Geothermal Energy and why I like it

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OVERVIEW

If you were to travel down into the Earth, you would notice that it gets hot, very hot. On average, the temperature goes up about 30 degrees Celsius for every kilometer you go below the earth's crust this is called the geothermal gradient. There are 3 ways that heat can be produced: the sun, collisions from meteors (of which we thankfully have few) and the decay of radioactive isotopes. Radioactive isotopes have been in the Earth from the beginning, and as time went on, they decayed. One by-product of the decay is heat. There are still some radioactive isotopes heating up the planet now. Uranium, Thorium, and Potassium all have long lived radioactive isotopes, which means they take a long time to decay. Any short lived isotopes like Aluminum 26 have all ready decayed (Basu). So its hot down there, and electricity can be formed by heat. Coal and nuclear power plants produce electricity by boiling water to turn turbines, which makes electricity. Inside the Earth, there are all ready the 2 key ingredients in making electricity- heat and water. Geothermal energy utilizes the hot water and steam naturally present in the Earth to run generators.

HISTORY

Geothermally heated water has been used by people all over the world for more than 2,000 years. Originally, the hot springs were used only for bathing and washing clothes. People came to believe that the water from these hot springs had medicinal value. Roman spas could be found throughout their vast empire. Hungarians were the first to drill their own, more than 100 years ago. By 1900, drilling for hot water was a common practice in many countries. Shortly afterwards, Japanese farmers were using hot springs to heat their greenhouses. By the 1930's, this water was being used in Budapest to heat homes. In the early 1940's, industries in New Zealand and Iceland started using the hot water. As time progressed, people found more and more uses for this source of heat. In addition to heating homes, recreation, agriculture and fish farming, fumaroles have been used for recovering drinking water as well as reclaiming minerals trapped in the water. The recovery of boric acid in Larderello, Italy was one of the first operations in place for recovering minerals. Starting in 1812, people boiled water from the hot springs with wood fires. In 1827, they realized that they could use the fumarolic steam to fuel the process. The real breakthrough came in 1904, engineers in Larderello managed to light 5 light bulbs with a ¾ H.P. generator, run on the steam there. That was the true beginning of geothermal energy (Halacy, 1977). By 1913, Larderello had a 250 kw station in service which produced a constant flow in electricity. 1922 saw America's first attempt at geothermal electricity, it was at a site in California called "The Geysers." They only managed to heat the resort there before the steam corroded the engines, it was a failure. We were not the only country to follow in Italy's footsteps. Japan dug their first geothermal well in 1919, 2 years before America. New Zealand and Mexico both had small geothermal plants in operation shortly before us as well (Kruger and Otte, 1973).

LOCATION

Most major geothermal areas are near plate margins. Areas of recent volcanism are ideal, whereas places with thick sedimentary rock deposits away from plate margins are generally not very productive areas to look. Geothermal systems can be found where the geothermal gradient is at or slightly above normal or in regions around plate margins. In the regions around plate boundaries, the geothermal gradient can be more than 10 times the average- more than 300 degrees Celsius per kilometer. A geothermal system contains a heat source, a reservoir and a fluid. The heat source can range from the normal Earth temperature (which depends on depth) to over 600 degrees Celsius when a magmatic intrusion gets to a depth of 5 - 10 kilometers. The reservoir is hot permeable rock, the fluid can circulate through the rock, getting very hot in the process. Usually, the reservoir will have a layer of impermeable rock above and below it. There is often a superficial recharge area- a gap in the impermeable rock on top, where water can seep into the system from rain or streams (Dickson and Fanelli). The permeable rocks at Larderello are limestone, dolomite and anhydrite. The capping rock is a mixture of carbonates, argillites and amphibolites (Kruger and Otte, 1973). The geothermal fluid is water, as a liquid or a gas. It often carries chemicals and gasses with it, carbon dioxide and hydrogen sulfide are common (Dickson and Fanelli). A geothermal hydrothermal system includes a geothermal reservoir, wells, and a power plant. Hydrothermal means that there is a lot of steam or water in geothermal system that can be brought to the surface (EREN).

