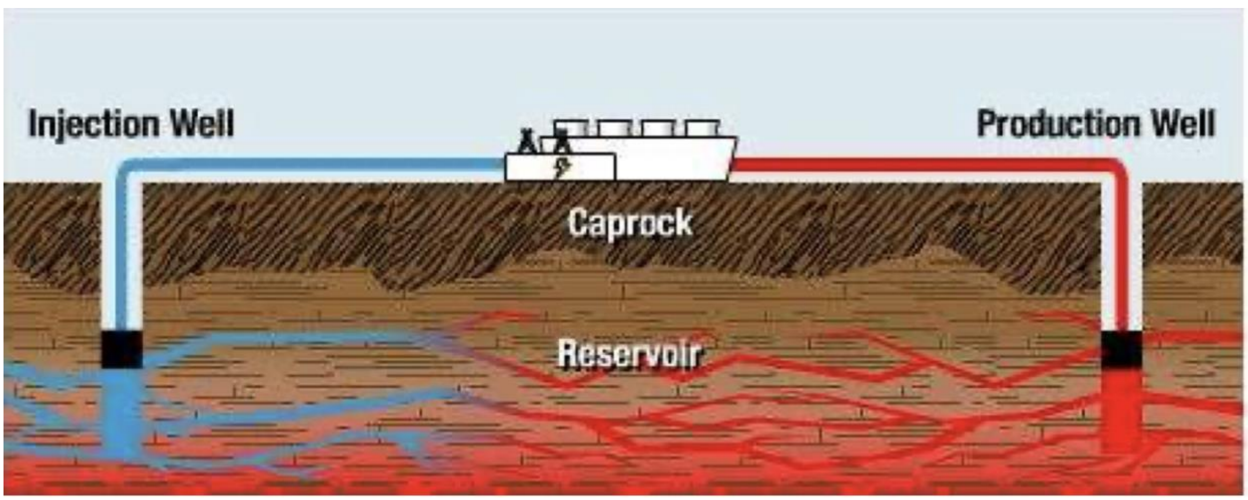
Enhanced Geothermal Systems

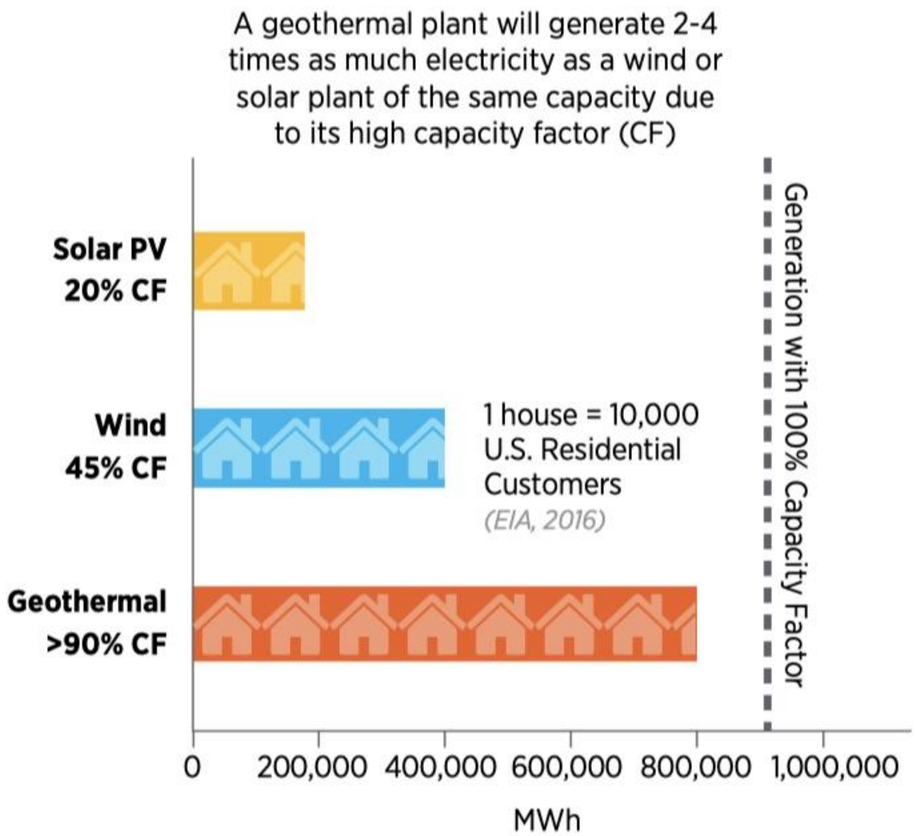
Geothermal energy is secure, reliable, flexible, and constant. It offers the United States a renewable source for power generation as well as heating and cooling of homes and businesses.

