Next-Generation Geothermal – An Overview

Executive Summary

After a decade or more of being relatively flat, electricity demand is now growing at the fastest pace in decades as data centers and increased electrification put pressure on the grid.[1] To meet this increased demand, while keeping electricity reliable and affordable for customers and helping companies meet their long-term clean energy goals, will require doing more with today's grid but also developing and commercializing new technologies that can provide 24/7 clean firm power for the United States. As a result, there is growing interest in advanced clean energy technologies such as next-generation geothermal.

Geothermal energy has been in commercial use for more than a century. Currently, there are 64 conventional geothermal energy projects in operation in the United States.[2] Conventional geothermal generates power by using the heat from naturally occurring underground reservoirs of hot water to generate electricity.[3] In contrast, next-generation geothermal is not reliant on naturally occurring underground reservoirs, and instead uses the heat from rocks deep in the Earth's crust to heat water that is pumped down.

In general, geothermal projects typically have high upfront costs but low operation & maintenance (O&M) costs. However, the upfront costs of next-generation geothermal are coming down significantly because of the increasing application of the seismic technologies traditionally used for identifying oil and gas reservoirs, making geothermal projects a more attractive option. In fact, many advanced geothermal startups receive support from oil and gas investments or have leadership teams comprised of oil and gas industry veterans. Additionally, some next-gen geothermal systems can be used to repurpose oil and gas fields for geothermal energy. Furthermore, the entire oil and gas operation – workers, skills, and drilling and digging technology – is transferable to advanced geothermal energy production.

Below is a more in-depth look into the different next-generation geothermal systems, including developers, challenges and opportunities for commercial deployment, and EEI member companies with announced next-generation geothermal projects.

Next-Generation Geothermal Systems

Next-generation geothermal technologies fall into three broad categories: Enhanced Geothermal Systems (EGS), Closed-Loop Geothermal Systems (CLG), and Supercritical Geothermal Systems.

Enhanced Geothermal Systems (EGS)

EGS utilizes directional drilling and hydraulic fracturing (also known as fracking) as artificial geothermal reservoirs. EGS utilizes pre-existing oil and gas fractured wells or can apply commercial drilling and fracturing to create fractures in hot, impermeable rock. This allows for fluids, typically water, to circulate between two wells that are connected by the fractures.

Cooler liquid is injected into the ground through the "injection well," the depth of which can range from 7-10km in the United States.[4] The liquid then enters the connected fractures area where thermal energy heats it. The heated liquid is then returned to the surface through a "production well" and the energy it carries is used for power generation. The liquid is then cooled and either reinjected into the ground to continue the loop or sent to heating pipelines for heating and other purposes. This allows for EGS to be constructed theoretically anywhere as it is not restricted to sites with conventional geothermal resources.

According to some experts, "out of all [next-generation geothermal] technologies, EGS have the highest level of commercial readiness with the most operating demonstrations."[5] While both EGS and CLG have been in active RD&D for over 50 years, large-scale CLG projects, discussed in the next section, have just recently come online.[6]

- **Potential vendors:** Fervo Energy, AltaRock Energy, Criterion Energy Partners, Renascent Energy

Closed-Loop Geothermal (CLG) / Advanced Geothermal Systems (AGS)

CLG or AGS use sealed wellbores to circulate a working fluid to absorb thermal heat and transport it back to the surface. To be economically viable, CLG systems typically must operate at depths beyond 5km due to the high rock temperatures at that level.[7] As compared to conventional hydrothermal geothermal and EGS, CLG systems can hypothetically operate in a wider variety of temperatures and rock types, consume little or no process water, do not interfere with subsurface water, and have no more risk of induced seismicity. Furthermore, CLG can be used in unproductive conventional geothermal wells and abandoned oil and gas wells.[8]

CLG can be implemented in different pipe configurations to optimize site specific costs and performance. In a "Closed U-Loop Configuration", a sealed, closed-looped pipe transports fluids through hot rock and then back to the surface for power generation. A "Tube-in-Tube" or "Concentric Tube Configuration" uses a single well with an insulated inner tube that sends down cool fluid, which absorbs thermal heat at the bottom and ascends back up through the outer part of the tube. Concentric Deviated Well Configuration is like the Tube-in-Tube configuration, but the well bore angles through the target zone temperature gradient or follows a targeted thermal contour to bottom-hole depth.

