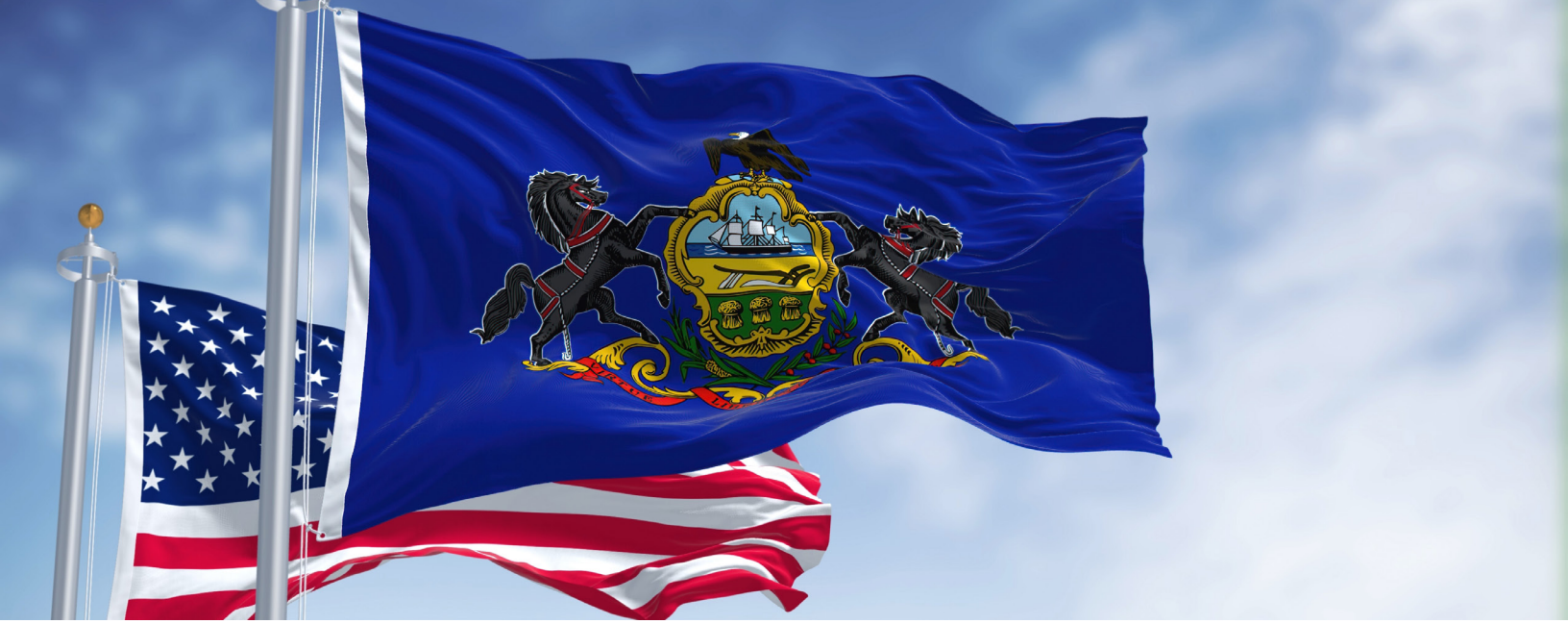
The Future of Geothermal in Pennsylvania

Executive Summary

February 2025



Executive Summary

Pennsylvania can help write the next chapter for American subsurface energy: leveraging abundant, secure and always-on geothermal energy. The Commonwealth's subsurface stores thousands of times more energy in the form of heat than it consumes annually. The resources and workforce of its existing oil and gas industry can be deployed to generate geothermal energy throughout Pennsylvania.

