Geothermal Energy – Using the Nuclear Earth as a Power Source

Course: Engr 597- Introduction to Nuclear Energy

Instructor/Editor: Dr. Elizabeth Ervin

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1. Introduction

The energy crisis is an increasingly important issue as the general public is becoming more aware of the green house effect, rising energy prices, and diminishing fossil fuel reserves. Renewable energy sources will be a very important source of energy in the future and large sums of money are spent on research in this field. This paper includes basic information about different geothermal power plant systems, potential energy production, challenges to geothermal energy expansion, and environmental benefits and predicaments. Lastly, the paper includes a “discussion and final thoughts” section to include my own opinion on the subject.

2.1 Geothermal Power Plant Operations

There are three different kinds of geothermal power plants; Dry Steam, Flash Steam, and Binary-Cycle power plants.[1] The general operation of a dry steam power plant is shown below in Figure 1. This is the most straight-forward way of generating electricity from geothermal energy. Steam is routed directly from the geothermal reservoir to the turbine which is linked to a generator to produce electricity.[1]

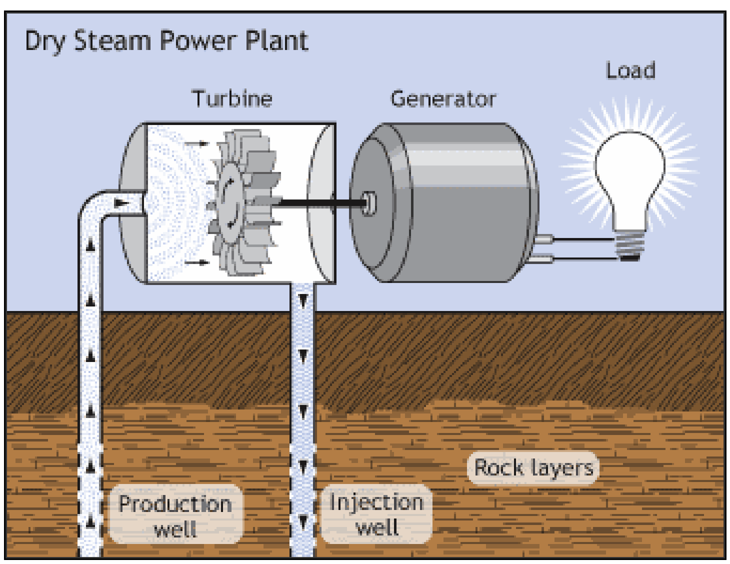

Figure 1. Dry Steam Power Plant Operation.[1]

The general setup of a flash steam power plant is illustrated in Figure 2. Water is pumped down through pipes deep into the ground to reach high heat rock layers. These high heat rock layers will heat the water up to 360°F (180°C) before it is pumped back up under high pressure to stay liquid. The pressure of the water is lowered as it is sprayed into the flash tank to rapidly vaporize, or "flash", before it enters the turbine. This vapor will drive the turbine and hot water that doesn't turn into steam can be flashed again in a second flash tank to create more steam that can drive the turbine for additional energy generation.[1]

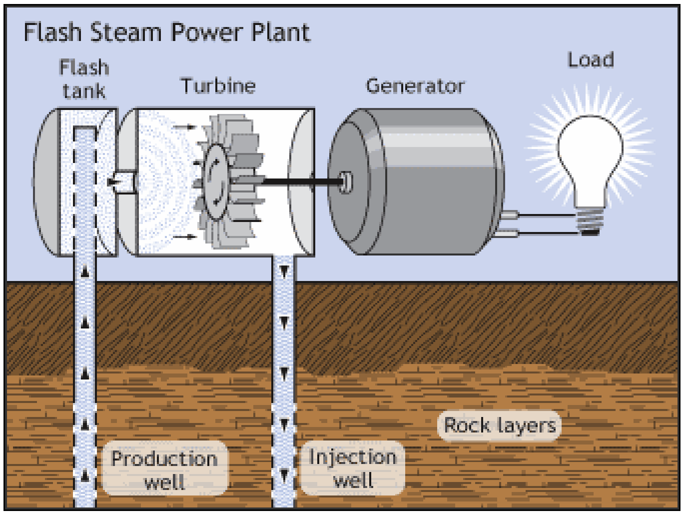

Figure 2. Flash Steam Power Plant Operation.[1]

Binary Cycle Power Plants (BCPP) is the third general way of generating electricity at geothermal power plants and it is shown in Figure 3. BCPP are used when the geothermal area contains fluids with moderate temperature (below 360°F). This fluid can be brought up through pipes and used to flash a separate fluid with a lower boiling point that runs in a closed system through the turbine. The closed system fluid will run through a heat exchanger where it is flashed by the geothermal area fluid and then driven into the turbine to produce electricity through the generator. The binary cycle system has the most promising future since the moderate temperature geothermal areas are fairly common.[1]

