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Geothermal Energy: A General Overview with Specific Reference to the Long Valley Caldera

Introduction

Geothermal energy is a process that uses heated groundwater to turn turbines that produce electricity. The water is warmed by the earth's natural heat. Geothermal energy was first developed by Count Lardarel of Lardarello, Tuscany in 1827 (Geothermal.marin). Since then many other countries have developed geothermal technology, yet it is a resource that remains mostly untapped. As the need to find alternative fuel sources grows, geothermal energy becomes an interesting option for potential future energy production.

Geothermal energy production involves a complex set of issues. First it is important to place geothermal energy in context of today's energy needs. Currently, one of the ongoing dilemmas of energy use is the worldwide allocation of resources and general rate of consumption. Within this essay, I will illustrate a brief history of energy use and development.

Geothermal energy can only be produced in particular geological settings. Only areas with recent volcanic activity can produce the heat needed for geothermal production. Therefore, a basic understanding of tectonic plate movement and volcanology is required to understand the production of geothermal energy. I intend to give a general background on the geological settings necessary for the production of geothermal energy production.

Lastly, I will center on one region in particular, namely the Long Valley Caldera in California. This is an area that is saturated with historical and present volcanic activity. The recent volcanic activity makes it an area that is perfect for geothermal energy production. I will discuss in particular the Mammoth Pacific plant that operates in Mammoth Lakes.

What is Geothermal Energy?

The production of geothermal energy is a way of utilizing heat that is created by volcanic activity to produce electricity. Within a geothermal system, ground water is heated by magma chambers to temperatures as high as 450 degrees Fahrenheit. However, the temperature of the water depends on the geothermal gradient. A gradient signifies how deep below the surface the heated water is. The deeper down the water is in the earth, the hotter it will be (this is called a steep geothermal gradient). The water either reaches the surface of the earth naturally in the form of geysers, fumaroles, or hot springs; or it must be drilled. Because the water is under such great pressure, it does not turn to steam until it reaches the earth's surface. The steam is then used to turn turbines whose movement is converted into electricity. If the water is not hot enough to turn into steam, then it is used to heat a secondary liquid whose steam is used to power the turbine instead.

Example of fumaroles, hot springs and boiling mud (starting at top left image and going clockwise) Image obtained from http://geothermal.marin.org/

Not all geothermal plants utilize the same production system. The amount of water and steam that is available to be mined depends greatly on the geology of the area that the plant occurs in. There are three main types of geothermal systems. These include flash steam plants, dry steam plants, and binary systems (geothermal.marin).

Flash steam plants are the most common type of geothermal plants. They occur in areas with surface temperatures of 150 degrees Celsius or higher. This system produces a mixture of hot water and steam. Water is pumped from a zone of circulating ground water, and as it reaches the surface, less pressure is exerted on it, and parts of it are flashed to steam. The steam and water is separated, and the steam is used to turn turbines to generate electricity. The steam is then re- pressurized and re- injected as water back into the earth so that the cycle can be completed again (Environmental Geology 2000).

