



GEOTHERMAL RESOURCES

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ABSTRACT

This paper deals with the use of geothermal resources for production of utility-scale electricity, drilling into earth, technologies of changes of geothermal energy into electrical energy, the future of geothermal electricity, and last chapter is conclusion.

1. INTRODUCTION

Heat is a form of energy and geothermal energy is, literally, the heat contained within the Earth that generates geological phenomena on a planetary scale. ‘Geothermal energy’ is often used nowadays, however, to indicate that part of the Earth's heat that can, or could, be recovered and exploited by man, and it is in this sense that we will use the term from now on [1].

Geothermal energy is energy derived from the heat of the earth's core. It is clean, abundant, and reliable. If properly developed, it can offer a renewable and sustainable energy source. There are three primary applications of geothermal energy: electricity generation, direct use of heat, and ground-source heat pumps. Direct use includes applications such as heating buildings or greenhouses and drying foods, whereas ground source heat pumps are used to heat and cool buildings using surface soils as a heat reservoir.

2. GEOTHERMAL RESOURCES

Understanding geothermal energy begins with an understanding of the source of this energy - the earth's internal heat. The Earth's temperature increases with depth, with the temperature at the center reaching more than 4200 °C (7600 °F) [2]. A portion of this heat is a relic of the planet's formation about 4.5 billion years ago, and a portion is generated by the continuing decay of radioactive isotopes [2]. Heat naturally moves from hotter to cooler regions, so Earth's heat flows from its interior toward the surface.

Because the geologic processes known as plate tectonics, the Earth's crust has been broken into 12 huge plates that move apart or push together at a rate of millimetres per year (fig. 1). Where two plates collide, one plate can thrust below the other, producing extraordinary phenomena such as ocean trenches or strong earthquakes. At great depth, just above the down going plate, temperatures become high enough to melt rock, forming magma [2]. Because magma is less dense than surrounding rocks, it moves up toward the earth's crust and carries heat from below. Sometimes magma rises to the surface through thin or fractured crust as lava.

However, most magma remains below earth's crust and heats the surrounding rocks and subterranean water. Some of this water comes all the way up to the surface through faults and cracks in the earth as hot springs or geysers. When this rising hot water and steam is trapped in permeable rocks under a layer of impermeable rocks, it is called a geothermal reservoir. These reservoirs are sources of geothermal energy that can potentially be tapped for electricity generation or direct use. Figure 2 is a schematic of a typical geothermal power plant showing the location of magma and a geothermal reservoir [3]. Here, the production well withdraws heated geothermal fluid, and the injection well returns cooled fluids to the reservoir.

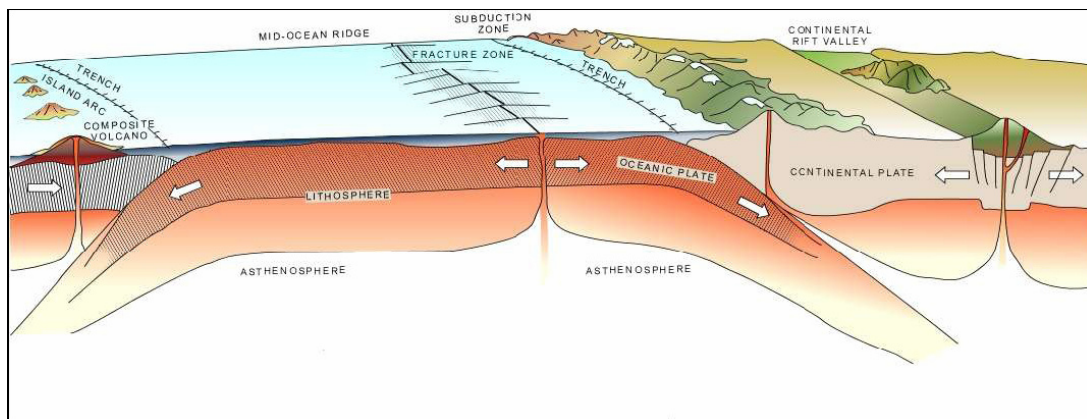


Figure 1 - Schematic cross-section showing plate tectonic processes [1].