Pennsylvania has been at the leading edge of American energy production since the 1700s, when coal mines were dug across the Monongahela River from Pittsburgh. The nation's first oil well was drilled in 1859 in Titusville, in the northwest corner of the Commonwealth. For the last twenty years, the Keystone State has led the shale boom, making Pennsylvania one of the world's top natural gas producers. Now, with the skills, knowledge, and resources, Pennsylvania is well positioned to become a leader in the next energy revolution to emerge in the U.S.: abundant, secure, and always-on next-generation geothermal energy.

To produce geothermal energy, fluids are circulated underground to capture some of Earth's ubiquitous subsurface heat, then brought back to the surface. There, the heat can be used for thermal energy or to make electricity. Traditionally, geothermal energy production has only been possible in volcanic regions—areas where the right mixture of heat, water, and rock permeability lies close to the surface. These unique conditions, called "hydrothermal resources," are often associated with surface features like hot springs and geysers. They are extremely limited geographically. However, it is hot everywhere underground. Technological advances in drilling and subsurface engineering over the past two decades have made it possible to tap into that geothermal energy almost anywhere, including Pennsylvania.

The New Geothermal Opportunity

Because of the robust oil and gas industry in Pennsylvania—and a corps of geologists and researchers—subsurface temperatures in the Commonwealth have been recorded and modeled for years. That data shows that there is 1000-fold (or more) energy available in the form of heat underground than Pennsylvanians consume each year. And there are opportunities to use it, in some form, all across the Commonwealth's 46,000-plus square miles.

If Pennsylvania were to develop and grow this abundant local energy source, the impact would be swift and

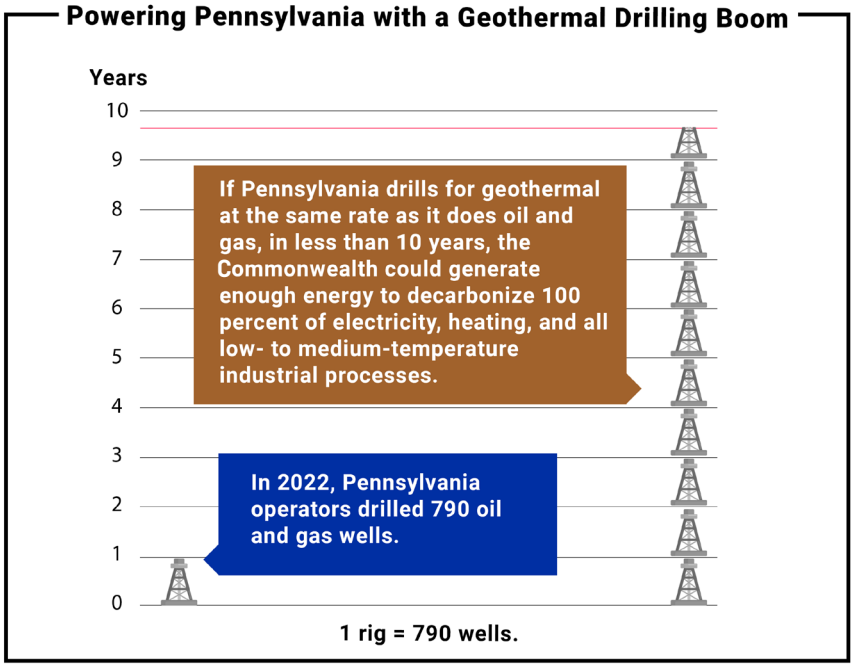


Figure ES.1: The potential for geothermal energy in Pennsylvania.

significant. Take the current energy industry: using its existing resources and workforce to drill for geothermal at the same rate it currently drills for oil and gas, in one year, the Commonwealth could generate enough geothermal energy to meet all thermal demands for its commercial heating and low-temperature industrial processes. Geothermal could also help some of the region's largest energy users—the industrial and agriculture sectors—reduce emissions while maintaining large numbers of jobs in the drilling sector.

Working with new and emerging technologies, geothermal could generate enough energy to meet 100 percent of Pennsylvania's electricity, and heating, and low- to medium-temperature industrial process needs in as few as 10 years.