Enhanced Geothermal System (EGS) is a high enthalpy (heat), conduction-dominated geothermal resource located 3 km to 10 km deep in the earth's crust. Rocks in potential EGS targets are usually incapable of sustaining fluid flow and require the creation of engineered fractured reservoirs to recover thermal energy. As shown in the following figure, cool injected water warms as it moves through the fracture network to the production well. At the surface, the heat is extracted to generate electricity or for direct use and the cooled water is reinjected.



Technology improvements could reduce costs and increase geothermal electric power deployment for EGS. Improving the tools, technologies, and methodologies used to explore, discover, access, and manage geothermal resources would reduce costs and risks associated with geothermal developments. These reductions could increase geothermal power generation nearly 26-fold from today, representing **60 gigawatts-electric** (GWe) of always-on, flexible electricity-generation capacity **by 2050**.

Capacity factor is measure of how often a power plant runs for specific period of time. It is expressed as a percentage of the actual output divided by the maximum possible output. The following figure compares the capacity factor for solar, wind, and geothermal.



In comparison to solar and wind, geothermal can run close to its maximum output.

Increased geothermal deployment could improve U.S. air quality and reduce CO_2 emissions. The GeoVision analysis (DOE, 2019) indicates opportunities for improved air quality resulting from reductions in sulfur dioxide (SO_2), nitrogen oxides (NO_x), and fine particulate matter (PM2.5) emissions. The analysis further identifies opportunities for reduced carbon-dioxide emissions.

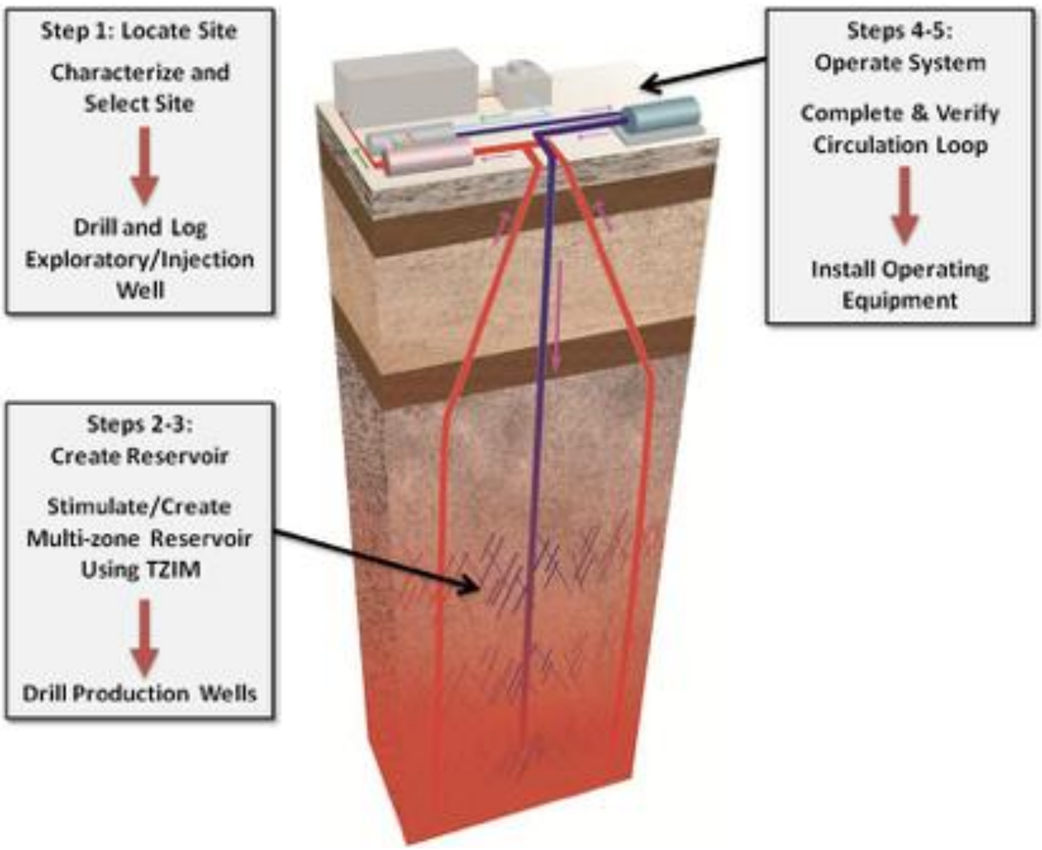
Use of CO_2 Carbon dioxide has been proposed as an alternative to water as a working fluid to produce geothermal electricity (Brown, 2000; Doughty et al, 2018). Direct CO_2 capture machines, such as Chimeworks, could be used to generate the CO_2. The primary benefits cited for using CO_2 as a replacement for water are: (1) its large compressibility and expansivity, which can lead to creation of a natural thermosiphon, wherein CO_2 circulates between injection and production wells without the need for external pumping; (2) lower viscosity; and (3) reduced chemical interaction with rock minerals. While CO_2 has a smaller heat capacity than water, when considered in light of its lower viscosity, the greater mobility leads to a net overall increase in efficiency (Pruess, 2006). Using CO_2 as a working fluid has been proposed for both traditional EGS in fractured rock and for EGS in deep sedimentary basins where it is sometimes referred to as CO_2 plume geothermal (CPG).