FINDING IT

There are several methods used for actually finding the productive areas. These range from aerial photography to studying the water in surrounding areas. Obviously, fumaroles and geysers are good indicators of a geothermal area, but its usually not that easy. There are lots of locations which do not have boiling water shooting out of the earth, so people have come up with more sophisticated prospecting techniques. One method involves infrared aerial photographs of the land. The infrared will show hotspot in the ground (Halacy, 1977). Geology and hydrogeology are the starting point for exploration. Information obtained in these studies can later help the reservoir and production engineers. Generally, these studies should be done by an geothermal geologist. Geochemical surveys are also very important. These surveys can yield vast amounts of important information, including: if the fluid is dominantly water or vapor, minimum temperature, what kinds of minerals are likely present in the water, the homogeneity of the water, and the source of the recharge water. These surveys are relatively cheap, they involve chemical and isotope analysis of the water and steam in fumaroles and other areas of geothermal activity at ground level. Wells can also be dug and surveyed. Geophysical surveys are done at or close to the surface. They include thermal, electrical, electromagnetic, seismic, gravity and magnetic surveys. Many of these techniques were developed by people searching for oil. Geophysical surveys can help determine the shapes, size and depth of the reservoir, but do not give any indication to whether there is any fluid in there. Drilling exploratory wells are the final, and most expensive step in an exploration program. It is also the only way to actually know what is down there. Before any field work is done, all of the preexisting data is studied to help cut down on the cost, as well as increase the effectiveness of the prospecting (Dickson and Fanelli).

METHODS

There are 3 main ways of approaching the problem of turning hydrothermal fluids (hot water and steam) into electricity: dry steam, flash steam and binary cycle. The method used depends on the state (gas or liquid) and the temperature of the fluid. There was an unsuccessful project started in the 1970's called the Hot Dry Rock project. Bore hole were drilled down into the earth, then pressurized water was put down there, making cracks in the rock, these were called hydraulic fractures. The hope was that the water they pumped down there would seep into the fractures and heat up, another well would be drilled into the reservoir, through which the hot water could be pumped, and…voila- an artificial geothermal system. It was too expensive, and didn't work (Dickson and Fanelli).

DRY STEAM

Dry steam is the oldest method, it is used in Larderello, Italy. This uses steam to turn a turbine. A hole is drilled down into the Earth to where there is steam present, this is called a production well. A pipe is put in this hole. The steam is less dense than the surrounding rock, so it rises. It turns the turbines at the top of the pipe, some what like how a windmill works. The steam is then condensed and put back into the ground through the injection well, so it will (hopefully) re-circulate through the impermeable rock, get hot again, and find it way back into the reservoir (EREN). Dry steam plants emit steam and some gasses into the atmosphere. The Geysers, in northern California uses dry steam, it produces more electricity than any other geothermal power plant in the world. Dry steam is great for powering a plant, D.S. Halacy states "Dry steam is the power engineer's dream. It is easy to handle, does not corrode equipment, and produces more power than lower temperature wet steam or hot water" (Halacy, 1977). The only problem with dry steam is that those geothermal systems are rather rare (Dickson and Fanelli).

FLASH STEAM

The flash steam method is the most common in practice today. High temperature water is pumped from under ground, where it is under a lot of pressure to the surface. It is kept pressurized until it gets to a tank at the surface with a much lower pressure. Some of the water is flashed to steam, turning turbines. The remaining brine is often sent to a second tank where the process is repeated. Any brine left after this is injected back into the ground via the injection wells. Double flash plants, those with 2 flash tanks, typically use 18-25% of the mass of the fluid in the reservoir for steam. The other 75-82% is injected back into the ground. Geothermal brine often contains a lot of silica, which can form on the walls of the equipment as hard scales. Another problem with flash steam is that it requires very high temperature water, at least 200 degrees Celsius (EREN).

BINARY CYCLE

Many people believe that the future of geothermal energy lies in the binary cycle (INEEL 2). The binary cycle system uses the earth's hot water to heat a secondary liquid with a boiling point lower than that of water, usually an organic compound (Dickson and Farreli). The hot water follows a pipe from the production well, up to the heat exchanger, to the injection well. The water is kept under pressure, so there is no buildup of silica scales. The secondary liquid is heated in the heat exchanger, boils, and the gas turns the turbines. Then the gas is cooled, either by air or water, and returned to its liquid state, ready to boil once again. There are a couple advantages to the binary cycle. First of all, once the power plant is in place, it is very cheap to operate because there is little wear and tear on the engines and plumbing. It can also run efficiently on lower temperature water that dry steam or flash steam can (EREN). With the proper secondary fluid, a binary cycle plant can be run with water temperature as low as 85 degrees Celsius (Dickson and Farreli). Freon was successfully used by the Russians as a low temperature secondary fluid in Paratunka (Halacy, 1977). Geothermal areas often provide water warm enough for a binary cycle where as it is difficult to find much water warmer than 200 degrees Celsius (INEEL 2). Binary cycle plants are easy to install, they can be ready for energy production in less than one year. Recently, there was a break through in binary cycles, it is a new system called the Kalina cycle. It uses a mixture of water and ammonium as the working fluid. This mixture has a very low boiling point, which allows the Kalina cycle to be up to 40% more efficient that regular binary cycles. There are virtually zero emissions from binary cycle plants, making them an excellent source of environmentally friendly energy. This is not to say that the other methods (dry steam and flash steam) are dirty, they are also very clean forms of energy, but do have more emissions (Dickson and Fanelli).

