

An Overview of the U.S. Department of Energy's *GeoVision* Roadmap

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ABSTRACT

The U.S. Department of Energy's (DOE's) Geothermal Technologies Office (GTO) engaged in a multiyear research collaboration among national laboratories, industry experts, and academia to identify a vision for growth of the domestic geothermal industry across a range of geothermal energy types. The effort, called the *GeoVision* analysis, assessed opportunities to expand geothermal energy deployment by improving technologies, reducing costs, and mitigating barriers. The analysis also evaluated the economic and environmental impacts of such deployment and investigated opportunities for desalination, mineral recovery, and hybridization with other energy technologies for greater efficiencies and lower costs.

In addition to summarizing analytical results about geothermal energy opportunities, the report includes a Roadmap of actionable items that can achieve the outcomes of the analysis. The *GeoVision* Roadmap is a comprehensive call to action to encourage and guide stakeholders toward the shared goal of realizing the deployment levels and resulting benefits identified in the *GeoVision* analysis. The actions address steps to advance both proven and unproven geothermal technologies. For proven technologies, technical advancements will help, but the most vital steps needed are to overcome barriers related to project financing, regulatory timelines, outreach and education, and market structures. For unproven and developing technologies, the most crucial steps are in research and development (R&D) and technology advancement.

1. Overview

The *GeoVision* analysis assessed the domestic geothermal industry across numerous resource types and technology applications, within the context of technical and non-technical barriers and improvements as well as economic and environmental impacts to the nation. The analysis quantified geothermal deployment that could be achievable under a range of potential scenarios and assessed economic and environmental impacts resulting from increased geothermal energy on the U.S. grid and in U.S. homes and businesses. The *GeoVision* analysis examined electricity generation as well as heating and cooling applications and evaluated the impact of additional value streams that could balance the costs of developing a geothermal resource. The results of the *GeoVision* analysis confirm the potential for geothermal to be an essential part of the nation's critical energy infrastructure.

Achieving a more prominent role for geothermal in America's energy future will require actions to overcome technical and non-technical barriers. The *GeoVision* Roadmap presents a compilation of technical, economic, and institutional actions across the geothermal community—including DOE, industry, academia, and other stakeholder groups—that can help realize the continued and expanded contribution of geothermal energy as a renewable and diverse energy solution for the United States.

The *GeoVision* Roadmap builds on the findings of the analysis, which examines geothermal energy potential across multiple market sectors. The Roadmap actions are intended to stimulate broadly inclusive, multi-stakeholder engagement to advance geothermal energy. The Roadmap resulted from a collaborative effort led by DOE, with contributions from national laboratories and a diverse set of industry peers and expert reviewers representing a range of geothermal stakeholders.

This paper provides an overview and summary of the *GeoVision* Roadmap, including text from the *GeoVision* report. Readers are encouraged to read the full report, which can be found at www.energy.gov/geovision.

2. *GeoVision* Analysis Roadmap

In addition to using robust modeling tools and datasets to assess geothermal deployment potential, the *GeoVision* analysis included developing actionable pathways to address challenges for geothermal development and enhance geothermal technologies. These actions comprise a technical and institutional Roadmap (DOE 2019) targeting key opportunities for geothermal growth, such as high-resolution resource assessments, technology improvements, and workforce development. As noted, the Roadmap is the basis of a broad call to action to engage stakeholders toward realizing geothermal deployment levels identified in the *GeoVision* analysis and the potential resulting benefits to the nation.

The Roadmap actions aim to address a range of technical and non-technical barriers and to enhance both proven and unproven technologies. For proven technologies, technical advancements will help, but the most vital steps needed are to address barriers related to project financing, regulatory timelines, outreach and education, and market structures. For unproven and

developing technologies, the most crucial steps are research and development and technology advancement.

The *GeoVision* analysis was founded in three key objectives essential to reducing risks and costs that can limit geothermal development (DOE 2019):

1. Increasing access to geothermal resources
2. Reducing costs and improving economics for geothermal projects
3. Improving education and outreach about geothermal energy.

The Roadmap addresses the three key objectives through activities in four key Action Areas:

- Action Area 1: Research Related to Resource Assessments, Improved Site Characterization, and Key Technology Advancements
- Action Area 2: Regulatory Process Optimization
- Action Area 3: Maximizing the Full Value of Geothermal Energy
- Action Area 4: Improved Stakeholder Collaboration

Each Action Area includes a series of 3–5 Key Actions and numerous sub-actions. The combined Key Actions and sub-actions target and cover the breadth of the main Action Area. For example, *GeoVision* Roadmap Action Area 1 includes five Key Actions related to activities such as resource assessments, drilling improvements, and detection of subsurface signals. Geothermal development potential is highly sensitive to cost, and advancing the industry depends on the extent to which costs can be lowered through collective stakeholder engagement and efforts. For this reason, many of the Roadmap actions focus on areas related to cost: reduced development timelines, which can improve project economics; improved technologies that can more reliably explore for and target wells; and improved technologies that can reduce well-drilling costs and improve well productivity through novel stimulation techniques. The Roadmap also discusses numerous actions related to risk in finding, characterizing, and extracting geothermal resources.