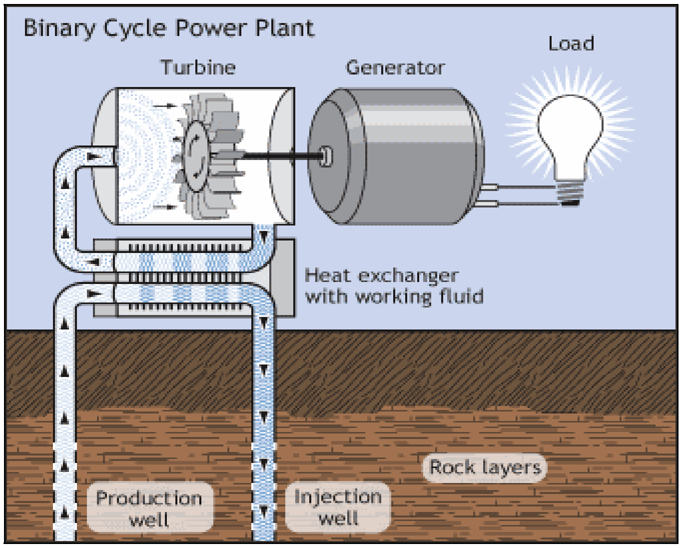

Figure 3. General operation of a Binary Cycle Power Plant.[1]

2.2-1 Existing Geothermal Power Plants (Dry Steam)

Iceland is known as one of the pioneers in utilizing geothermal energy. The high heat geysers and similar geothermal areas provide optimal conditions for generating geothermal energy. The Reykjanes Geothermal Power Plant is utilizing dry steam and is since 2006 producing a total of 100 Mwe (megawatts of electricity) from two separate turbines.[5] The plant was designed by Enex and is owned by Sudurnes Regional Heating Corporation. The dry steam is brought from reservoirs at 600°F (320°C). This is the first power plant to utilize steam at these extreme temperatures. The steam and geothermal brine (saturated salt water) is extracted from twelve 2,700m (8,700 ft) wells. The plant was positioned close to the ocean to enhance the cooling process of the left over steam and hot water coming out of the turbine. The RGPP pumps seawater in at a rate of 4000 liters/second (1055 gallons/s) to assist in the cooling and condensing process. The short end of the Reykjanes Geothermal Power Plant can be seen in Figure 4.[5]

Figure 4. The Reykjanes Geothermal Power Plant in Iceland.[5]

2.2-2 Existing Geothermal Power Plants (Flash Steam)

California is the state with the highest current geothermal energy capacity in the United States, and also more than any other country in the world with a total production capacity of over 2,500 MW. Several flash steam geothermal power plants are located in Southern California's Imperial Valley. Some examples are Leathers, CE Turbo, Elmore, and Del Ranch. These plants individually produce between 10 MW and 45 MW. However, the majority of the geothermal power plants in this region are dry steam power plants.[6]

2.2-3 Existing Geothermal Power Plants (Binary Cycle)

Binary Cycle Power Plants (BCPP) is believed to be the most used type of geothermal energy system in the future. One of the reasons is that the BCPP do not need the extreme heat reservoirs that the dry steam and flash steam power plants require. The lower heat reservoirs are more common and are usually located closer to the earth's crust, thus cutting down on the high costs of deep drilling. The Heber plant in Southern California's Imperial Valley consists of several independent BCPP each consisting of several binary units. The total output of the plant is approximately 92 MW, and the latest addition to the plant, Heber South, opened in 2008. Heber II is one of the plants located within the main Heber power plant and it is shown in Figure 5.[10]

Figure 5. Heber II located in Southern California's Imperial Valley.[10]

3.1 Potential Energy Production

As stated in the "National Geothermal Action Plan"on page 43, the current power generation from geothermal power sums up to a mere 3 GWe which translates to 0.4% of the total power generation in the U.S., or 13.5% of the renewable energy power generation. [2] It is also stated that there are 126 projects currently in development that is supposed to increase the total output to 5.7 GWe. The future development of geothermal energy depends on several factors including further technology development and exploration beyond the western states (where all current geothermal power is extracted).[2]

The future potential energy production greatly depends on the utilization of Enhanced Geothermal Systems (EGS), which is also referred to as engineered geothermal systems.[7] Figure 6 illustrated the basic concept of EGS. These systems consist of an injection well that injects cold water deep into the ground. The water is heated by the hot rock layers before it is brought back to the surface through production wells scattered in vicinity to the injection well(s). This system is currently in use, but is yet not proven commercially viable for mass production.[2] However, planned funding for 21 EGS projects intended to further develop and demonstrate the possibilities of EGS was announced in October 2008, of which 13 were first time recipients.[2]

