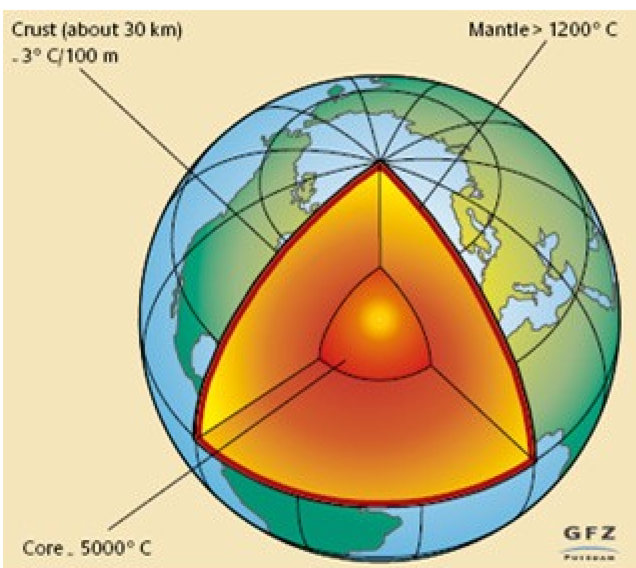
Perma Works' Geothermal Vision: Advanced Geothermal Engineering

Introduction

At Perma Works, we're about engineering the production of energy from the earth's subsurface is such an abundance so as to exceed mankind's need for energy. Providing clean, renewable earth's energy on demand when, where and in volume to provide invisible service to the consumer. Of all the natural energy sources (hydro, solar, wind), only geothermal and nuclear energy are capable of providing continuous, load bearing electrical power. At Perma Works, once we have the engineering tools in hand, geothermal power production will become the power generation of choice, now and forever.



Geothermal heat occurs everywhere under the surface of the earth, it's just a matter of how deep to go. Approximately, 99.9% of the earth is >100ºC; from the German Energy Agency. Historically, geothermal power production has taken place where the earth's heat comes very near the surface (geysers, hot springs are such examples). This natural geothermal is called hydrothermal.

Hydrothermal areas are found on continental fault boundaries where the earth's crust is highly faulted. In such areas, water is trapped and heated inside deep natural faults. Unfortunately, natural faults are found only in less than 10 percent of Earth's land area. Being able to produce geothermal power from hydrothermal is considerable with nearly 5% of California's electrical power is hydrothermal. The potential for hydrothermal power production in Alaska is huge. Perma Works builds logging and drilling tools to support hydrothermal power production.

Figure 1 shows a diagram of a hydrothermal power plant. In this power plant, superheated fluid is produce from one well and reinjected in a second well after passing through a turbine and heat exchanger. In the turbine, power is generated. Lots of power, some hydrothermal plants generate over 200MWatts. The heat exchanger has two functions, condensation of the steam coming from the turbine and generating hot fresh water for secondary customers needing heat. The use of hot fresh water is unique to geothermal as an energy source. In many geothermal power plants around the world, the use of hot fresh water generates more revenues more than the actual power production.

Some uses of secondary hot fresh water:

1. Raising fish or heating green houses
2. Heating water resorts for year round operation
3. Growing algae for fuel production
4. Heating homes
5. ... anyplace heating is needed!

An approach for capturing the heat in dry areas (no hydrothermal) is known as "hot dry rock", also referred to as Enhanced Geothermal Systems. Here at Perma Works, we like the term Engineered Geothermal Systems, EGS. The DOE estimates that the worldwide potential of EGS power generation is 50,000 times that of fossil energy. Here, heat is mined from the rock by man made (engineered) geothermal reservoirs.