What are these new technologies? 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. For Advanced Geothermal Systems (AGS), drillers bore lengthy wells deep into hot rock, but instead of using hydraulic fracturing to create a reservoir, fluids are simply circulated within a closed loop of pipes, absorbing the heat and bringing it back to the surface.

Engineers have also developed geothermal direct-use systems to use heat energy just below a source or a region. These include improved Ground Source Heat Pumps (GSHP) to harvest the constant temperature of the shallow subsurface, as well as deeper direct-use wells drilled to reach higher temperatures. In some areas, developers are supplying direct-use geothermal to a large area, clusters of buildings, or a full district from a central location. This is called district heating or a Thermal Energy Network (TEN).

In many cases, the hotter the subsurface rock, the more effective and economical geothermal energy can be. This is especially true if the goal is to produce electricity. But—importantly for Pennsylvania— super hot rocks are not actually necessary to effectively put geothermal to work. Many uses only need high-enough temperatures. In fact, worldwide, temperatures below 150°C are perfectly sufficient for 30 percent of heat for manufacturing processes, and all building heating and cooling. Much of the thermal demand in agriculture also uses lower temperatures, from 0°C to 99°C. (See Figure ES.2.) There is a robust manufacturing sector and agriculture industry in Pennsylvania—and the Commonwealth's subsurface characteristics are especially well-suited to provide them with geothermal energy at the temperatures they need.