Graphene An additional innovative technique includes the use of graphene replacing pipes and geothermal fluid due to its high thermal conductivity. Graphene is chemically very stable, flexible, a hundred times more tear-resistant than steel and, at the same time, very light. Most important for geothermal applications is its very high thermal conductivity when compared to traditional materials.

Direct Electric Extraction Finally, rather than pulling hot fluid up from the earth and converting it to electricity in a power plant, the Direct Electric Geothermal Resource Extraction (DEGREe) concept is to just bring up electricity. That is, one would make a solid-state heat exchanger in the subsurface and then couple that with thermometric materials to make electricity. The installation would be expensive, but after that the solid-state electricity source would last for the lifetime of the heat and materials. It would take a new generation in materials, but it would also totally change the geothermal landscape. Such thermoelectric generators are currently in testing in the laboratory to optimize power generation (Chen et al., 2017), and there are plans to conduct small-scale field testing of such units in China in the near future. The electrical output is not that great.

Companies doing EGS An easy way for our foundation to support EGS is to fund a company experienced in the technique and support them. One stands out.

AltaRock Energy Is privately held. It is the recipient of money from Google.org among other investors. AltaRock has attracted plenty of attention for its **Enhanced Geothermal System** (EGS), a plan to drill far into the Earth's crust to reach superheated rocks. Once this is done, cold water can be pumped down, to return as steam that drives generators.



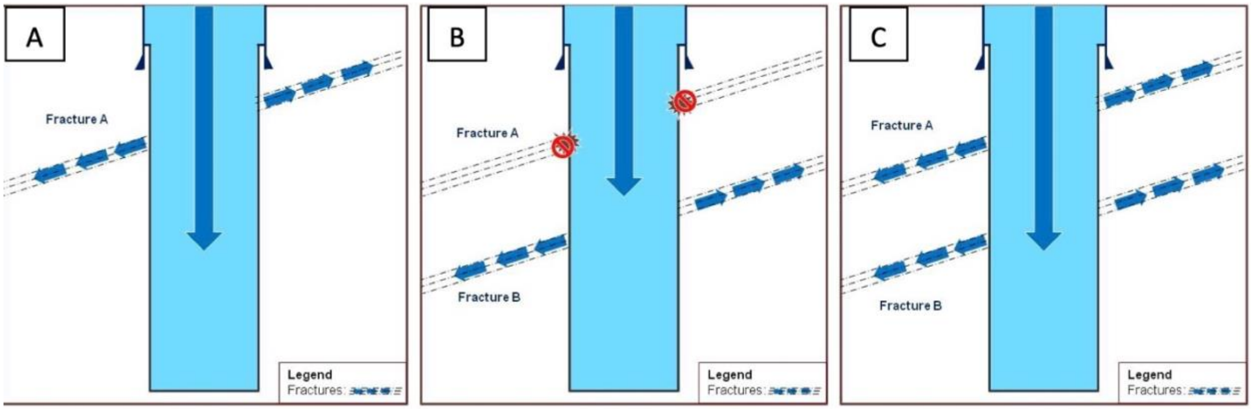
AltaRock Energy has developed new technology and methods to safely and economically create artificial geothermal systems from the hot dry rock that underlies most of the American west as well as many areas around the world. Development of an EGS system from the ground up involved many steps. Well stimulation with TZIMs (Thermally-degradable Zonal Isolation Material (proprietary) is used to create a multi-zone EGS reservoir in hot rock. Production wells are drilled into the EGS reservoir, and circulation from the injection well through the hot rock and into the production wells brings steam to the power plant.