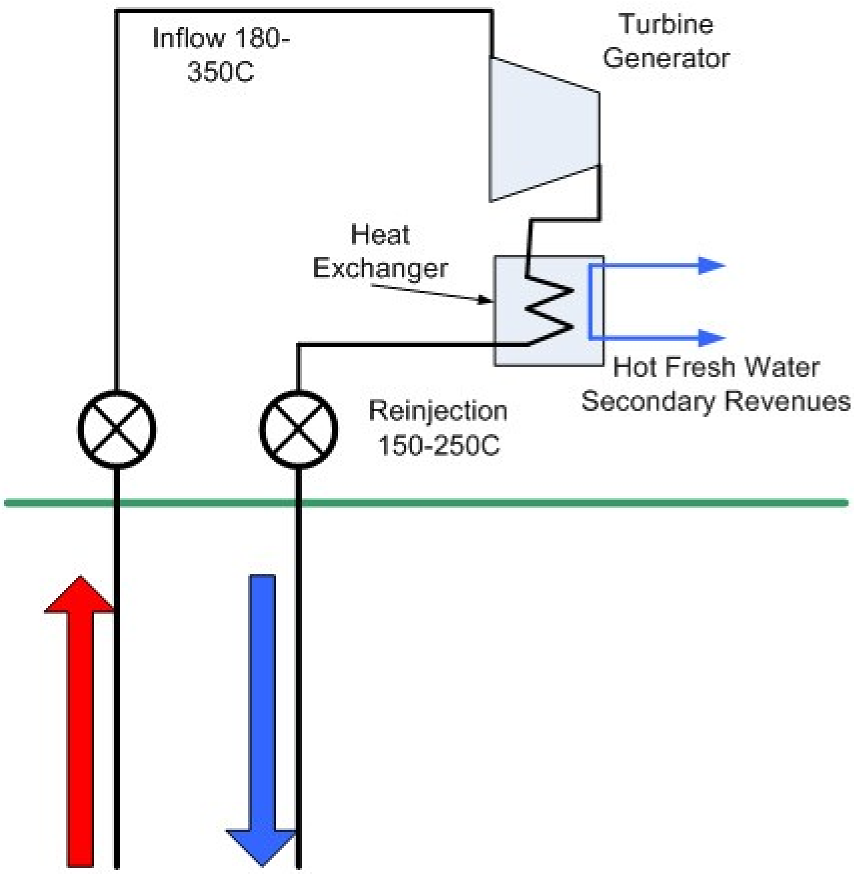


Figure 1: Geothermal plant diagram

It is the fundamental belief at Perma Works that when we learn to harness EGS power, we will have endless, clean and renewable energy. EGS can supply power 24-7, 365 days a year. EGS power plants can be scaled up to 100s - 1000s of MWatts. EGS is generating power from the closest infinite energy resource the world has, its own molten core.

Mother Earth's Eternal Energy Source

The earth's core is molten. Scientists believe the Earth would have cooled to a solid core if it were not for the naturally occurring radioactive decay found in all rocks. In short, the Earth's core will remain molten for billions of years yet to come. As you move down from the Earth's surface to its molten center, temperatures raise approximately 17-30ºC per Km. This heat is everywhere below the surface independent the surface temperatures.

The US EGS Potential

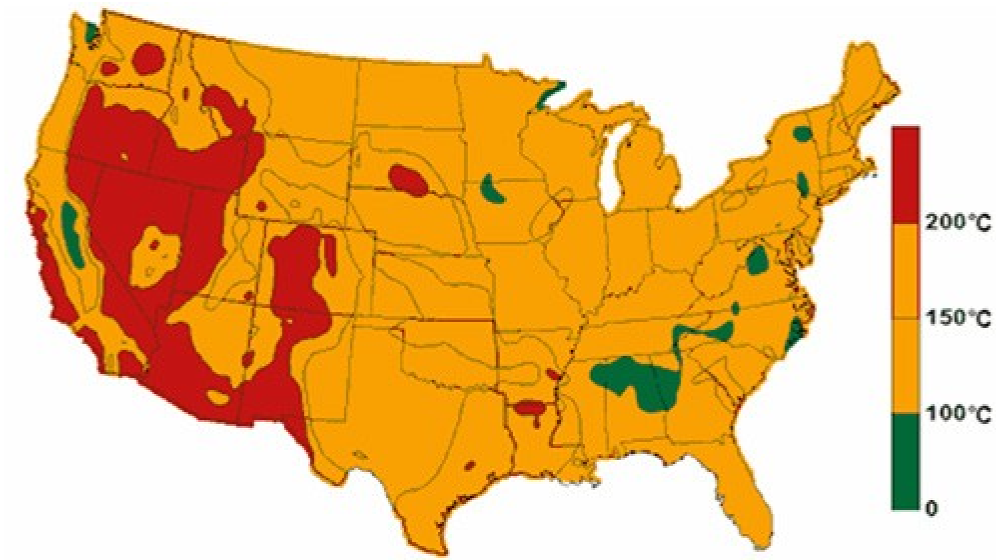


Figure 2. US temperature profile at 6 Km depth.

Above is an estimated geothermal resources map (http://www1.eere.energy.gov/geothermal/geomap.html) of the United States showing the estimated subterranean temperatures at a depth of 6 Km. The fossil energy industry routinely drills wells to 5 Km and has drilled a large number of wells to 8 Km.

In general, it takes temperatures above 150ºC for extracting geothermal energy from the earth. Temperatures in excess of 200ºC could significantly increase the energy efficiency of the geothermal power plant. It can be clearly seen from the temperature profile of the US, temperatures of 150ºC and above can be achieved today using conventional oil drilling technologies.

The question is now, "What is needed to mine the heat beneath our feet?"