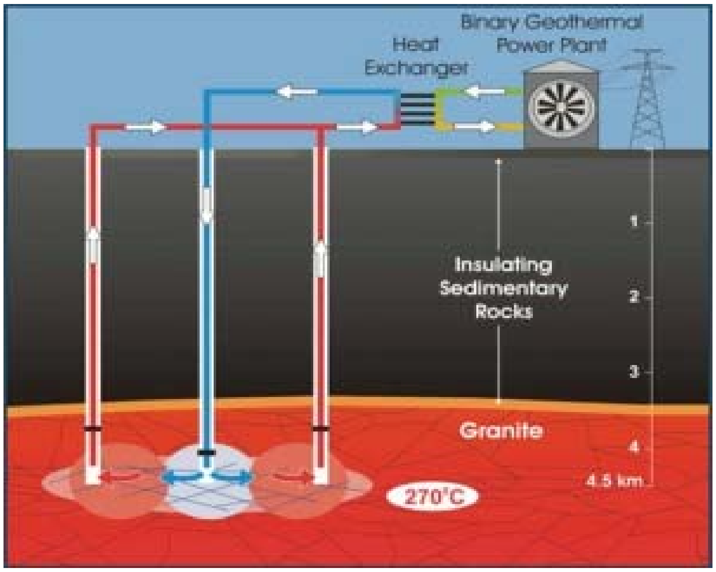

Figure 6. Enhanced Geothermal System (EGS).[11]

By incorporating the EGS, the "National Geothermal Action Plan" estimates that the total geothermal production has a capacity of more than 500 GWe, with a potential to reach an installed capacity of 100 GWe by 2050.[2] The Energy Information Administration (EIA) provides information about the total energy production in the U.S., which was approximately 73 quadrillion British Thermal Units (BTU) in 2008.[8] One BTU equals 0.2928 W-hr, a quadrillion is 10^{15}, and there is 8760 hours in a year. This gives a total energy production of about 2,340 GWe.

EIA estimates that the total energy generation will increase by 25% during the next 20 years (until 2030). That can be translated into a yearly increase of about 1.1%, and holding this constant for the next 40 years would give U.S. a total energy production of 3,600 GWe (or 55% increase). The predicted 100 GWe geothermal energy generation would then contribute 2.5 to 3% of U.S. total energy output. If all of the estimated 500 GWe could be utilized which is possible if there is a technological breakthrough, geothermal energy would provide close to 14% of U.S. total production. That is comparable to the current contribution of nuclear energy in the U.S, which is about 19.5%.[9] Either way it would be a substantial increase compared to the current 0.4% geothermal energy generation contribution. The EGS are more suitable for mass production due to their wider operation range, being able to produce electricity utilizing substantially lower heat sources than the conventional geothermal power plants, such as the dry steam and flash steam power plants. According to the various sources I have looked into, it seams like geothermal power never will become a substantial source of energy in the U.S. without the EGS.

3.2 Challenges to Geothermal Energy Expansion

The authors and providers of the “National Geothermal Action Plan” (NGAP) believe that there are three major fields that need improvement to secure the future expansion of geothermal energy: technologies, market structure, and policy and regulation.[2] Technical challenges include such topics as exploration, drilling, the environment, and the EGS challenge. The market structure can be split into investment patterns and risks, transmission lines, and labor force. Finally the policies and regulations can be divided into federal, state, and awareness. These topics will be discussed in order to evaluate the possible use of geothermal energy as a cost efficient energy sources in the future.[2]

The first subtopic of the technical challenges, exploration, deals with finding optimum sites for geothermal development. There is yet no cost efficient way of quickly finding these areas.[2] Drilling costs can be the most expensive part of the whole constructing process if the geothermal activity is not close to the surface. According to the NGAP the drilling cost will account for 10 to 20% for conventional wells that are relatively close to the surface (about 3 km). However, the cost of drilling can account for up to 70%, especially for deep drilling which is usually the case for EGS. This makes it apparent that lowering the cost of deep drilling is one of the main priorities for the geothermal industry to succeed in the future.[2]

There have been concerns with geothermal energy even though it is known to be one of the most environmental friendly energy sources available. One of the reasons is that the fresh water is also demanded by the public. The wastewater that runs through the geothermal system is brought up from deep sources and can contaminate the fresh water system. Also, if more water is drawn out of the deep sources than is put back, it will create voids. These voids can collapse causing the surface to dip, referred to as subsidence. Research has also been made to determine whether the deep drilling associated with geothermal plants can cause seismic events. A protocol was adopted in 2009 after the study was published in 2008 that deal with liabilities and precautions related to this topic.[2] There is currently ongoing research in this area to further evaluate this connection not only for geothermal energy, but also for oil and gas exploration.[2]

