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1-26-04

Geothermal Energy

[Comments by Bent in italics and brackets]

Geothermal energy, energy recovered from the heat of the earth's core, has provided heat and electricity for human consumption for hundreds of years. From the earliest spas to pipeline heat to more modern techniques of energy extraction, geothermal technology has become increasingly useful as an energy source. It provides a largely environmentally friendly alternative to fossil fuels and has wide application throughout the world. In order for a sustainable energy supply to be feasible, geothermal energy cannot be ignored as very large contributor to the global energy supply.

[See Table 2.4, p. 47 of Sheffield for the world potential of geothermal energy. It is one of the smaller players on a global scale but may be important locally in certain regions where other energy sources are not available (e.g., Iceland) and for special purposes (e.g., space heating).]

The concept of using geothermal energy as a source for human consumption is hardly a recent innovation. Hot springs have been used for bathing and washing for thousands of years in many countries. Health spas have also sprung from this source of heat, dating back as far as to ancient Greece. The first power plant using steam from wells drilled in volcanic areas was located in Tuscany, Italy (Meador 53). It was established in 1904. But even before that time, geothermal energy was being used to provide district heating in Boise, Idaho in 1894 and hot water was pumped to homes in

Klamath Falls, Oregon in 1900 (Priest 250). Geothermal energy became used on a much larger scale for heating houses and especially greenhouses in Iceland and Hungary in the 1930s (“Positive”). By the early 1940s, the Italian railway system was receiving 130 megawatts of energy from the Tuscany plant. The oil crisis in the early 1970s caused thermal energy to become even more mainstream in Europe, leading to the tapping of the Paris sedimentary basin in order to pump geothermal water to heat houses. The United States didn’t further its investment in geothermal energy substantially until 1960 when The Geysers in California was started (“Positive”). The only other major source of geothermal energy in use is on the main island of Hawaii, which produces 25% of the states energy needs (“Experts”).

Geothermal energy is energy obtained from the natural heat contained in the earth’s core, which has a temperature of approximately 6000˚C (Mustoe 130). The reserves of heat are so gigantic that for any practical purposes, they are unlimited. For example, the thermal energy stored under the continental United States to a depth of six miles is equivalent to the energy obtainable from the combustion of trillions of tons of coal. Unfortunately, there is no way of accessing most of this energy until we are able to drill 32 km towards the center of the Earth in order to tap this resource. Until that point, the only useful geothermal heat is that closer to the surface, which consequently has a much lower temperature (up to 600˚C) (Mustoe 130). In general, the temperature of the crust of the Earth increases about 2˚C for each 100-meter increase in depth (Priest 250).

There are 4 different types of geological formations from which energy can be usefully extracted from: hydrothermal, geopressurized, hot dry rock, and magma (Baird). The energy from all of these reservoirs can be tapped and used for heating or electricity generation. Hydrothermal reservoirs are characterized as having a layer of impermeable rock protecting a porous rock formation with hot water and/or steam trapped inside of it Baird). Hydrothermal reservoirs represent a very small percentage of the geothermal resource base despite the fact that it produces most of the energy obtained from geothermal sources. Geopressurized resources are from formations where moderately high temperature brines are trapped in a permeable layer of rock under high pressure. Hot dry rock reservoirs are usually located at shallow depths and are therefore easily accessible, but require the rock to be fractured and a fluid circulation developed (Baird). Magma, partially molten rock, is the final and most abundant geothermal resource.

There are two main techniques by which energy is extracted from these geothermal sources; flash steam processes and binary power plants ("Experts"). In the flash steam process, water from underground wells is separated into water and steam. The water is returned to the reservoir and the steam is used to drive a turbine and generate electricity. The steam is then condensed and also returned to the source. This method is often used on such sources as geysers and other high temperature reserves. The binary system is used for lower temperature sources ("Experts"). The hot water from a geothermal source is used to heat a secondary working fluid in a closed-loop system. The working fluid is vaporized in a heat exchanger and is then used to drive the turbine generator. The fluid is then cooled back into a liquid form and cycled through again. The hot water from the source is returned to the source and kept separate from the working fluid in order to minimize environmental issues ("Experts").