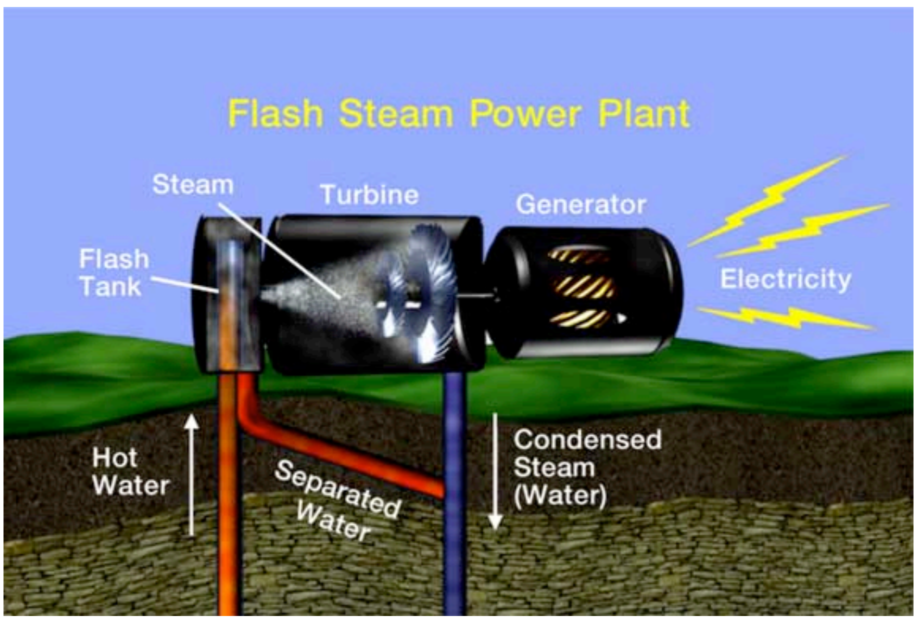
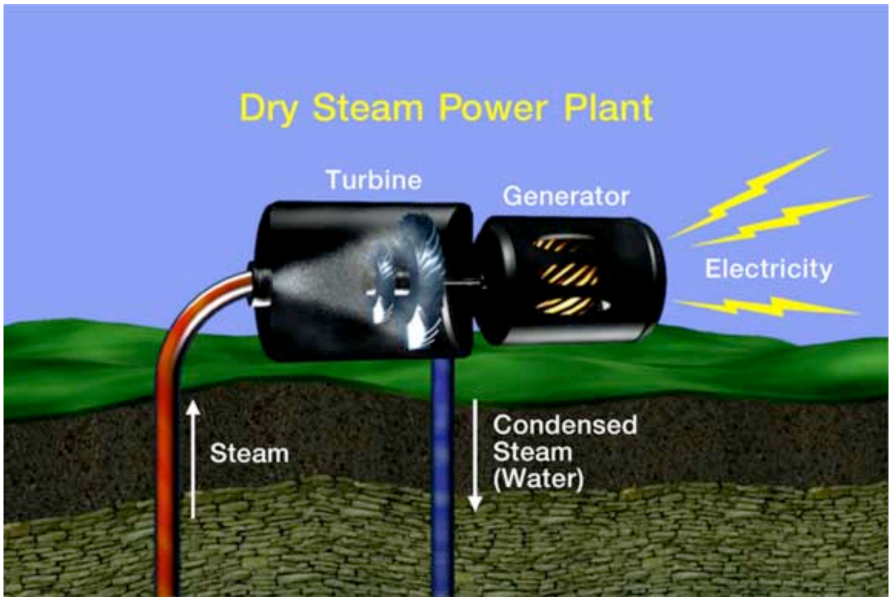


Image obtained from http://geothermal.marin.org/

Dry steam plants are very rare. Within this system, amounts of heat are so great that underground water is turned completely to steam. The steam shoots out of natural vents on the earth's surface and is directly used to power the turbines. The Geysers geothermal plant in northern California is the world's largest Dry steam plant, and produces enough electricity yearly to supply power to a city the size of San Francisco! (geothermal.marin).