- **Potential vendors**: Eavor, GreenFire Energy, Novus Earth, XGS Energy, Sage Geosystems

Supercritical Geothermal Systems

Supercritical Geothermal Systems, also known as Superhot or Superdeep Geothermal Systems, are the most extreme form of deep geothermal and are in the early experimental stages.[9, 10] While supercritical resources have been found at depths of 2km, the range can also be as far as 5km.[11] Supercritical geothermal systems can be harnessed through both EGS or CLS but require advanced drilling techniques such as millimeter wave energy technology, electricity, or a plasma drilling head.[12]

In this system, water or other liquids enter a supercritical state where fluids reach temperatures greater than 374 °C and 221 bars of pressure. In this state, the fluid has properties of both a liquid and a gas. A supercritical geothermal system can produce 5-10 times the amount of energy output compared to operational geothermal wells today.[13] However, due to challenges during drilling, such as the potential for damage to heat transfer equipment and circulation components, toxic gas emissions, highly corrosive geofluids, and difficulties maintaining fractures and permeability, supercritical geothermal is not a commercial solution currently.[14, 15]

- **Potential vendors**: Quaise, Eden GeoPower, GA Drilling

Challenges and Opportunities

The development and commercial deployment of next-generation geothermal energy presents opportunities to expand the availability of geothermal resources, clean firm power, and long duration energy storage options.[16] However, it also faces challenges such as high upfront costs and risks, long and unpredictable development lifecycles, and community opposition.[17] Below is a summary of these opportunities and challenges, which are covered extensively in the U.S. Department of Energy's *Pathways to Commercial Liftoff: Next-Generation Geothermal Power*.[18]

Opportunities

Next-generation geothermal technologies offer a number of opportunities, including the potential to expand geothermal capacity and resource availability in the United States from 40 GW to over 5,000 GW.[19] Next-generation geothermal technologies can use drilling and/or hydraulic fracturing to "allow fluid to flow through hot rock that was previously impermeable".[20] As a result, these technologies can hypothetically be located anywhere in the U.S.

Additionally, next-generation geothermal can provide up to 90 GW of clean firm power by 2050.[21] Because next-generation geothermal is a clean, firm, and flexible energy that requires one of the "smallest land area per kilowatt of any energy technology, firm or renewable,"[22] it has the potential to capture a large share of the market.

Furthermore, next-generation geothermal technologies have the potential to act as an energy storage system, increasing their value.[23] However, while this ability to store energy has been proven conceptually with field tests, [24] it has not been proven in the commercial market.[25]

Lastly, next-generation geothermal industry can leverage existing workforces and supply chains found in the oil and gas industry, which reduce key commercial adoption barriers and can provide jobs for fossil fuel workers as the economy decarbonizes.[26]

Challenges

Next-generation geothermal systems face a number of challenges, chief of which are the "high costs and high risks at the start of new projects [which can] limit available capital, slow the pipeline of new demonstrations, and reduce opportunities for cost reduction".[27] In comparison to onshore wind or solar, an EGS project would require "seven to eight times more overnight capital expenditure per megawatt…".[28]

Potential environmental concerns over the use of hydraulic fracturing technologies also have the potential to hurt the industry, particularly for EGS due to its use of hydraulic fracturing.[29]