Hydroshearing Creating artificial geothermal reservoirs for an EGS involves using hydraulic pressure to create a network of small, interconnected fractures in the rock that act as a radiator, transferring the heat in the rock to water circulating through the system. Hydraulic pressure is applied to “stimulate” existing cracks in the rock to slip, opening slightly and increasing rock permeability. The slip is caused by the tectonic forces that exist in the earth’s crust and are enabled by the lubrication from the water in the opened crack. This stimulation process is called hydroshearing. The pressures involved are much less than those for natural gas fracking.

Hydroshearing utilizes the rough surface texture of rock fractures to allow self-propping of open fractures. Furthermore, hydroshearing does not use chemically-based fracking fluids; only water is pumped into the well during hydroshearing, eliminating the problem of ground water contamination.

TZIMs AltaRock has developed a revolutionary new technology (TZIMs) which makes **multi-zone EGS reservoirs** possible. Multi-zone stimulation increases the size of the reservoir and the amount of energy that can be produced from the well by a factor of three or more. Stimulating multiple zones requires that one zone be sealed off before another zone can be stimulated. While other companies have tried using mechanical techniques borrowed from the oil and gas industry to block successive stimulation zones, AltaRock has developed an advanced, **biodegradable diverter** made from thermally sensitive polymers to block successive zones. This approach reduces the risk of equipment getting stuck in the wellbore and eliminates the cost of having a drill rig on-site during the stimulation process.

The following figure illustrates the principle.



TZIM Technique. Stimulation of a single fracture zone (A), stimulation of second fracture zone after diverter application to first fracture zone (B), and well with multiple fracture sets after TZIM degradation.

Multi-Zone EGS Lowers the Cost of Geothermal Power

Until this process was developed, EGS was experimental, expensive, and not commercially competitive. Wells with a single permeable zone simply did not produce enough hot water or steam to pay for the capital investment required to drill the wells and create the system. Increasing the flow of hot water or steam three to five times with multi-zone stimulation leverages those capital costs and can decrease the cost of power produced by over 50%.

Put in real-world terms, a typical single-zone EGS with one injection well and two production wells might produce on the order of 1.5 MW of power. Using multi-zone stimulation on the same 3 well layout would result in 10-15 MW of power production. A five-acre geothermal pad could support nine directionally wells, three injectors and six producers. In this scenario, a single-zone EGS could produce 5 MW of electricity on the five-acre pad. Multi-zone EGS would produce 30-50 MW of electricity on the same pad. The capital investment for the single-zone and multiple-zone systems is similar, so the ramifications for return on investment and power generation are dramatic and quite clear.

A 2007 study led by the Massachusetts Institute of Technology estimated that with suitable investments and improvements to existing technology, EGS could supply up to 10 percent of the country's electricity needs within 50 years at prices competitive with fossil-fuel fired generation.

These same techniques can be applied to existing geothermal fields to dramatically increase power production and extend the life of those fields by expanding and enhancing permeability into previously impermeable rock. This greatly increases the heat transfer efficiency and steam production of the field which leads to an increased power production capacity.

AltaRock estimates that we could effectively double the power generation capacity of the existing geothermal plants in the U.S. using this method; an increase of over 3 Gigawatts of clean power to the grid without developing a single new field!

The EGS concept provides the potential to remove the "dry hole" risk associated with conventional geothermal, which require finding existing fractures that contain economically viable flows of naturally occurring hot water. Enhanced geothermal systems have the potential to allow the development of geothermal power projects at sites without conventional geothermal resources. With this technology, EGS can be applied in many areas not suitable for conventional geothermal development. The ability to engineer a geothermal reservoir and develop fluid circulation through hot rock means that many new areas could be producing clean, renewable energy in the near future from the ground beneath our feet.

Think GeoEnergy is also working on EGS, but recently suffered an unexpected a well blow-out that could put AltaRock ahead. A subscription to their newsletter will keep us up-to-date.

References

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