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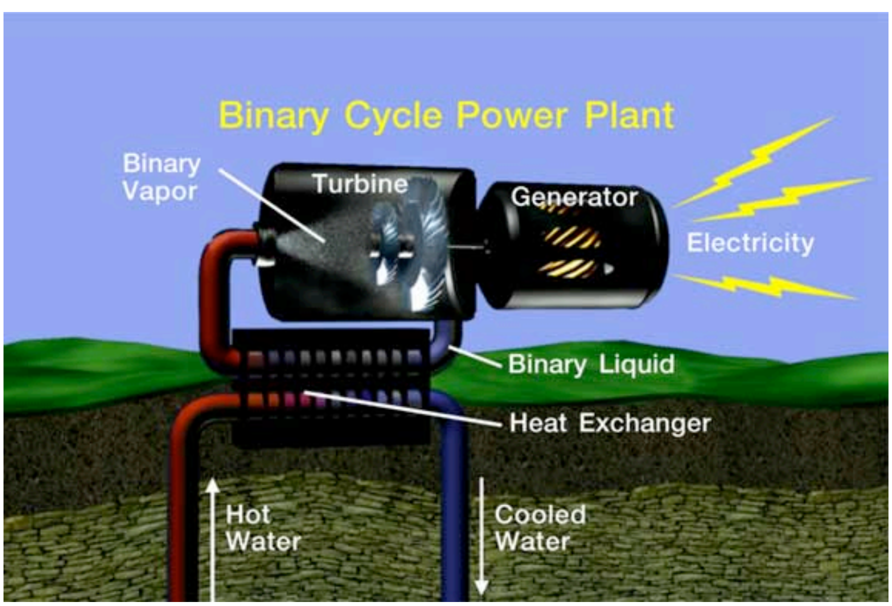
The final type of geothermal system is known as a binary system. Within this process, geothermal water is used to heat a secondary liquid (such as isobutene). The working liquid is turned to steam and then used to power the turbines. The steam is then converted back into liquid form so that it can be recycled through the system again. The water is also recycled and re- injected in to the ground. The binary system is generally used when ground temperatures are not hot enough to turn water to steam. The Mammoth Pacific geothermal site is a primary example of a binary system (Mammothpacific).



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A Brief History of Energy: Putting Geothermal Energy in Context

Before the 1700's there were few applications of the earth's natural resources as sources of power aside from burning firewood for cooking and warmth. Human labor, along with farm animals were used for transportation and other needs. The development of the steam engine in the early 1700's was a turning point in energy use. Propelled mostly by firewood, the steam engine was used to fuel ships, engines, locomotives, and run saw mills and textile mills as well as other industrial plants. By the end of the 1800's firewood was almost completely replaced by coal, which could also be used for heating and cooking. Although coal was a more efficient substance than firewood, it created large amounts of fog and Carbon Dioxide emissions. New advances in the late 1800's included the development of oil well drilling, the internal combustion engine and the refinement of crude oil. Slowly, natural gas, crude oil, and gasoline became the three main energy sources of the United States. Although these sources brought about more efficiency, they still had an adverse environmental impact. In 1831 the electrical power was developed. Although it seems like a relatively clean fuel, the process used to create electricity (burning coal), leaves a deep impact on the environment (Environmental Science 2000).

In the present, the US is still mainly dependent on the use of crude oil, coal, and natural gas as energy sources. Although alternative energy sources have been explored, fossil fuels still make up 86 % of the USA's fuel input. The problem remains, of course, that these energy sources have their limits, and that they are being depleted very quickly. Therefore, the necessity for alternative energy sources is great. Some of the different methods for creating energy include nuclear power, solar power, wind power, and hydroelectric power. However, these methods do not come without drawbacks. Although nuclear fusion and fission have a great potential for energy production, the risk associated with nuclear waste or a nuclear plant explosion (such as Chernobyl) have been a deterrent to making them a more abundant resource. Rerouting streams and rivers to produce hydroelectric power has had negative drawbacks on the environments in which they have been created. The change in stream flows have affected fish populations as well as altered the landscape around rivers by increasing and decreasing the amount of irrigation that they receive. Creating electricity through wind power is a very clean way to produce energy, however its main disadvantage is that it is an intermittent source and is problematic for migrating bird populations. Solar energy has great potential with few drawbacks; however time and money have not been spent to develop it to a point where it could be a major energy producer (Environmental Science 2000).

As the need for alternative energy sources grows, geothermal energy emerges as an attractive option with many positive features. If the water is recycled, and the system is given time to recover as it is used, then geothermal energy can be a sustainable resource. It produces very few toxic emissions (less than 1 % nitrous oxides and 5 % of Carbon Dioxide than is produced by coal burning power plants). There is no refining of fuel, or extensive transportation required. If a breakdown of the system occurs, there is little risk of major scale biohazards (unlike nuclear power plants) (Environmental Geology 2000). The greatest risk associated with geothermal energy production is thermal pollution. Hot water released into streams kill fish and stunt the vegetation around the streams. This affects the food sources for animals nearby. Geothermal plants can also be very noisy as well as being esthetically unpleasing. Minerals tend to build up in the pipelines through which the water is transported. Some are valuable, such as gold and silver (although usually the amount found is so small it is not worth mining) however, others are toxic, such as arsenic. If released into the environment, these toxins can be harmful to humans, animals, and vegetation. Therefore they must be disposed of as toxic waste. A possible problem that has never occurred but worries some, is the possibility that re-injecting the water in bedrock could reactivate fracture systems and cause earthquakes (Environmental Geology 2000).