Engineering the Earth Heat Exchanger

In order to mine the heat from the earth, a subterranean heat exchanger is needed. In order to gain 100's of KWatts of energy, the heat exchanger must be huge. In fact, the heat exchanger must look like a manmade hydrothermal reservoir.

For years the oil industry has used hydraulic fracturing of rock formations to increase well productivity. This process is suggested for the creating of the reservoir. Hydraulic fracturing of the rock is done by pumping high-pressure water into the rock from the wellbore.

The fractured rock is mapped using an array of seismic sensors. Seismic mapping is used to target additional wells needed to mine the heat.   These wells are drilled to intercept the fractured rock at remote locations away from the original well. Hydraulic fracturing can reach out miles. Figure 4 shows actual fracture mapping of a future EGS well.

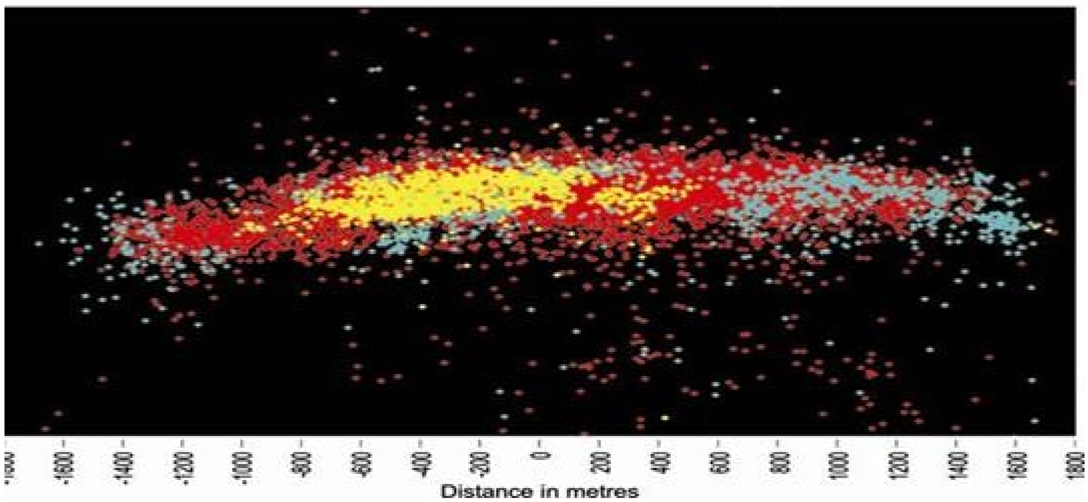


Figure 4. Each dot represents a seismic event created by hydraulic fracturing of the rock. Fracturing is moving out over 1600 meters from the well located at distance zero.

Figure 5 is now showing the completed EGS power plant. Cool water is being supplied from the surface down through two injection wells. The cool water is heated by the fractured rocks like in any heat exchanger. After the water heats up, it is brought back to the surface through a production well and used to drive turbines to produce electricity or to provide heat for home and business. In general, depending on the thermal conductivity of the rock, the rock temperature and the rate of heat mining, EGS power plants can run for 20 years or longer.

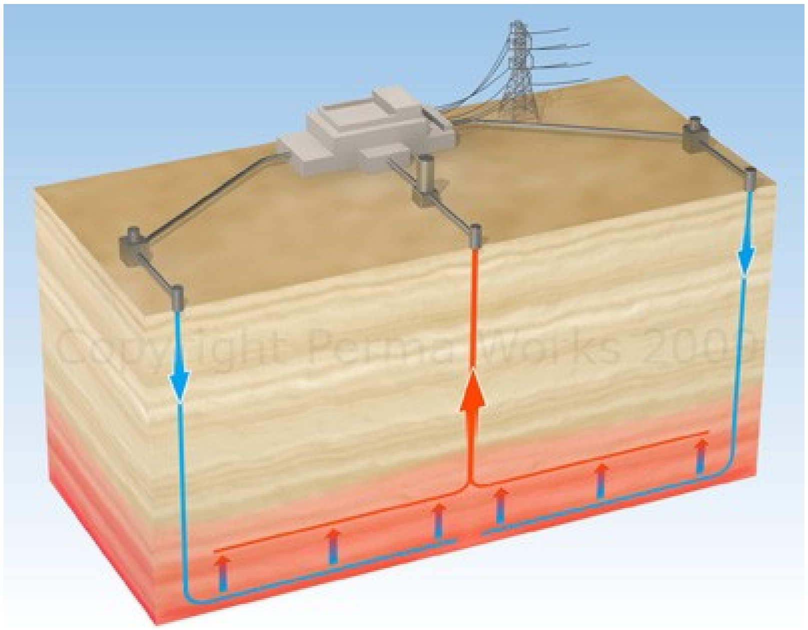


Figure 5. The EGS power plant is now up and running. The plant is mining heat (energy) from the hot rock deep in the earth.

