

What is an Enhanced Geothermal System (EGS)?

A naturally occurring geothermal system, known as a hydrothermal system, is defined by three key elements: heat, fluid, and permeability at depth. An Enhanced Geothermal System (EGS) is a man-made reservoir, created where there is hot rock but insufficient or little natural permeability or fluid saturation. In an EGS, fluid is injected into the subsurface under carefully controlled conditions, which cause pre-existing fractures to re-open, creating permeability.

Increased permeability allows fluid to circulate throughout the now-fractured rock and to transport heat to the surface where electricity can be generated. While advanced EGS technologies are young and still under development, EGS has been successfully realized on a pilot scale in Europe and now at two DOE-funded demonstration projects in the United States.

Visit the GTO website at geothermal.energy.gov for more information on EGS development, or contact geothermal@ee.doe.gov.



The Geysers field in northern California boasts the largest geothermal complex in the world and the first successful demonstration of EGS technologies in the United States.

Photo credit: Calpine Corporation

EGS Resource Potential

EGS offers the opportunity to access an enormous, domestic, clean energy resource. A 2006 Massachusetts Institute of Technology (MIT) study predicted that in the United States alone, 100 GWe of cost-competitive capacity could be provided by EGS in the next 50 years.¹ To take advantage of this vast resource, the U.S. Department of Energy's (DOE) Geothermal Technologies Office (GTO) promotes and invests in industry, academia, and the national laboratories to develop and demonstrate EGS throughout the United States.

Benefits of Enhanced Geothermal Systems

- EGS has the potential to be an important contributor to the U.S. energy portfolio as a source of clean, renewable energy.
- EGS emits little to no greenhouse gases. Most geothermal power plants use a closed-loop binary cycle power plant and have no greenhouse gas emissions other than water vapor that may be used for cooling.
- EGS could facilitate geothermal development outside of traditional hydrothermal areas in the western U.S., thereby extending geothermal energy production nationwide.
- EGS can supply baseload energy with limited to no intermittency, eliminating the need for energy storage technologies.

¹ Massachusetts Institute of Technology (MIT). 2006. The future of geothermal energy. Cambridge, Massachusetts. Available: http://geothermal.inel.gov/publications/future_of_geothermal_energy.pdf.



The Geysers field in northern California contains optimal conditions for validating EGS resources.

Induced Seismicity

During EGS reservoir creation and stimulation, rocks may slip along pre-existing fractures and produce microseismic events. Researchers have found these microseismic events, also known as induced seismicity, to be a very useful diagnostic tool for accurately pinpointing where fractures are re-opened or created, and characterizing the extent of a reservoir. In almost all cases, these events occur in deep reservoirs and are of such low magnitude that they are not felt at the surface.

Although induced seismicity data allows better subsurface characterization, GTO also understands public concern. With this in mind, DOE led an effort to create a protocol for addressing induced seismicity associated with geothermal development, which all DOE-funded EGS projects are required to follow. This work was informed by panels of international experts and culminated in an International Energy Agency-accepted protocol in 2008. The protocol was updated in early 2011 to reflect the latest research and lessons learned from the geothermal community.

In addition, in June 2012, the National Academy of Sciences (NAS) issued *Induced Seismicity Protocol in Energy Technologies*. The report found that geothermal development, in general, has a low potential for hazard from induced seismicity. The NAS report cited the DOE *Induced Seismicity Protocol* as a best practice model for other subsurface energy technologies.

EGS Reservoir Creation and Operation

Step 1: Identify/Characterize a Site

- Develop a geologic model of a potential site via surface, geologic, geophysical, and remote sensing exploration.
- Assess the temperature gradient, permeability, in-situ stress directions of the resource, rock mechanical properties, and whether fluid is present.
- Determine if the necessary characteristics to create an EGS reservoir are present.

Step 2: Create a Reservoir

- Drill an injection well into hot rock with limited fluid content and/or permeability.
- Inject water at sufficient pressure (or temperature differential) to create a fracture network.
- Continue operation until there is enough fractured volume to create a reservoir (flow rate, temperature, volume, and sustainability).
- Drill a production well into the fracture network, intersecting the created flow paths.

The resulting circulation loop allows water to flow through the enhanced reservoir, picking up in situ heat. The hot water is then pumped to the surface through the production well (see diagram below).

Step 3: Operate the Power Plant and Maintain the Reservoir

- At the surface, the water flashes to steam, or it heats a working fluid that produces vapor.
- The steam/vapor turns a turbine to create electricity.
- The original geothermal water is recycled into the reservoir through the injection well to complete the circulation loop.