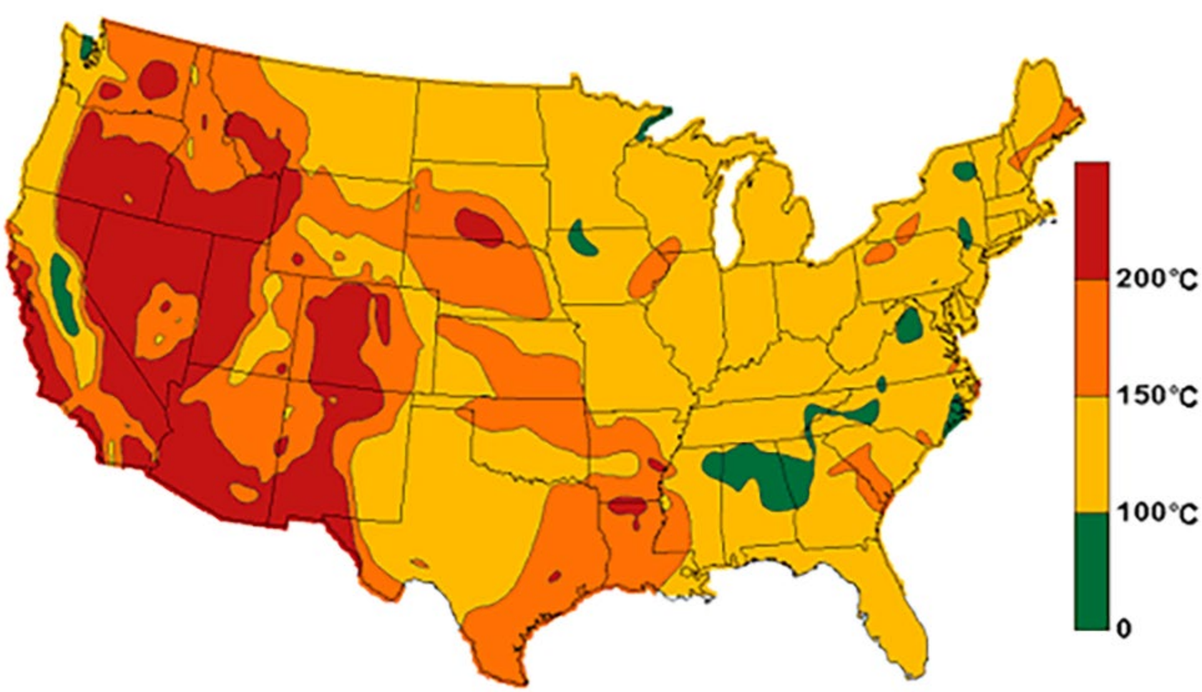
Significant perceived and actual operability risks and costs also limit demand and investor interest in next generation geothermal. This is partly due to elevated, site-specific resource characterization risks driven by the developmental nature of the technology along with a lack of detailed subsurface heat mapping.[30] Besides addressing these risks, developers also need to demonstrate that repeated, modular operations in multiple environments are being realized.[31]

Another challenge is the long timeline for project development, which can run between seven to ten years.[32] Nearly two-thirds of all identified and undiscovered geothermal resources in the United States are on public lands, which are managed by the Bureau of Land Management (BLM).[33] Developers planning to site geothermal projects on public lands will have to go through federal leasing and siting and permitting processes that can include multiple environmental reviews.[34] In addition to BLM requirements, the development of geothermal projects requires a variety of permits, which vary from state to state and can involve several federal, state, and local authorities.[35] See Appendix 1 for an outline of this process.

Geothermal Resource Map

Below is a map showcasing the distribution of geothermal resources in the United States. Currently, geothermal projects are most often only economically viable in areas with high subsurface temperatures, which generally occur in western states. As a result, that region has the highest potential for geothermal production. However, with advances in drilling techniques, next-generation geothermal is becoming economically feasible in a wider range of areas.

Geothermal resources of the United States



Source: U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy (public domain)

EEI Member Next-Generation Geothermal Projects

1. **EEI Member**: NV Energy
   Project Partners: Google, Fervo
   Technology: Enhanced Geothermal Systems (EGS)
   Project Scope: On June 11, 2024, Google announced its partnership with NV Energy to create a new Clean Transition Tariff (CTT) with the intention of operating Google's data centers and office campuses on 24/7 carbon-free energy by 2030. To meet these goals, NV Energy and Google plan to proceed with advanced geothermal to increase firm clean power to their local grid. Partnering with Fervo Energy, an energy developer, NV Energy has included 115 MW of new advanced geothermal power within the CTT partnership.
   - Press Release

2. **EEI Member**: PNM
   Project Partners: Meta, XHS Energy, Baker Hughes
   Technology: Closed-Loop Geothermal (CLG)
   Project Scope: 150-megawatt geothermal project in New Mexico. The project, once developed, will support the delivery of clean, round-the-clock power to the Public Service Company of New Mexico's (PNM) grid in support of Meta's data center operations in the state.
   - Press Release

EEI Member Conventional Geothermal Projects

1. **EEI Member:** Berkshire Hathaway Energy (BHE) / CalEnergy
   Technology: Conventional Geothermal
   Project Scope: 10 geothermal facilities in California's Imperial Valley with a total net capacity of 345 MW.
   - Renewable Fact Sheet