The Roadmap is not intended to be an exhaustive list of activities, nor is it prescriptive in terms of specifying how or by whom suggested actions should be accomplished. The Roadmap is instead meant to serve as a guide that the collective geothermal community can employ to meet the key objectives of the *GeoVision* analysis and allow the nation to harness the potential offered by geothermal resources. It was also beyond the scope of the *GeoVision* analysis to propose unintroduced policies or policy changes; the analysis and any associated Roadmap actions consider only policies that are in force or that have been introduced but not enacted.

3. Action Areas in the *GeoVision* Roadmap

The following subsections summarize the *GeoVision* Roadmap Action Areas, including listing the associated Key Actions for each Area. Full details about the objectives, deliverables, and expected outcomes for each Action Area and Key Action are available in DOE (2019).

3.1 Action Area 1: Research Related to Resource Assessments, Improved Site Characterization, and Key Technology Advancements

The actions outlined in Action Area 1 aim at understanding where geothermal resources exist as well as increasing access to and optimizing use of those resources. These objectives will be achieved by improving resource assessments, advancing technology, and improving efficiency. Results of these actions include better and more widespread opportunities for domestic geothermal resource use as well as reduced development cost through improved technologies and lower risk. Success will require increased collaboration among the global geothermal industry and its stakeholders. Outreach to other energy sectors will also contribute to achieving these actions.

Geothermal resources are unique among renewable energy technologies in that significant exploration and capital expenditure are required to locate, characterize, and prove a resource. Wind, solar, and hydropower resources are already well characterized, whereas the majority of hydrothermal resources are still undiscovered and—as such—uncharacterized. National assessments are available for enhanced geothermal system (EGS) resources, but not at a resolution that can support practical investments in development. Similarly, geothermal heat pump (GHP) resources lack a central database of properties that indicate GHP suitability, such as a national map of soil thermal conductivity at the appropriate resolution. Improved resource and site characterization are key for increasing geothermal deployment in both the electric and non-electric sectors.

Harnessing geothermal resources at the scale envisioned by the *GeoVision* analysis will require improving and advancing technology. Progress is needed in detecting subsurface signals to remotely identify and characterize underground attributes. Similar to the way the medical field uses radiology to assess the need for and improve the success rates of more costly and invasive procedures, the geothermal industry would benefit from technology breakthroughs in non-invasive, lower-cost geophysical and remote-sensing technologies. Once geothermal resources are identified and characterized at a level that justifies a more capital-intensive investment toward development, technology advances in drilling and wellbore integrity will play a critical role in lowering the costs of development. Major advances in reservoir and subsurface engineering will be required to enable the cost-effective creation of EGS reservoirs and sustain their productivity once they are created.

Enhanced and innovative tools and techniques can also ensure optimal resource use, improve well life cycles, and enhance overall performance of geothermal wells. These results can, in turn, reduce risk and costs for geothermal developers and minimize adverse environmental effects. Technology advances are crucial for developing commercially competitive EGS projects and unlocking the full potential of U.S. geothermal resources in the electricity and district heating and cooling sectors. New geothermal technologies should also leverage existing innovations from other U.S. industries, including oil and gas. At the same time, investments in geothermal technology advancements are likely to yield benefit back to the oil and gas industry—e.g., the geothermal industry's DOE-supported development of polycrystalline drill bits and the subsequent adoption of this technology across the global oil and gas industry.

Once geothermal resources are located, characterized, and harnessed, long-term production of geothermal energy will rely on improved resource monitoring, modeling, and management.

Achieving these objectives can improve decision making and ensure longer life and better management of reservoirs and resources.

The DOE's 2019 Frontier Observatory for Research in Geothermal Energy (FORGE) Roadmap includes activities that are synergistic with and cross-cut several key actions and sub-actions in Action Area 1. The FORGE Roadmap focuses on critical research areas in fracture control, reservoir management, and stimulation. These activities are applied specifically to technology advancements for EGS and are intended to be implemented at the DOE FORGE site in Milford, Utah. The *GeoVision* Roadmap highlights other activities that can be implemented by various stakeholder groups to address additional research areas and opportunities.

- Key Action 1.1 – Conduct national- and local-scale resolution resource assessments across the geothermal resource spectrum
- Key Action 1.2 – Improve detection of subsurface signals
- Key Action 1.3 – Improve geothermal drilling and wellbore integrity
- Key Action 1.4 – Improve geothermal energy resource recovery
- Key Action 1.5 – Improve geothermal resource and asset monitoring, modeling, and management

3.2 Action Area 2: Regulatory Process Optimization

Regulatory processes are essential in helping to ensure that geothermal development is carried out responsibly and consistently. However, geothermal regulations have evolved over time in separate instances, resulting in processes that are often inefficient and complex. In addition, regulatory processes do not always account for advances in technology, changes in the energy market, or other factors.