Researchers at the Los Alamos National Laboratory in New Mexico have studied hot dry rock since 1974. An experimental facility was built in Fenton Hill, New Mexico, involving a well drilled 11,500 feet into rock at 430°F to demonstrate the feasibility of EGS technology. Water pumped down the well at 80°F returned to the surface at 360°F. Research and development is continuing in the United States as well as in Australia, France, Germany, and Japan in an effort to make EGS technology commercially feasible. Though several technical hurdles remain, Europe and Australia are currently working toward the establishment of the first commercially viable EGS system. The US is currently lagging in the commercial development of this technology.

To this point, the EGS example given is a relatively simple illustration. In truth, the EGS wells are going to be more complex and more like the wells used to extract oil. Many oil wells have multiple bottom hole sections drilled horizontally to maximize production.

By drilling a single vertical well to the required depth to reach geothermal temperatures and then drilling multiple horizontal offshoots, the power production per vertical well can be maximized by creating multiple heat exchangers in hot rock formations. Figure 6 below is attempting to show a more complex EGS well configuration in 2D. By adding values (also used in oil production), the geothermal plant owner has greater control to regulate power production allowing reservoir heat recovery during low production periods and to ensure continued production if reservoir conditions change.

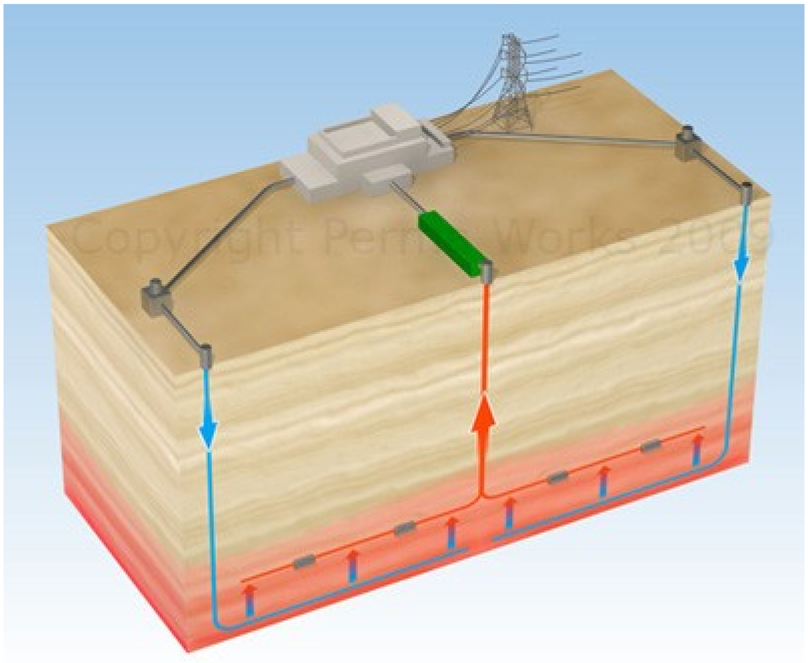


Figure 6. This more complex well design maximizes well production and allows for the geothermal plant owner to better control fluid production.

In order to realize the EGS configuration illustrated in figure 6, a number of new technologies will need to be developed from existing oil industry services. These are new technologies because the existing oil industry services are designed for lower temperatures and lower flow rates. In some cases, oil industry in wells controls are designed for one time use as the oil production declines. EGS wells will be more interactive and be required to operate for 20 to 50 years or be replaceable.

1. HT valves and motor controls to operate valves from the surface. Valves with linear controls while oil industry valves are all opened or all closed.

2. HT Measurement While Drilling (MWD) tools to directionally control the drilling process inside a favorable rock formation.

3. HT Logging While Drilling (LWD) to understand the rock properties while drilling such that EGS targets zones can be quickly identified. Where oil industry LWD tools are sensitive to oil or natural gas bearing formations.

4. Stimulation monitoring tools needed to know where the rock is fracturing such that placement of slotted casing and valves can be correctly located.

5. HT flow and temperature sensors located between production zones in order for the plant owner to understand reservoir heat and fluid production.

By working with other EGS researchers Perma Works is committed to the development of EGS while finding markets with the oil industry and existing geothermal industry. By crossing industry boundaries and working jointly with others, Perma Works will enable the technology solutions needed to develop future EGS power production.

Once EGS becomes a matter of engineering an rock heat exchanger, EGS can become the business of supplying energy on a commercial basis of where, when and how much. It’s the engineering of the reservoir which will enable the EGS to become the premier renewable energy: it clean, its 24-7 and its abundant.