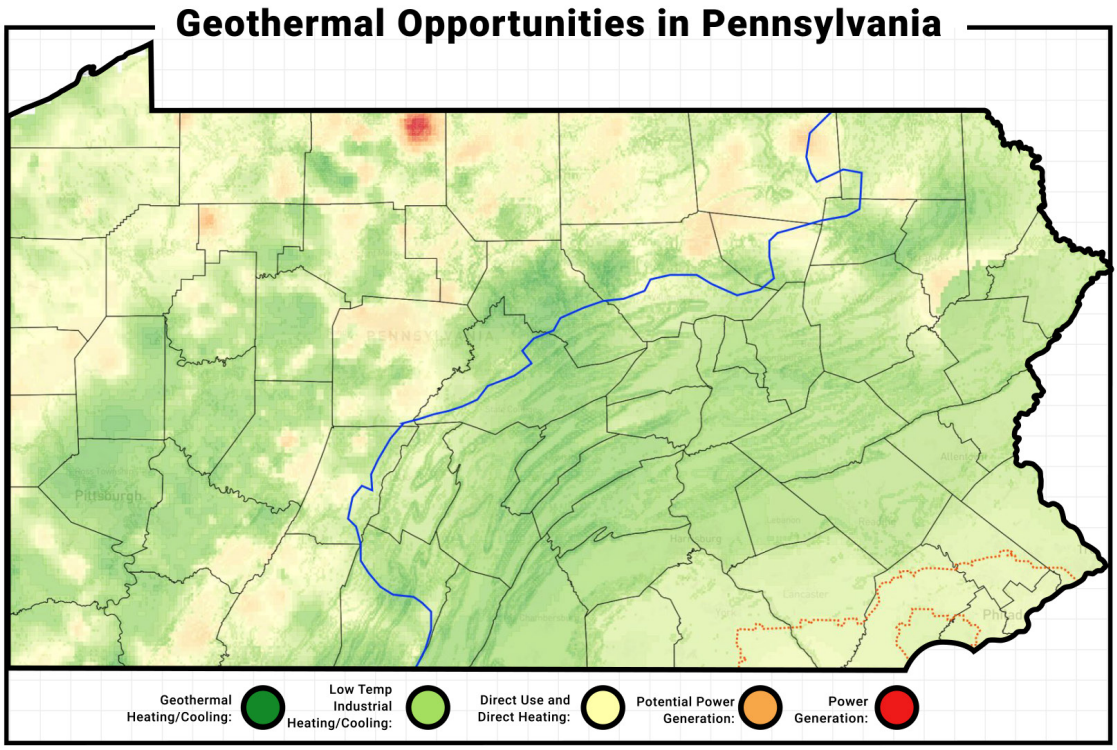


Figure ES.2: Dark green portions of the map are likely limited to using ground-source heat pumps in buildings to provide heating and cooling. Light green and yellow areas are suitable for heat pumps but also present opportunities to use geothermal directly for district heating and to provide heat for industrial processes. Locations in orange and red may be suitable for electricity generation. The area to the right of the blue line shows the parts of the state lacking sufficient direct measurements and requiring the use of geological models to estimate temperatures. Regional geological modeling indicates the areas near Philadelphia within the red dotted line are likely hotter at shallower depths than the surrounding areas, though exploratory wells are needed to verify modeled favorability. Source: GeoMap

Measurements and models of subsurface temperature in Pennsylvania indicate that its agriculture sector is an ideal candidate for geothermal direct-use in places such as York, Lancaster, and Chester counties. (See chapters 2 and 3.) As for manufacturing, the distribution of Pennsylvania's subsurface heat indicates promising opportunities for industrial geothermal direct-use in the petroleum and coal sector in Philadelphia, Delaware, McKean, Butler, and Warren counties, and the pharmaceutical sector in Montgomery County. Add to all of this, there are "hot spots" in the Commonwealth where geothermal technology could cost-competitively generate electricity via EGS or AGS.

Pennsylvania has robust potential for geothermal energy development. Realizing it will require putting the right legal, regulatory, and policy framework into place, building on its already strong foundation.

Legal, Regulatory, and Policy Support

A key question to ask when developing geothermal as an energy source is: Who owns the resources associated with geothermal energy? The heat, the water, the pores in the earth? No Pennsylvania court has addressed all of these questions, but case law and statutes offer guidance; in general, they seem to support the conclusion that heat and pore space are owned by the surface owner of real property, and they can be deeded or conveyed to another user. (See Chapter 4.) This is all good news: Because ownership of resources associated with geothermal energy can be derived from existing Pennsylvania law, geothermal projects in the Commonwealth should be able to move forward without waiting for further clarification or change in state law on the issue of property rights.