The enhanced geothermal systems (EGS) have already been discussed briefly in the previous section. Ways of improving the flow rate between the injection wells and production well(s) is an important issue. The process will be inefficient if only some of the injected water actually reaches the production well. Geothermal energy is competing for financial support with other renewable energy sources such as solar, biomass, and wind. Geothermal energy is currently most dependent on research funding in the areas previously discussed, i.e. drilling, EGS, exploration etc. Transmission lines are also an issue since geothermal power plants usually are located in remote areas. New geothermal projects in remote areas are usually dependent on further development in the form of additional power plants, industries, etc. to validate the high costs of transmission lines.[2]

Geothermal development will require a growing labor force of geologists, engineers, drillers, and hydrologists. A 2004 survey predicted that every MWe of geothermal energy will create almost 2 full time jobs. Also every MWe developed will generate 6.4 years of work experience. Specific training through development of new university degrees and an expansion of current ones will be needed to fill these positions. Certification programs should also be considered to secure the supply of skilled personnel.[2]

Policies and regulations that add cost and hinder the expansion of geothermal power must be simplified to make investments commercially viable. Most new technologies will be faced by strict policies by simply placing them in a group of existing industries before substantial research has been done in the area to justify more lenient regulations. The most important federal policy is Production Tax Credit (PTC) which supports renewable energy programs and was introduced in 1992.[13] PTC assists power plants that utilize renewable energy with 1.5 to 2 cents per kWh produced.[13] It was recently extended for an additional three years after first being lengthened to benefit geothermal power projects launched before 2011. However, the magnitude of the future funding will be dependent on the future economic condition in the U.S.[2] Bureau of Land Management (BLM) is a federal agency that controls what sites are available for geothermal development. As of December 2008 BLM controls 700 million acres, but only 0.1% of this land is available for geothermal expansion.[2]

The current most important state policy to secure the future of geothermal energy is the Renewable Portfolio Standard (RPS) which is enforced in some states and requires a certain percentage of utilities' energy production to come from renewable resources. As of August 2008 more than 30 states had implemented RPS. Renewable energy credits (RECs) is a document that is ascribed for each MWh of renewable energy produced. Utilities can fulfill their requirement by buying or trading RECs. Finally it is important to raise the public awareness of the new technologies that makes it possible to generate geothermal energy from reservoirs that previously were deemed useless.[2]

4. Environmental Benefits and Predicaments

Paul Brophy wrote a journal in 1996 that discusses the environmental benefits of geothermal power plants compared to other energy sources.[12] One of the major environmental issues with geothermal power is water quality, as briefly discussed. The water that is used in the plants is usually well below drinking standard, so if this water is dumped back in the ground water it will be harmful to the local population and wildlife. It is therefore important to inject the fluid back into the geothermal system where it was initially taken. Geothermal plants do also release carbon dioxide, but an insignificant amount compared to coal and oil plants. Coal and oil power plants release 1800 to 2200 lb of carbon dioxide per MWh produced while geothermal power plants discharge about 1lb/MWh.[12]

Hydrogen sulfide can accidentally be released when drilling and testing is in progress, or if a well is leaking. However, high doses of hydrogen sulfide are needed for it to be dangerously toxic. There are also geological issues that can occur, mainly from drilling the deep wells. Seismic activity, landslides, sedimentation, and volcanic hazards can be caused by deep drilling. Landslides can occur when the plant and drilling is close to steep slopes, and there has been either an overinjection of water into the reservoir, or if insufficient water has been replaced back into the geothermal system. Seismic activity is a risk, but it should be added that all measured responses to deep drilling has been at the “microseismic level.”[12] Volcanic eruptions should be avoided by performing a risk assessment prior to drilling. Another benefit is that geothermal power plants require substantially less land than other power plants, both renewable and fossil fuel plants.[12]

5. Discussion and Final Thoughts

After completing this paper I decided to give some personal thoughts on the future possibilities of geothermal energy as a substantial contributor to the U.S. power production. It sounds promising that geothermal energy could produce up to 500 GWe as mentioned in the “National Geothermal Action Plan”, but the technology required to reach this number is yet to be invented, or not optimized enough to be commercially viable. EGS (enhanced geothermal systems) is definitely the most important technology that needs to be improved, but drilling and exploring reservoirs must be advanced. With the current economic situation there will be less money available for new technologies in general. I believe that geothermal energy will contribute more in the future, but not to the extent predicted in the “National Geothermal Action Plan.” However, there are significant environmental benefits with geothermal power that should not be overlooked. Extremely low carbon dioxide discharge compared to coal and oil power plants and significantly less land needed than solar and wind power are some of its benefits.

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