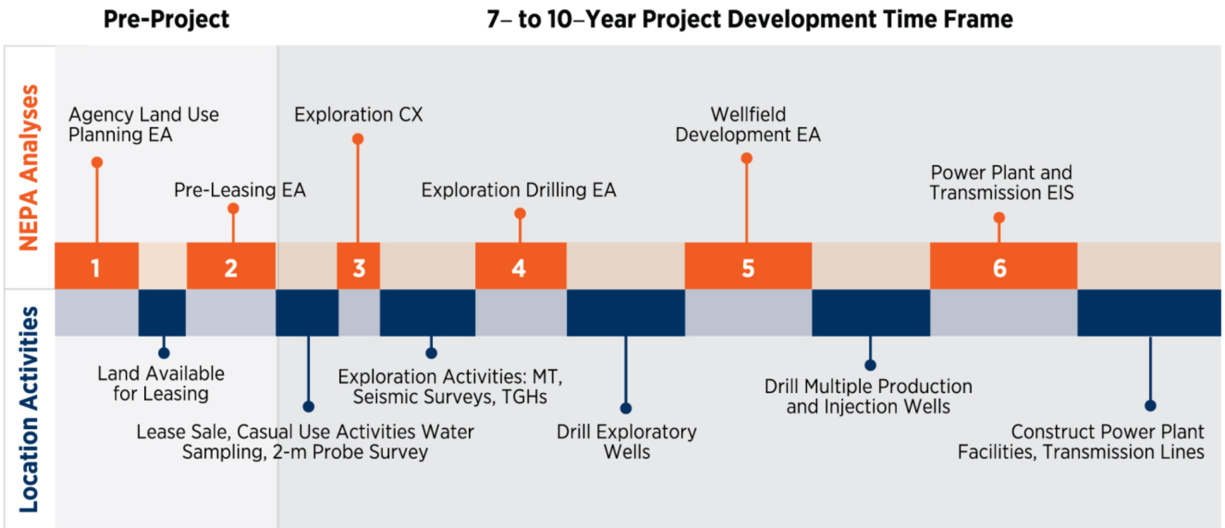
2. **EEI Member:** PacifiCorp Energy
   Technology: Conventional geothermal – Ormat Technologies
   Project Scope: "Blundell Geothermal Power Plant" in Beaver County Utah supplies 11 MW geothermal energy.
   - Fact Sheet

3. **EEI Member:** Enel Green Power/ Enel
   Project Partner: NVEnergy
   Technology: Conventional geothermal
   Project Scope: "Salt Wells geothermal power plant" in Churchill County, Nevada supplies 23.6 MW of geothermal energy.

4. **EEI Member:** Enel Green Power / Enel
   Project Partner: NVEnergy
   Technology: Conventional geothermal
   Project Scope: "Stillwater Triple Hybrid Power Plant" has 61 MW solar and geothermal plant in Nevada. Includes 26MW of solar PV, 2 MW solar thermal, and 33 MW geothermal.

5. **EEI Member:** Enel Green Power / Enel
   Technology: Conventional geothermal
   Project Scope: "Cove Fort Geothermal Power Plant" in Cove Fort, Utah supplies 25 MW of geothermal power.
   - Press Release

Appendix 1: Geothermal Project Development Timeline



Source: Katherine Young et al., "GeoVision Analysis Supporting Task Force Report: Barriers-An Analysis of Non-Technical Barriers to Geothermal Deployment and Potential Improvement Scenarios," Technical Report (National Renewable Energy Laboratory, May 2019), 44

End Notes

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[16] Blankenship et al., "Pathways to Commercial Liftoff: Next-Generation Geothermal Power." 9.
[17] Blankenship et al., "Pathways to Commercial Liftoff: Next-Generation Geothermal Power." 48.
[18] Blankenship et al., "Pathways to Commercial Liftoff: Next-Generation Geothermal Power."
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[20] Blankenship et al., "Pathways to Commercial Liftoff: Next-Generation Geothermal Power." 10.
[21] Blankenship et al., "Pathways to Commercial Liftoff: Next-Generation Geothermal Power." 9.
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[30] McLaughlin et al., "Next-Generation Geothermal." 20.
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