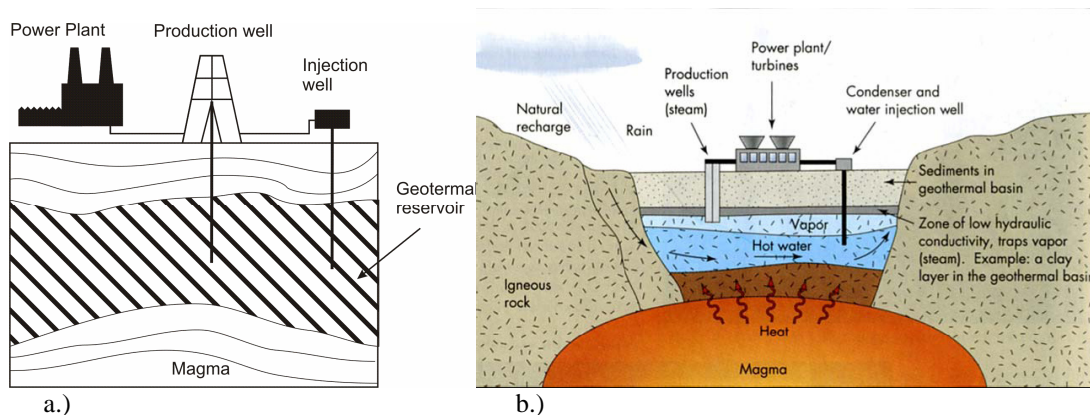


Figure 2 - a.) Schematic cross-section showing plate tectonic processes [2],
 b.) Illustration shows idealized geothermal resource [4].

2.1. Resource Identification

Geological, hydrogeological, geophysical, and geochemical techniques are used to identify and quantify geothermal resources. Geological and hydrogeological studies involve mapping any hot springs or other surface thermal features and the identification of favorable geological structures. These studies are used to recommend where production wells can be drilled with the highest probability of tapping into the geothermal resource. Geophysical surveys are implemented to figure the shape, size, depth and other important characteristics of the deep geological structures by using the following parameters: temperature (thermal survey), electrical conductivity (electrical and electromagnetic methods), propagation velocity of elastic waves (seismic survey), density (gravity survey), and magnetic susceptibility (magnetic survey) [2]. Geochemical surveys (including isotope geochemistry) are a useful means of determining whether the geothermal system is water or vapor-dominated, of estimating the minimum temperature expected at depth, of estimating the homogeneity of the water supply and, of determining the source of recharge water.

Geothermal exploration addresses at least nine objectives [2]:

- identification of geothermal phenomena,
- ascertaining that a useful geothermal production field exists,
- estimation of the size of the resource,
- classification of the geothermal field,
- location of productive zones,
- determination of the heat content of the fluids that will be discharged by the wells in the geothermal field,

- compilation of a body of data against which the results of future monitoring can be viewed,
- assessment of the pre-exploitation values of environmentally sensitive parameters,
- determination of any characteristics that might cause problems during field development.

2.2. Drilling

Once potential geothermal resources have been identified, exploratory drilling is carried out to further quantify the resource. Because of the high temperature and corrosive nature of geothermal fluids, as well as the hard and abrasive nature of reservoir rocks found in geothermal environments, geothermal drilling is much more difficult and expensive than conventional petroleum drilling. Each geothermal well costs \$1–4 million to drill, and a geothermal field may consist of 10–100 wells [2]. Drilling can account for 30–50% of a geothermal project’s total cost. Typically, geothermal wells are drilled to depths ranging from 200 to 1,500 meters depth for low- and medium-temperature systems, and from 700 to 3,000 meters depth for high-temperature systems [2]. Wells can be drilled vertically or at an angle. Wells are drilled in a series of stages, with each stage being of smaller diameter than the previous stage, and each being secured by steel casings, which are cemented in place before drilling the subsequent stage. The final production sections of the well use an uncemented perforated liner, allowing the geothermal fluid to pass into the pipe. The objectives of this phase are to prove the existence of an exploitable resource and to delineate the extent and the characteristics of the resource. An exploratory drilling program may include shallow temperature-gradient wells, “slim-hole” exploration wells, and production-sized exploration/production wells. Temperature-gradient wells are often drilled from 2–200 meters in depth with diameters of 50–150 mm. Slim-hole exploration wells are usually drilled from 200 to 3000 meters in depth with bottom-hole diameters of 100 to 220 mm. The size and objective of the development will determine the number and type of wells to be included in exploratory drilling programs [2].

3. GEOTHERMAL POWER TECHNOLOGY

Utility-scale geothermal power production employs three main technologies. These are known as dry steam, flash steam and binary cycle systems. The technology employed depends on the temperature and pressure of the geothermal reservoir. Unlike solar, wind, and hydro-based renewable power, geothermal power plant operation is independent of fluctuations in daily and seasonal weather.