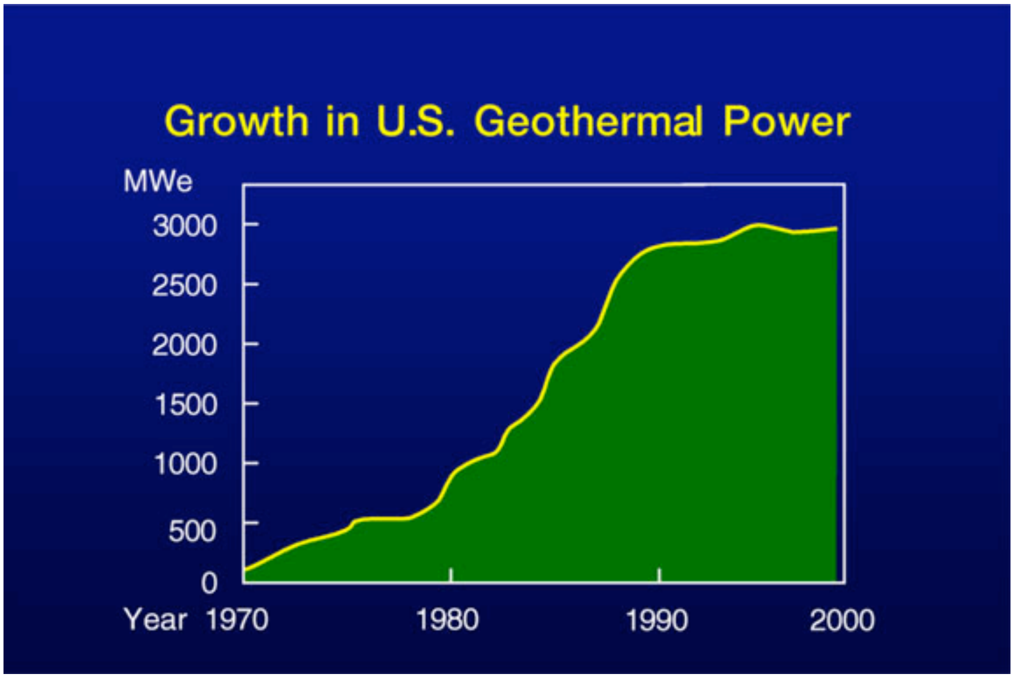
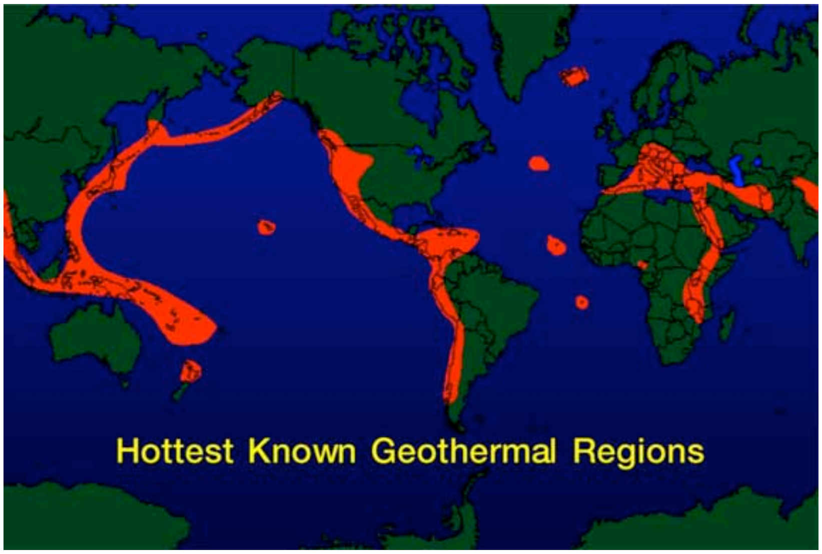


