.72
Luzerne County Community College	Nanticoke	Luzerne	3	12.75
Pennsylvania State University - Penn State Shenango	Sharon	Mercer	1	10.48
Empire Beauty School-Pottsville	Pottsville	Schuylkill	5	8.96
Lehigh Carbon Community College - Airport Site	Tamaqua	Schuylkill	11	8.72
Saint Vincent College	Latrobe	Westmoreland	4	13.26
Westmoreland County Community College - Laurel Education Center	Latrobe	Westmoreland	4	8.53

Source: Analysis by JSGC; "AML Inventory Sites," DEP, 2025; "Colleges and Universities Campuses," GeoPlatform ArcGIS Online, 2022.

Hospitals Near Mine Water Sources				
Hospital	**City**	**Zip Code**	**County**	**Mine Water Sites within One Mile**
AHN Jefferson Hospital	Jefferson Hills	15025	Allegheny	1
AHN-Allegheny General Hospital	Pittsburgh	15212	Allegheny	1
Forbes Hospital	Monroeville	15146	Allegheny	1
PAM Health Specialty Hospital of Pittsburgh	Oakdale	15071	Allegheny	7
Select Specialty Hospital -McKeesport, Inc.	McKeesport	15132	Allegheny	2
University of Pittsburgh Medical Center Mckeesport	McKeesport	15132	Allegheny	2
University of Pittsburgh Medical Center Mckeesport	McKeesport	15132	Allegheny	2
Heritage Valley Beaver	Beaver	15009	Beaver	3
PAM Health Specialty Hospital at Heritage Valley	Beaver	15009	Beaver	3
Conemaugh Memorial Medical Center	Johnstown	15905	Cambria	11
Conemaugh Miners Medical Center	Hastings	16646	Cambria	3
Select Specialty Hospital Johnstown	Johnstown	15901	Cambria	3
Clarion Hospital	Clarion	16214	Clarion	1
Penn Highlands DuBois	DuBois	16830	Clearfield	3
Penn Highlands Elk	St. Marys,	15857	Elk	1
Penn Highlands Connellsville	Connellsville	15425	Fayette	1
Geisinger Community Medical Center	Scranton	18510	Lackawanna	1
Lehigh Valley Hospital - Dickson City	Dickson City	18519	Lackawanna	2
Geisinger Wyoming Valley Medical Center	Wilkes-Barre	18711	Luzerne	3
John Heinz Institute of Rehabilitation Medicine	Wilkes-Barre	18702	Luzerne	1
PAM Health Specialty Hospital of Wilkes Barre	Wilkes-Barre	18764	Luzerne	1
Sharon Regional Medical Center	Sharon	16146	Mercer	1
Lehigh Valley Hospital - Schuylkill	Pottsville	17901	Schuylkill	14
St. Luke's Miners Memorial Hospital	Coaldale	18218	Schuylkill	3
Chan Soon-Shiong Medical Center at Windber	Windber	15963	Somerset	2
Penn Highlands Mon Valley	Monongahela	15063	Washington	2
Excela Health Latrobe Hospital	Latrobe	15650	Westmoreland	3
Select Specialty Hospital- Laurel Highlands, Inc	Latrobe	15650	Westmoreland	3
Source: Analysis by JSGC; “AML Inventory Sites,” DEP, 2025; “PA Hospitals,” DOH, May 2025.				

Correction Facilities Near Mine Water Sources					
Correction Facilities	City	Zip code	County	Nearby Mine Water Sources	Approximate Distance
Allegheny County Bureau of Corrections	Pittsburgh	15219	Allegheny	1	1.5
Carbon County Correctional Facility	Nesquehoning	18240-1801	Carbon	1	1.1
Clarion County Correctional Facility	Shippenville	16254	Clarion	1	0.6
SCI Houtzdale	Houtzdale	16651	Clearfield	2	0.7
Fayette County Prison	Uniontown	15401	Fayette	1	1.2
SCI Fayette	La Belle	15450	Fayette	1	1.3
Lackawanna County Prison	Scranton	18509	Lackawanna	2	1.2
Luzerne County Correctional Facility	Wilkes-Barre	18702	Luzerne	1	1.4
SCI Retreat*	Glen Lyon	18617	Luzerne	1	1.4
SCI Coal Township	Coal Township	17866	Northumberland	1	0.8
SCI Frackville	Frackville	17931	Schuylkill	1	1
SCI Mahanoy	Frackville	17932	Schuylkill	1	0.4
SCI Somerset	Somerset	15510	Somerset	1	0.9

*Prison closed.

Source: Analysis by JSGC; “PA Prison Locations,” Bucknell University, 2023; “AML Inventory Sites,” DEP 2025.

Museums, Libraries, and Cultural Centers Near Mine Water Sources				
Entity	**City**	**Zip**	**County**	**Mine Water Sites within One Mile**
Andrew Carnegie Free Library	Carnegie	15106-2644	Allegheny	3
Andy Warhol Museum	Pittsburgh	15212	Allegheny	1
Bridgeville Area Historical Society	Bridgeville	15017-0652	Allegheny	4
Carnegie Science Center	Pittsburgh	15212-5850	Allegheny	1
Children’s Museum of Pittsburgh	Pittsburgh	15212-5250	Allegheny	1
Children's Museum of Pittsburgh	Pittsburgh	15212	Allegheny	1
George Westinghouse Museum	Wilmerding	15148	Allegheny	6
National Aviary in Pittsburgh	Pittsburgh	15212	Allegheny	1
National Museum of Broadcasting	Pittsburgh	15221-1522	Allegheny	3
Pittsburgh Jazz Artist Museum Organization	Pittsburgh	15205-1520	Allegheny	2
Tour-Ed Mine and Museum	Tarentum	15084	Allegheny	1
West Penn Cultural Center Inc	Pittsburgh	15220-4034	Allegheny	1
Western Pennsylvania Jewish Sports Hall of Fame Inc	Pittsburgh	15217-1563	Allegheny	1
Armstrong County Historical Museum and Genealogical Society	Kittanning	16201-0735	Armstrong	6
Beaver County Industrial Museum	Beaver Falls	15010-2956	Beaver	2
Cambria County Community Art Center	Johnstown	15907-0866	Cambria	3
Johnstown Flood Museum	Johnstown	15901	Cambria	3
Nant-Y-Glo Tri Area Museum & Historical Society	Nanty Glo	15943-1302	Cambria	17
No. 9 Coal Mine and Museum	Lansford	18232-1213	Carbon	3
Clearfield Community Museum	Clearfield	16830-2565	Clearfield	2
Coal and Coke Museum Association of Pennsylvania	Connellsville	15425	Fayette	1
Flatiron Building Heritage Center	Brownsville	15417	Fayette	1
Monongahela River Railroad and Transportation Museum	Brownsville	15417-0360	Fayette	1
Nemacolin Castle	Brownsville	15417	Fayette	1
Anthracite Museum	Ashland	17921	Lackawanna	3
Everhart Museum of Natural History Science & Art	Scranton	18510-2380	Lackawanna	1
Houdini Museum	Scranton	18504	Lackawanna	1
Maslow Collection	Scranton	18509	Lackawanna	2
Lower Anthracite Model Railroad Club Inc.	Shamokin	17872-6858	Northumberland	13
Source: Analysis by JSGC; “AML Inventory Sites,” DEP, 2025; Museum location data by Esri users, 2016.				