3.1. Dry Steam Power Plant

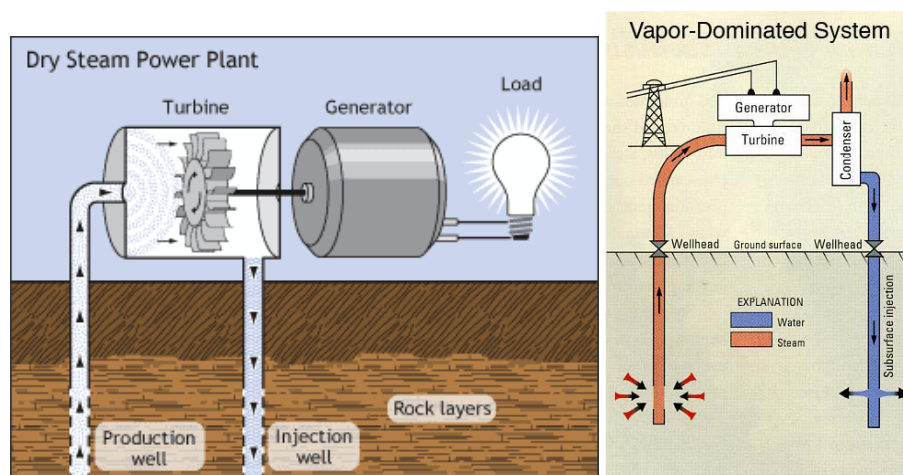


Figure 3 - Dry steam power plant schematics [2], [5].

Dry steam power plants use very hot (>455 °F, or >235 °C) steam and little water from the geothermal reservoir [2]. Steam plants use hydrothermal fluids that are primarily steam. The steam goes directly to a turbine, which drives a generator that produces electricity. The steam eliminates the need to burn fossil fuels to run the turbine. (Also eliminating the need to transport and store fuels!) This is the oldest type of geothermal power plant. It was first used at Lardarello in Italy in 1904, and is still very effective [3]. Steam technology is used today at The Geysers in northern California, the world's largest single source of geothermal power. These plants emit only excess steam and very minor amounts of gases.

3.2. Flash Steam Power Plants

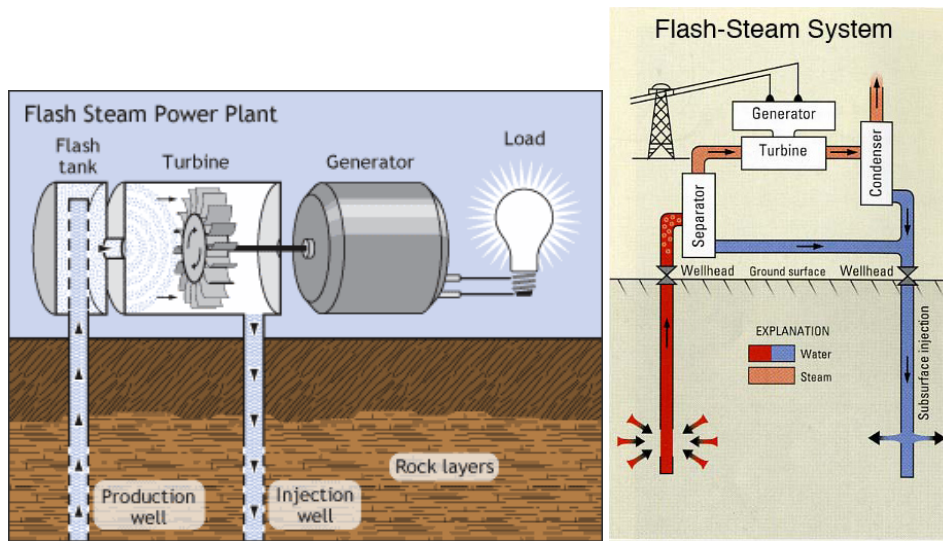


Figure 4 - Flash steam power plant schematics [2], [5].

Hydrothermal fluids above 360°F (182°C) can be used in flash plants to make electricity [2]. Fluid is sprayed into a tank held at a much lower pressure than the fluid, causing some of the fluid to rapidly vaporize, or "flash." The vapor then drives a turbine, which drives a generator. If any liquid remains in the tank, it can be flashed again in a second tank to extract even more energy.