Image obtained from http://geothermal.marin.org/

Geological Setting Necessary for Geothermal Plants

Geothermal plants can only be built in areas that have enough ground heat to warm water to super high temperatures. Heat of that magnitude is created by volcanic activity. Movement of tectonic plates below the earth's surface causes volcanic activity. As plates collide into each other, mountains are built. This activity causes magma (hot, molten rock) to rise to the earth's surface. As plates move apart from each other or subduct beneath one another, molten rock rises up to fill the new rift (Encarta.msn). Many times however, the magma doesn't make it to the surface, and large magma chambers are formed underground. Groundwater is then heated by coming in contact with the magma. The supply of groundwater is replenished as rain and snow melt run off by nearby mountain peaks and seep into the ground through faults (Mammothpacific). Often times, the best place for a geothermal plant is not necessarily a geyser or fumarole, but an underground circulating zone of water near a magma chamber. This is because heat is stored better in these areas, whereas much of it is lost through natural openings in the earth. Magma with high silica content tends to store more heat, and is therefore more efficient for heating groundwater. The heat that an area is able to produce is measured by the geothermal gradient (degrees per kilometer). A steeper geothermal gradient signifies that that there is hot molten rock nearer to the surface of the earth (Environmental Geology 2000).



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There are three main geological settings in which geothermal activity is formed. The first is called a hydrothermal convection system. Water collects above a magma chamber, and is heated by contact with the hot rock. The water maintains its heat by creating a convection flow system through permeable layers of rock. The water reaches the earth's surface naturally through geysers, steam vents, or drilling. This type of setting is good for both dry steam plants and flash steam plants.

The second setting is called a Hot Igneous Rock system. In this situation igneous rock is heated to temperatures of 650- 1200 degrees Celsius. However, there is no thermal contact with water. To heat the water, holes must be drilled into the rock and water must be injected. A natural convection system then develops. An example of this setting can be found the Jemez Mountains of New Mexico.

The final setting is called a Geopressured System. This occurs in areas where there has been vast amounts of sediments deposited very quickly. Groundwater gets trapped under these depository layers that also act as insulators. The water is then heated by contact with magma to temperatures as high as

150- 723 degrees Celsius. Such a geopressurized setting was found in the Gulf coast of the United States (Environmental Geology 2000).