Overcoming complexity and uncertainty in costs and development timelines resulting from regulatory processes can support increased geothermal deployment. The *GeoVision* analysis confirmed that shortening permitting and regulatory process times alone can result in increased exploration and a higher rate of geothermal project development over the status quo; increased deployment projected to occur through improved regulatory timelines would occur even in the absence of technology improvements. The majority (90%) of conventional geothermal resources in the United States are located on federally managed lands (Young et al. 2014), and collaboration among federal, state, and local agencies with land-management responsibilities will be essential to optimizing regulatory processes. Action Area 2 includes activities for stakeholders to evaluate and navigate regulatory processes, not to propose requirements or modifications to regulations. These actions rely on collaborative processes, careful and objective analysis, and consideration for a range of stakeholder needs.

As previously noted, it was beyond the scope of the *GeoVision* analysis to identify or propose policy changes, and no attempt is being made to do so in this section. The activities in Action Area 2 focus on reviewing and researching the effects of regulation on the geothermal industry to help inform decisions and provide understanding for the industry.

- Key Action 2.1 – Improve land access
- Key Action 2.2 – Improve the ability to develop geothermal energy in accessed lands
- Key Action 2.3 – Evaluate geothermal heat-pump regulatory processes

3.3 Action Area 3: Maximizing the Full Value of Geothermal Energy

Geothermal energy is a renewable and diverse domestic energy solution for the United States—delivering reliable and flexible electricity generation as well as serving heating and cooling needs. Leveraging “always-on” and broadly available geothermal resources can provide a range of benefits, including grid stability, reliability, and resiliency; efficient residential and commercial heating and cooling; environmental improvements; and geothermal industry growth. However, the benefits that geothermal brings are not always valued accurately in the marketplace.

Action Area 3 of the *GeoVision* Roadmap presents actions that can help the United States realize these benefits by encouraging geothermal development and improving geothermal project economics for both the electric and non-electric sectors. These actions are intended to address improvements in economic and revenue structures that extend beyond levelized cost of electricity or levelized cost of heat. Activities in this area focus on assessing economic barriers; creating new geothermal business models; investigating geothermal–hybrid applications; and assessing value-added markets for geothermal, such as desalination and mineral recovery.

- Key Action 3.1 – Improve valuation of and compensation for geothermal energy
- Key Action 3.2 – Investigate geothermal hybrid opportunities
- Key Action 3.3 – Quantify additional geothermal value streams
- Key Action 3.4 – Assess the economic barriers and solutions pertaining to direct-use applications and geothermal heat pumps
- Key Action 3.5 – Identify opportunities to improve standards, business models, and markets for direct-use applications and geothermal heat pumps

3.4 Action Area 4: Improved Stakeholder Collaboration

Helping consumers, businesses, investors, and the prospective workforce to better understand the benefits and impacts of geothermal energy will require stakeholder collaboration and enhanced outreach. This work should include an ongoing effort to revise and update the *GeoVision* Roadmap. Maintaining the Roadmap can help in overcoming economic, technical, and regulatory barriers to geothermal deployment as the industry evolves. In addition, expanded education and communication can raise public awareness of the benefits of geothermal energy and how challenges such as induced seismicity are addressed. This could improve public acceptance and help increase deployment and market penetration. In addition, growing the geothermal industry to the deployment levels identified in the *GeoVision* analysis will require developing and sustaining a qualified, well-trained workforce.

- Key Action 4.1 – Maintain the Roadmap as a vibrant, active process
- Key Action 4.2 – Improve public education and outreach about geothermal energy
- Key Action 4.3 – Increase awareness of employment and training opportunities across all geothermal energy technologies

6. Conclusions

Geothermal energy is secure, reliable, flexible, and constant. It offers the United States a renewable source for power generation as well as heating and cooling of homes and businesses.

Geothermal resources and technologies are primed for strong deployment growth and stand ready to provide solutions to meet America's 21st-century demands for energy security, grid stability and reliability, and domestic and commercial heating and cooling. By outlining a series of activities directed at key challenges to geothermal development—primarily risk and cost—the *GeoVision* Roadmap provides a foundation for an evolving, collaborative, and dynamic process to inform future action across industry, government, academia, and other geothermal stakeholders. The *GeoVision* Roadmap is intended to be modified in regular reviews of progress toward the objectives—particularly in light of changing technologies, markets, public priorities, and policy factors. Enacting the activities in the Roadmap and conducting regular updates can help geothermal energy contribute to the nation's economic development and energy security while contributing to the long-term portfolio of affordable energy options for Americans.

Acknowledgement

The *GeoVision* report, including the Roadmap, reflects a collaborative, multi-year effort with contributors from industry, academia, national laboratories, and federal agencies. A total of 20 independent experts vetted each step of the analytic process, and a group of more than 40 reviewers representing the domestic and international stakeholder community appraised and commented on the report draft. All participants in this process were instrumental in documenting the state of the industry. Complete acknowledgements are in Appendix D of the *GeoVision* report (DOE 2019).

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