Pennsylvania also has existing regulations, programs,

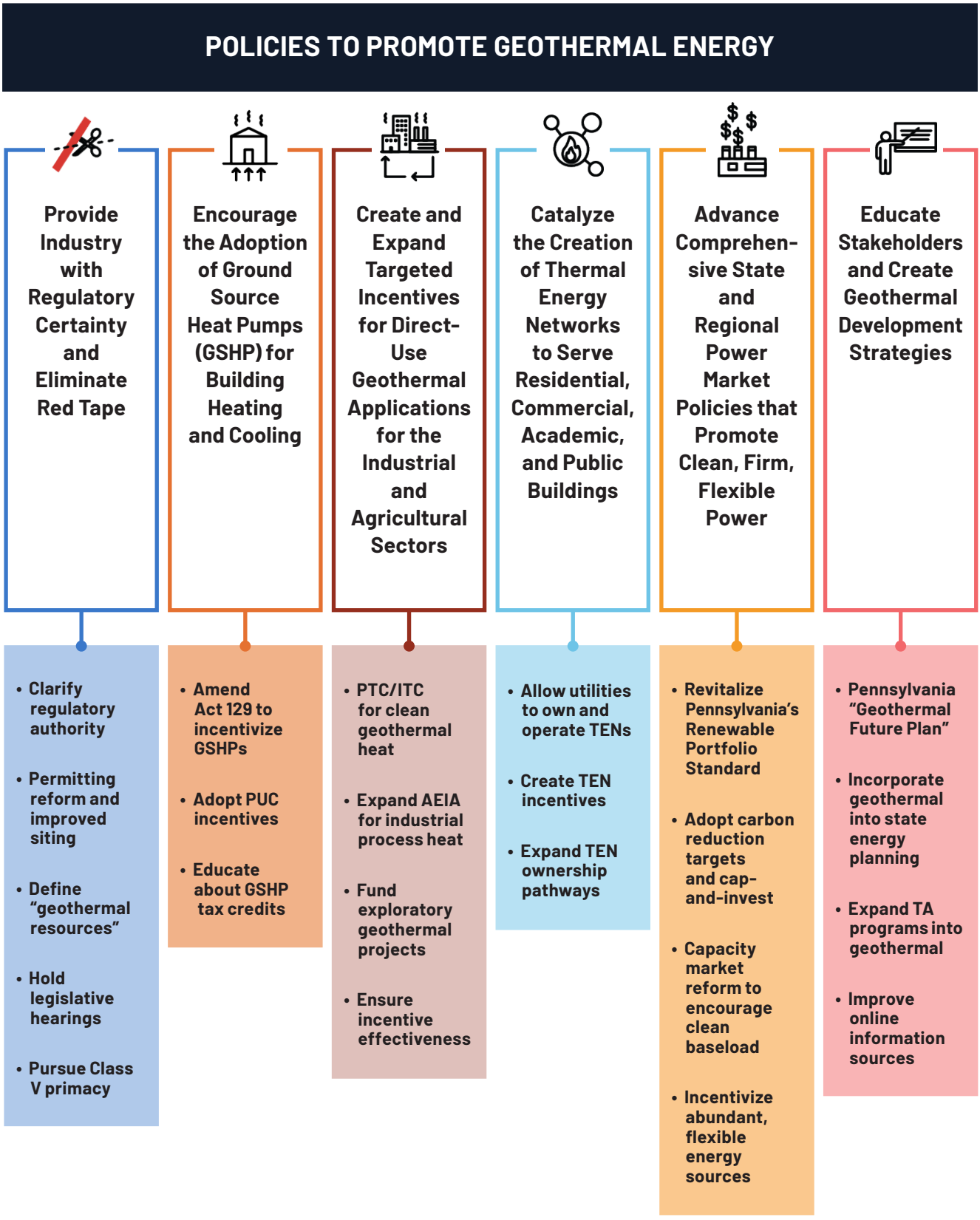

POLICIES TO PROMOTE GEOTHERMAL ENERGY
Provide Industry with Regulatory Certainty and Eliminate Red Tape
• Clarify regulatory authority
• Permitting reform and improved siting
• Define "geothermal resources"
• Hold legislative hearings
• Pursue Class V primacy
Encourage the Adoption of Ground Source Heat Pumps (GSHP) for Building Heating and Cooling
• Amend Act 129 to incentivize GSHPs
• Adopt PUC incentives
• Educate about GSHP tax credits
Create and Expand Targeted Incentives for Direct-Use Geothermal Applications for the Industrial and Agricultural Sectors
• PTC/ITC for clean geothermal heat
• Expand AEIA for industrial process heat
• Fund exploratory geothermal projects
• Ensure incentive effectiveness
Catalyze the Creation of Thermal Energy Networks to Serve Residential, Commercial, Academic, and Public Buildings
• Allow utilities to own and operate TENs
• Create TEN incentives
• Expand TEN ownership pathways
Advance Comprehen-sive State and Regional Power Market Policies that Promote Clean, Firm, Flexible Power
• Revitalize Pennsylvania's Renewable Portfolio Standard
• Adopt carbon reduction targets and cap-and-invest
• Capacity market reform to encourage clean baseload
• Incentivize abundant, flexible energy sources
Educate Stakeholders and Create Geothermal Development Strategies
• Pennsylvania "Geothermal Future Plan"
• Incorporate geothermal into state energy planning
• Expand TA programs into geothermal
• Improve online information sources