CONCLUSION + SOME FUN FACTS

Well, not a whole lot to say in the way of a conclusion, I must admit that before I started researching this topic I was biased in favor of geothermal energy because of the environmental factors, but now I am even more convinced that geothermal energy is a place that deserves a whole lot of research as a means of helping to solving our energy problem. I'm a huge fan of it, especially the binary cycle, which is the cleanest and the most useful in most areas. Direct use of geothermal energy (using warm water to heat and cool houses, for aquaculture, agriculture, etc.) saves millions of barrels of oil every year, and has the potential to save many million more. It can also be up to 80% cheaper than using fossil fuels. The cost of geothermal energy is usually between 5 and 8 cents/kWh, but as low as 3 cents. Plants put in now would have to charge about 5 cents/kilowatt-hour to be cost efficient because they generally have to drill into lower temperature areas (the really good spots are taken.) The cost of energy from natural gas is about 3 cents/ kWh. The extra price of geothermal energy can be partially compensated for by the fact that some plants are able to recover large amounts of minerals, such as zinc and silica (CREST). How many natural gas plants can sell their emissions? Geothermal energy emits no nitrous oxides, tiny amounts of sulfur dioxides, and a little bit of carbon dioxide. Fossil fuel burning plants emit between 1,000 and 2,000 times more carbon dioxide than geothermal plants. Geothermal plants take up significantly less land than fossil fuel and nuclear plants do: 1-8 acres per MW versus 5-10 acres/MW for nuclear and 19 acres/MW for coal. Another thing is that they are productive more than nuclear or fossil fuel plants, 90% of the time in comparison to only 65%-75% (INEEL 1)

Unfortunately, geothermal energy only accounted for 0.4% of the U.S. electrical generation, and .26% of the global electrical generation. The good news is that in the U.S. alone, this prevents the emissions of 22 million tons of carbon dioxide, 200,000 tons of sulfur dioxide, 80,000 tons of nitrogen oxides, and 110,000 tons of particulate matter every year (INEEL 1). Well that's about all I've got, but I'd like to say that I really think that geothermal energy is a win-win situation. Although I hardly mentioned direct use in this paper, I think that shows possibly even more promise than using it as a fuel for electricity Any way you use it, its clean and cheap, and who doesn't want that?

Sources

1.) Basu, Abhijit
Info taken out of various lectures from his class "G121 meteorites and planets"

2.) CREST (Center for Renewable Energy and Sustainable Technology)
Geothermal power : FAQs
http://www.crest.org/articles/static/1/995653330_5.html

3.) Dickson, Mary H. and Fanelli, Mario
What is Geothermal Energy?
Instituto di Geoscienze e Georisorse, Pisa, Italy
http://iga.igg.cnr.it/documenti_igaenergia/Geothermal Energy.pdf

4.) Energy Efficient and Renewable Energy Network (EREN)
Geothermal Hydrothermal
http://www.eren.doe.gov/power/pdfs/geo_hydro.pdf

5.) INEEL (INEEL 1 in the paper)
Environmental and Economic Impacts of Geothermal Energy
http://geothermal.id.doe.gov/xweb/other/framed.shtml?http://www.eren.doe.gov/geothermal/

6.) INEEL (INEEL 2 in the paper)
Geothermal Power Plants and Electricity Production
http://geothermal.id.doe.gov/x-web/other/framed.shtml?http://www.eren.doe.gov/

7.) INEEL (INEEL 3)
What is Geothermal Energy?
http://geothermal.id.doe.gov/what-is.shtml

8.) Halacy, D.S.
Earth, Water, Wind and Sun, Our Energy Alternatives
Harpor & Row Publishers 1977

9.) Kruger, Paul and Otte, Carel
Geothermal Energy: Resources, Production, Stimulation

Stanford University Press, 1973

The diagrams come from INEEL's page What is geothermal energy?
http://geothermal.id.doe.gov/what-is.shtml

The map comes from the Oregon Institute of Technology's geo-heat center website
dusys.htm
http://geothermal.id.doe.gov/x-web/other/framed.shtml?http://www.eren.doe.gov/geothermal/