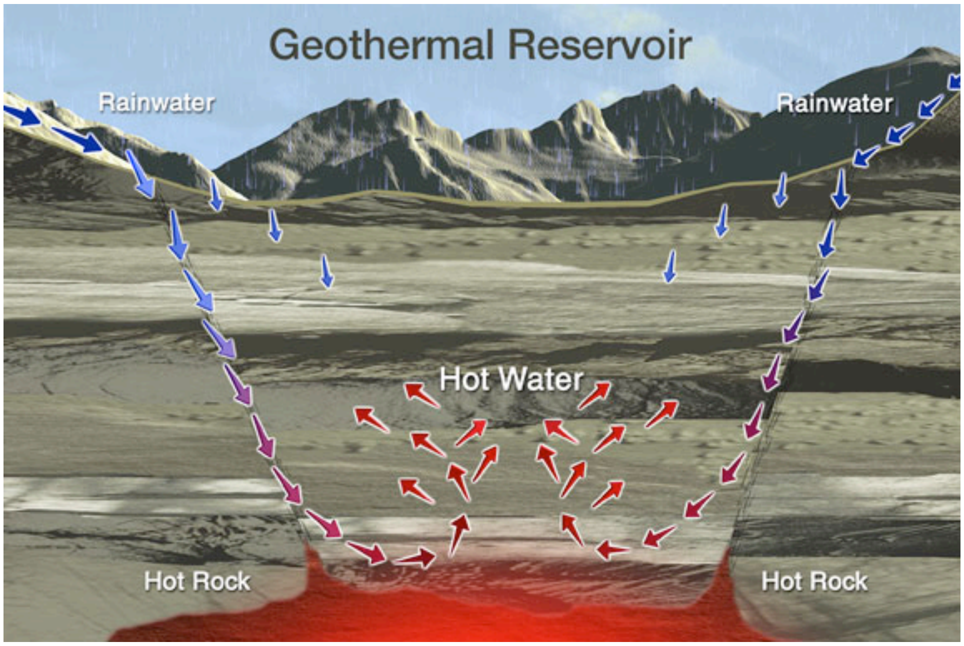

Image obtained from http://geothermal.marin.org/

Specifics of Geothermal Energy in Mammoth Lakes, California

Mammoth Lakes, California has three geothermal plants located at Casa Diablo: G-1 (MPI), G-2 (MP-II), and G-3 (PLES-1). Together the three plants produce enough energy for about 40,000 homes. The project is spread out over 15 acres of land and has 12 production wells that are 500 ft. deep and 6 injection wells that are 2,000-2,500 ft. deep. The water pumped comes out at temperatures ranging from 300-350 degrees Fahrenheit. Mammoth Pacific is rare in that it uses the binary system where geothermally heated water is used to heat isobutene. The isobutene is turned to steam and then used to power the turbines (Mammothpacific).

The specific geology of the Mammoth and Long Valley caldera region is what creates the necessary environment that has potential for geothermal energy production. The climax of the Long Valley Caldera eruption occurred 760,000 years ago. During this eruption 600 cubic ft. of ash spread as far as Nebraska. The explosive eruption created the large topical depression that is known as the Long Valley Caldera region. This area measures about 15x30 km long. The ash produced from the eruption is called Bishop Tuff and creates a large tableland to the North and Southeast of the caldera.

The eruptions that created the Mono-Inyo volcanic chain that stretched Northwest of the caldera began 200,000 years ago. Series of eruptions have formed the Mono craters, Inyo crater, Panum crater, Black Point, and most recently the two islands situated in Mono Lake- Negit and Paoha (Fire Mountains 1988).

The area is part of the Basin and Range province, which is being spread apart slowly by divergent plate boundaries. This plate motion creates many faults in the earth's surface that trigger volcanic activity. The recently formed resurgent dome in the center of the caldera is formed by magma rising up close to the earth's surface. Growth of the resurgent dome could signify an eruption in the near future (Fire Mountains 1988).

The Casa Diablo geothermal field is located on the Southwest edge of the resurgent dome, which is its main heat source. Rain and snow melt flow down from Mammoth Mountain and seep into the earth through fractures in the ground. The subsurface water then flows from west to east, and up through faults beneath a Rhyolite plateau towards Casa Diablo. The water then surfaces at Casa Diablo in the form of fumaroles. The water is reinjected back into the ground on the east side of the field that is intersected by a deep fault zone (Mammothpacific).

The Mammoth Pacific geothermal plant. Image obtained from www.eere.energy.gov.html

Conclusion

As problems with pollution and resource shortages arise, geothermal energy is a relatively clean and efficient way to produce energy. It is possible for it to remain one of the world's sustainable energy resources. As it can be produced in many different countries it can help to soothe the debate of who receives the world's dwindling energy supply.

Geothermal energy can be produced in any area that has the correct geological setting. This includes places with recent volcanic history that provide the land with adequate ground heat. Areas that have great potential for geothermal production include places bordering the South Pacific, the South American Andes, central America, Mexico, the Cascade Range of the US, Canada, the Aleutian Range, the Kamchatka Peninsula of Russia, Japan, the Philippines, Indonesia, and New Zealand (geothermal.marin).

The United States is one of the top energy consumers in the world. With natural resources dwindling the question of where we will get our energy looms large. As solutions to this question are sought for, the need to embrace alternative energy sources seems clear. Now geothermal energy is being produced in as many countries as the US, New Zealand, Italy, Iceland, Mexico, the Philippines, Indonesia, and Japan. However, only about 1.6 % of the world's energy is produced through geothermal systems (Encarta.msn). As we search for new resources to create energy, geothermal production seems to have great potential.

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