Figure ES.3

and policies that can support geothermal energy in other ways, including a renewable energy loan program and an Alternative Energy Portfolio Standard. By modifying existing policies and initiatives and adopting a suite of new ones, policymakers could spur much greater geothermal adoption in the Commonwealth and influence the pace and scale of deployment for both mature and next-generation geothermal applications. This report recommends 23 targeted ideas across six areas of focus:

1. Provide industry with regulatory certainty and eliminate red tape;
2. Encourage the adoption of ground source heat pumps for building heating and cooling;
3. Create and expand targeted incentives for direct-use geothermal applications for the industrial and agricultural sectors;
4. Catalyze the creation of thermal energy networks to serve residential, commercial, academic, and public buildings;
5. Advance comprehensive state and regional power market policies that promote clean, firm, flexible power;
6. Educate stakeholders and create geothermal development strategies.

These policies could bring to the Commonwealth a myriad of economic, workforce, energy security, and environmental benefits.

Environmental Impacts and Stakeholder Engagement

Geothermal energy development is likely to lead to better environmental outcomes across multiple measures than other forms of both conventional and renewable energy. The types of geothermal likely to be deployed in Pennsylvania could decrease pressure on land use and wildlife habitats, reduce air pollution, and lower emissions while providing jobs for oil field services professionals. Geothermal adoption could further reduce land-use impacts by repurposing the Commonwealth's many abandoned oil and gas wells to tap into geothermal energy. In other words, upcycling sites that have already been disturbed.

Like all energy sources, geothermal development can also come with local environmental impacts that require careful management. Well drilling for geothermal resources largely involves the same techniques used in the oil and gas industry, and so presents some similar issues, including wastewater management,

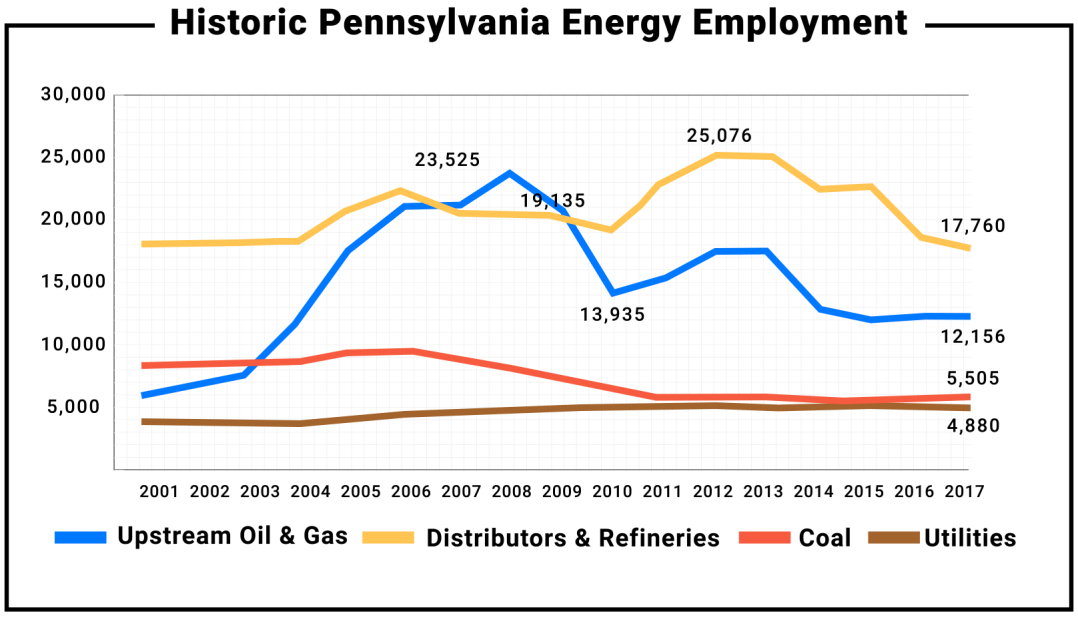


Figure ES.3: Number of workers; excludes transportation fuel retailing. Source: Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages

water use, traffic, and noise. These issues are all quite manageable, but they will require careful oversight and mitigation during geothermal project assessment and development in Pennsylvania.

