Superhot Rock Geothermal

Technology Innovation Spotlight

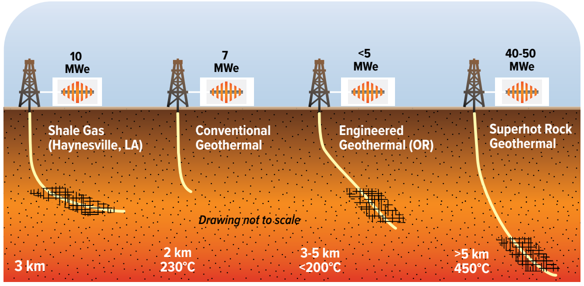
Photo Credit: US Geological Survey

Key Takeaways

- Superhot rock geothermal exploits geologic formations deep underground, where extreme temperatures could result in 5- to 10-fold increases in generating capacity per well relative to current geothermal plants. This concept, which leverages existing and advanced technologies from the oil and gas extraction and power generation industries, has disruptive potential.
- Assuming continued investment and innovation, superhot rock geothermal could become a commercial reality within 10 to 15 years. The exceptional promise of this technology arises from the ubiquitous nature and massive scale of the underground resource and the ability to supply baseload energy and grid balancing services with zero carbon emissions and competitive cost.

Overview

Conventional geothermal delivers clean energy as a baseload and load-following resource but is limited to sites where wells can connect natural hydrothermal reservoirs near the Earth's surface to above-ground electric generating facilities. Global capacity totals only about 15 GW. Enhanced geothermal system (EGS) technology, which involves engineering a reservoir at relatively shallow depths where heat is available but permeability and/or fluid are lacking, could expand geographic applicability. However, the path to scalability is uncertain due to cost and other challenges.



Comparison of depth, temperature, and approximate power output per well. (Data Source: AltaRock Energy)

Developing EGS reservoirs in deeper rock formations—where temperatures exceed 450°C—could result in 5- to 10-fold increases in power output per well. **Superhot rock (SHR) geothermal has disruptive potential as an enormous and ubiquitous resource** that could be harnessed by leveraging existing and advanced technologies from the oil and gas (O&G) and power generation industries. Additional benefits include a small above-ground footprint, high energy density, and potential for deployment at existing and decommissioned fossil fuel extraction sites and power plants

Current Situation & Latest Developments

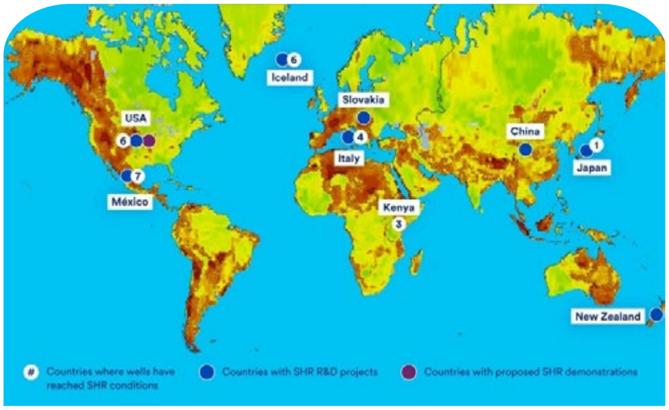
At a few existing geothermal projects including sites in California, Iceland, and New Zealand, natural reservoirs with fluid temperature and pressure exceeding 374°C and 221 bar, respectively, have been drilled into or assessed. These supercritical fluids could enable use of higher-efficiency power cycles. In addition, a small number of research groups around the globe are exploring development of natural supercritical reservoirs and SHR geothermal projects at other sites. Six groups are funded through the European Union, consisting mostly of universities, government organizations, and private developers. Japan, China, and Mexico also are funding research, and New Zealand has launched a public-private partnership. While US Department of Energy (DOE) is not directly supporting SHR development, 13 EGS research projects were announced in November 2023 through DOE's field laboratory, the [Frontier Observatory for Research in Geothermal Energy (FORGE)] in Utah. In Oregon, a consortium led by [AltaRock Energy] is planning what could become the first demonstration of geothermal energy extraction from a manmade SHR reservoir.

SHR resources become ubiquitous from 5 to 20 km down, but accessing them can be challenging and costly. Today's mechanical drilling technologies can be used up to about 10 km in depth. Innovations are being actively pursued by the O&G industry, with government support and venture capital investment. Promising unconventional techniques include projectile, thermal spallation, laser, plasma, millimeter wave, and chemical and electrochemical dissolution drilling.

Challenges

The technical challenges associated with developing and extracting heat from SHR reservoirs are considerable. Wells must be drilled to significant depths, at high temperatures and pressures, in hard crystalline rocks, and with reasonable cost. Resistant casing materials (metals and cements) are needed to avoid well failures. Deep reservoirs with sufficient size and hydraulic conductivity must be created to allow for sustained extraction of geothermal fluid. Downhole power supply and monitoring technologies that can withstand extreme conditions are needed, and above-ground systems must support reliable long-term power generation using highly corrosive geothermal fluid.

According to a [2021 Clean Air Task Force report], these challenges involve engineering rather than scientific breakthroughs. The potential for induced seismicity during SHR reservoir development and operation represents a key risk shared with the O&G industry, as well as geologic carbon storage technologies.



Global distribution of SHR geothermal resources at depth less than 10 km, wells with SHR conditions, and relevant R&D projects. (Credit: Clean Air Task Force)

Opportunities

Proof-of-concept demonstrations encompassing successful and safe reservoir development and reliable power generation are a key next step, progressing from sites with relatively shallow hot dry rock formations—such as the planned AltaRock Energy project—to other locations requiring use of next-gen drilling methods. Relevant EPRI R&D topics and areas of expertise include the following:

- **Reservoir development:** geological characterization, hydro-thermal-mechanical modeling, reservoir stimulation, induced seismicity, and risk assessment
- **Power generation:** geothermal plants, supercritical power cycles, and corrosion control and prevention methods

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