Geothermal energy is labeled as renewable and thus grouped with other alternative energy sources like solar, wind, and biomass (Ryback). But this label is only correct to a certain degree; without proper management, thermal energy sources can be depleted. Often these natural resources are taken into production mainly to meet economic goals like a quick payback for the initial investment for exploration and equipment in such a way that reservoir depletion is the result. A good example of this phenomenon is the handling of The Geysers in California, whose production has decreased 150% over 10 years (average daily flowrate versus time) (Ryback). In order to avoid situations like these, a lower sustained production level must be obtained in which a source is not tapped for more than the natural discharge. This balance is feasible, though rarely economical. For example, many thermal springs in many parts of the world have been providing large amounts of heat to the surface without showing any sign of decline over a period of hundreds of years. When depletion does occur because of intensified production rates, it is largely due to the depletion of the fluid content, as the heat stored in the matrix remains largely in place. In order to avoid this, many production schemes utilize reinjection methods, which keep the fluids in a closed pressurized system and returns them to the source (Ryback). This technique helps maintain fluid content and helps to sustain or restore the reservoir pressure. Many sources have already been depleted by considerable amounts, but they will recover on a relatively short timeline. Recovery rate is asymptotic in behavior, so establishing the original state theoretically only happens after an infinite amount of time, but practical replenishment (defined at 95% recovery) will generally be re-established after about 100 years (Ryback).

Another barrier of entry into geothermal energy production is its unbalanced economic structure (Veziroglu 471). Like most energy sources, setting up a geothermal plant requires a large fixed cost for exploration costs and capitol equipment. After this investment is made, there is very little variable cost (the cost of producing one extra unit) and no fuel cost ("Experts"). Usually, financing is structured so that the project pays back its capitol cost in the first 15 years. After that, the only cost is labor and maintenance, which tends to be extremely low. An unfortunate consequence of the fixed costs being so high, though, is that many plants operate at a lower efficiency because the capitol equipment is more affordable (Veziroglu 488). On average, though, energy can be created at 4.5-7¢/kWh; a price competitive with that of some fossil fuel factories ("Experts").

Currently, all of Europe utilizes about 18,000 GWh/y of geothermal energy, which constitutes 60% of the world production ("Positive"). The European Union countries represent only 11%, 17% of which is composed by Iceland alone. Electricity is currently produced with geothermal steam in 21 countries all over the world, producing 4,300 GWh/y in Europe alone, which displaces the emission to the atmosphere of 5 million tons of carbon dioxide, 46 thousand tons of sulphur dioxide, 18 tons of nitrogen oxides, and 25 thousand tons of particulate matter every year in comparison with the production of the same amount of electricity from an average coal-fired plant. Geothermal resources from the USA displace 22 million tons of carbon dioxide, 200 thousand tons of sulphur dioxide, 80 thousand tons of nitrogen oxides, and 110 thousand tons of particulate matter every year, an amount equivalent to 4.5 million barrels of oil ("Positive").

[Need to put the above numbers in perspective some way to convey their meaning – how big or small they are – as you do in the paragraph below.]

These numbers point to one of the largest benefits that geothermal energy has to offer; it is a "clean" energy source. In fact, the newest generation of georthermal power plants emits an average of only .136 Kg of carbon dioxide per kilowatt-hour of electricity compared with the 128 Kg/kWh of carbon dioxide for a power plant fuelled by natural gas or 225 Kg/kWh for a coal fired plant ("Positive"). Another high point of geothermal energy is that it is used to produce electricity directly and is thus incredibly reliable (Miller 58). It is consistent for as much as 95 to 100 percent of the time.

Geothermal energy is not completely harmless, though, and its dangers should be known so as to be monitored and avoided completely if at all possible ("Positive"). Geothermal fluids contain a variable quantity of chemicals and dissolved gas. The amount of components depends largely on the geological conditions present, but in many cases the gas content is insignificant, being lower than the content in the groundwater. In sedimentary basins, like that of Paris, the gas content may be too high to be released, so it is reinjected into the reservoir, as previously described, without any degassing taking place ("Positive"). The sediments in the water can provide a more technical problem, though, in that they are very corrosive to many building materials, causing geothermal plants to be more expensive (Baird). Seismicity may also be a growing concern when using geothermal energy (Ryback). This is especially true with the practice off reinjection as described above. Increasing volumes of pressurized fluids injected back into the subsurface lead to more frequent, though not larger, earthquakes (Ryback). There is generally very little concern over this point as it is rarely mentioned and has little evidence.

Despite some of these drawbacks, geothermal energy remains vastly better for the environment than any source of fossil fuels. It also has a large base of technology, as it has been used in the modern sense for a hundred years. There are 500 active volcanoes in the world, a fraction of which are being utilized for the massive amount of energy they contain (Meador 54). In the northwestern states of the USA alone, there are 11 potential sites identified by the Northwest Power Planning Council where 2 thousand MW are developable (“Experts”).

[Which is roughly equal to the power produced by two large nuclear or coal burning power plants. This is an example of a region where geothermal power could be significant.]

With a bit of planning and care towards making sources sustainable, geothermal energy could alleviate the growing energy concerns of the world by a considerable degree.

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