To ensure effective deployment, developers should engage with a range of stakeholders affected by and central to geothermal energy development in the Commonwealth. Private landowners may stand to gain the most from geothermal development, and arrangements for royalties will be a principal element of obtaining their participation and support. As well, talking to communities that may be impacted by geothermal development in the commonwealth will be necessary to address concerns and bolster public support. Engaging with natural gas and electricity providers and distributors will also be key to help ensure there is interest and infrastructure to support using geothermal energy for local heating, cooling, and power.

There are also myriad groups—including labor unions and environmental groups—who could benefit from and help advocate for geothermal in Pennsylvania. For example, there are nearly 40,000 Pennsylvania workers 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. Geologists, drillers, engineers, and landmen can develop next-generation geothermal wells with minimal retraining. Utility workers and pipefitters can install and repair thermal energy networks in the same rights-of-way, and with similar tools and techniques, as those used for natural gas. Process engineers can design, develop, and maintain direct-use systems.

With robust engagement with these and other stakeholders, a range of Pennsylvanians will reap the benefits of and be key players in promoting geothermal energy development in the Commonwealth.

Conclusion

As the demand for energy grows over the coming years, ground-source heat pumps and next-generation geothermal are poised to become key sources of abundant energy. The Commonwealth is well-suited to be at the forefront of the emerging geothermal boom. Building on its history as an energy pioneer and an energy-producing powerhouse, with thoughtful approaches and the right policies and incentives for this burgeoning ecosystem, Pennsylvania can help write the next chapter for American subsurface energy while bringing new jobs to its energy sector and economic and environmental benefits to every corner of the Commonwealth.

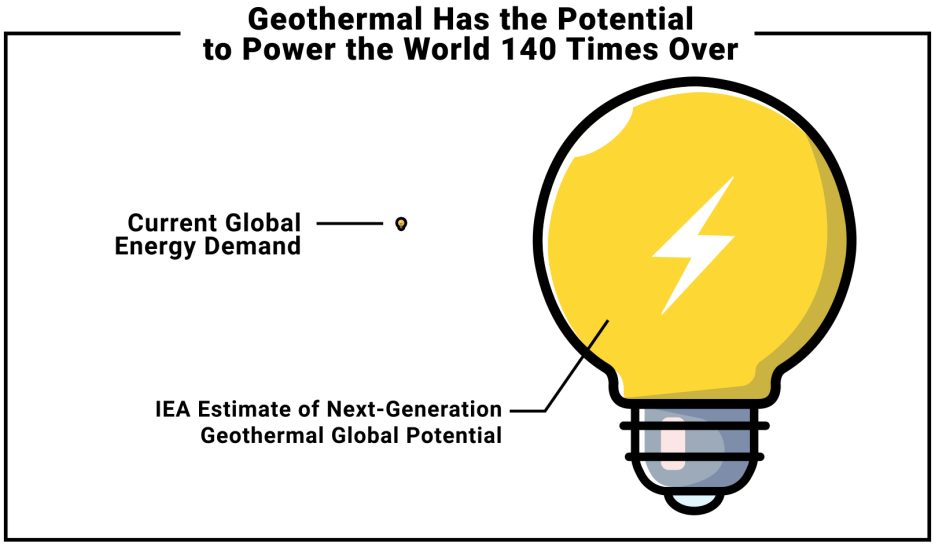


Figure ES.5: Information from IEA's Future of Geothermal Report which uses data produced by Project InnerSpace to develop global estimates for next-generation geothermal energy. https://www.iea.org/reports/the-future-of-geothermal-energy/executive-summary.