3.3. Binary – Cycle Power Plants

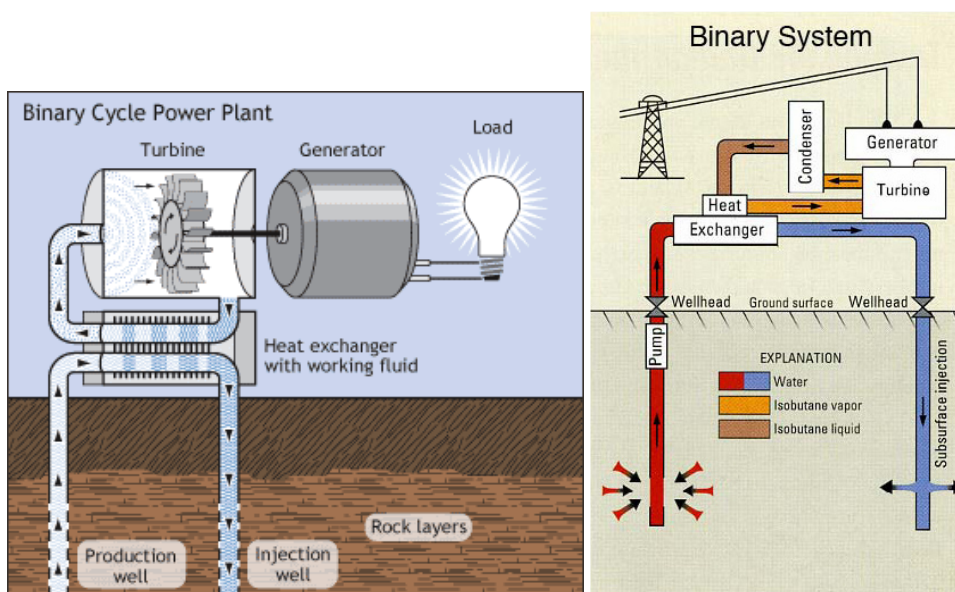


Figure 5 - Binary – cycle power plant schematics [4].

Most geothermal areas contain moderate-temperature water (below 400°F). Energy is extracted from these fluids in binary-cycle power plants [2]. Hot geothermal fluid and a secondary (hence, "binary") fluid with a much lower boiling point than water pass through a heat exchanger. Heat from the geothermal fluid causes the secondary fluid to flash to vapor, which then drives the turbines. Because this is a closed-loop system, virtually nothing is emitted to the atmosphere. Moderate-temperature water is by far the more common geothermal resource, and most geothermal power plants in the future will be binary-cycle plants [2].

4. THE FUTURE OF GEOTHERMAL ELECTRICITY AND ENVIRONMENTAL IMPACT

Steam and hot water reservoirs are just a small part of the geothermal resource. The Earth's magma and hot dry rock will provide cheap, clean, and almost unlimited energy as soon as we develop the technology to use them. In the meantime, because they're so abundant, moderate-temperature sites running binary-cycle power plants will be the most common electricity producers.

Before geothermal electricity can be considered a key element of the U.S. energy infrastructure, it must become cost-competitive with traditional forms of energy. The U.S. Department of Energy is working with the geothermal industry to achieve \$0.03 to \$0.05 per kilowatt-hour [2]. We believe the result will be about 15,000 megawatts of new capacity within the next decade [2].

During the 1960s, when our environment was healthier than it is nowadays and we were less aware of any threat to the earth, geothermal energy was still considered a 'clean energy'. There is actually no way of producing or transforming energy into a form that can be utilised by man without making some direct or indirect impact on the environment. Even the oldest and simplest form of producing thermal energy, i.e. burning wood, has a detrimental effect, and deforestation, one of the major problems in recent years, first began when our ancestors cut down trees to cook their food and heat their houses. Exploitation of geothermal energy also has an impact on the environment, but there is no doubt that it is one of the least polluting forms of energy.

Table 1 summarises the probability and relative severity of the effects on the environment of developing geothermal direct-use projects [1, 6].

Table 1 - Probability and severity of potential environmental impact of direct-use projects [1], [6]

Impact	Probability of occurring	Severity of consequences
Air quality pollution	L	M
Surface water pollution	M	M
Underground pollution	L	M
Land subsidence	L	L to M
High noise levels	H	L to M
Well blow-outs	L	L to M
Conflicts with cultural and archaeological features	L to M	M to H
Social-economic problems	L	L
Chemical or thermal pollution	L	M to H
Solid waste disposal	M	M to H

L = Low; M = Moderate; H= High

5. CONCLUSIONS

Geothermal energy has many advantages over most other forms of electricity. Geothermal energy does not produce any pollution, and does not contribute to the greenhouse effect and the power stations do not take up much room, so there is not much impact on the environment. The advantages of geothermal energy use vastly outweigh the disadvantages which conclude that it would be an effective way of preserving our earth and environment.

As supplies of fossil fuels are running out, it is obvious that other sources of energy must be developed. These new energy sources not only need to meet current and future demands, but must be

environmentally safe as well. A solution to this problem could be solved with the development of more renewable energy sources, such as solar, wind, and geothermal energy. Geothermal energy has been shown to work, not only in the United States, but all over the world as well, including thousands of years ago. In order to develop this energy source, there must be a concentrated effort in the government, private enterprise and especially individuals to steer clear of fossil fuels.

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