Geothermal Energy

In geological terms, geothermal energy is defined as the heat above the mean ambient temperature of the earth's solid core, which is about $8x10^{30}$ joules. The amount is massive and represents 35 billion times the world's present total annual energy consumption. In reality however, only a tiny fraction of natural heat can be extracted(1). But in our terms, a geothermal resource can be defined as a reservoir from which heat can be extracted economically (cost wise less expensive than or comparable with other conventional sources of energy such as hydroelectric power or fossil fuels) and utilised for generating electric power or any other suitable industrial, agricultural or domestic application(2). Radioactive decay of unstable isotopes continuously generates heat within the earth and the centre of the Earth is around 6000 degrees Celsius - hot enough to melt rock. Even a few kilometres down, the temperature can be over 250 degrees Celsius. In general, the temperature rises one degree Celsius for every 36 metres you go down. In volcanic areas, molten rock can be very close to the surface and in such areas geothermal energy has been used for thousands of years for cooking and heating.

Since geothermal is often a replacement for diesel or other fossil fuels, it has great benefits for people's health through improved air quality. There are atmospheric emissions from geothermal power plants which are predominantly CO_2 and H_2S. However, in the context of global climate change, geothermal has significantly lower CO_2 emissions than fossil fuels. Atmospheric emissions from geothermal plants average only about 5% of the emissions from equivalent generation sized fossil fuel power plants. The actual land use for geothermal energy production is relatively small for both the fuel acquisition and the energy production. The common practice of re-injecting spent geothermal fluids means the impacts on aquatic life have been eliminated. Geothermal plants also co-exist successfully with other land uses(7).

There are three main ways of tapping geothermal energy:

- **Direct use:**
  Geothermal heat found near the surface of the Earth can be used directly for heating buildings (CHP) and for a number of commercial and industrial uses.

- **Geothermal heat pumps:**
  The relatively constant temperature of the top 15 metres of the Earth's surface (or ground water) can be used to heat or cool buildings indirectly. The pump uses a series of pipes to circulate fluid through the warm ground. In the winter when the ground is warmer than the buildings above, the liquid absorbs heat from the ground, which is then concentrated and transferred to the buildings. This can also be used to heat domestic water. In the summer, when the ground is cooler, the pump transfers heat from the buildings back into the ground, however, does a heat pump use solar or geothermal energy?

While geothermal resources are not spread uniformly, heat pumps can be used nearly anywhere. This answers the question that using a heat pump uses solar energy, as they can be used in places where no geothermal energy is available!

- **Electricity production:**
  There are three types of power plant that can convert geothermal energy to electricity, depending on the temperature of the

geothermal fluid used. All three use a turbine that is driven by steam, which then drives a generator to produce electricity.

Direct Use:

Shallower reservoirs of lower temperature (20-150°C) are used directly in health spas, greenhouses, fish farms, and industry and in space heating systems for homes, schools, and offices. The direct use of geothermal energy in homes and commercial operations yields net savings in energy costs to the consumer. Direct use systems typically require a larger initial investment, but have lower operating costs and no need for ongoing fuel purchases, therefore reducing life-cycle costs. The savings depend on the application and the industry, but can be as much as an 80% reduction from traditional fuel costs. Geothermal power is not only an economic energy source, it is also very clean, producing only a small percentage (and in many case none) of the air pollutants emitted by burning fossil fuels. Schemes utilising geothermal heat provide over 80% of the central heating needs of Reykjavik city in Iceland and are employed in many towns in USA, Poland and Hungary.

Southampton's geothermal heat

Launched in 1986, Southampton Geothermal Heating Company was the UK's first geothermal energy scheme. .

The Water Source

Within the well, water was found at a depth of nearly 1.8km and at a temperature of 76°C. Its reservoir is the Triassic sandstones, between about 1720 - 1780 million years old. The water rises naturally within the well to within 100 metres of the surface, from where it is pumped to the station. By the time it reaches the surface, the temperature of this hot, corrosive brine is 2 degrees cooler. At the station a heat-exchanger working in conjunction with an absorption pump is used to transfer heat energy to clean water. The cooled brine, now at 28°C, is then released into the River Test and thence the sea.

The District heating scheme in Southampton

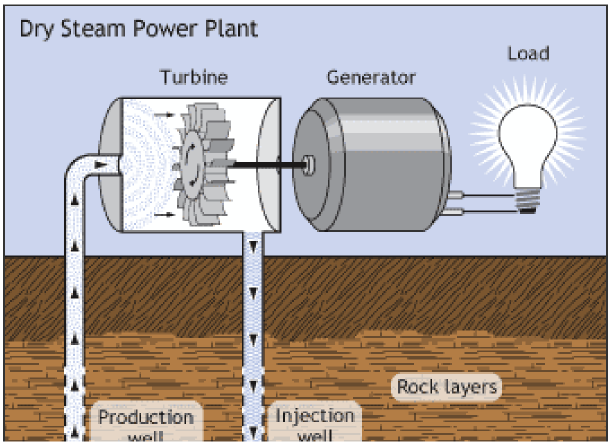
The geothermal heat provided by the well is used as part of Southampton's District Heating scheme, where it works in conjunction with the Combined Heat and Power scheme. Geothermal energy provides between 15-20% of the total heat-input into this scheme.
The combined heat and power generators use conventional fuels to make electricity. "Waste heat" from this process is recovered for distribution through the 11km mains network.

The district heating scheme in Southampton helps reduce energy bills by 25% and the city's CO_2 omissions by 10kt a year. It closely resembles a huge domestic central heating system, with hot, treated water circulating underground from the heat station. It supplies heat to a growing number of customers in the city centre, before being returned for reheating.

Electricity Production

Underground reservoirs of hot water or steam that are heated by an up welling of magma, can be tapped for electrical power production[3].

Hydrothermal systems of three main types are currently utilised for electric power production.



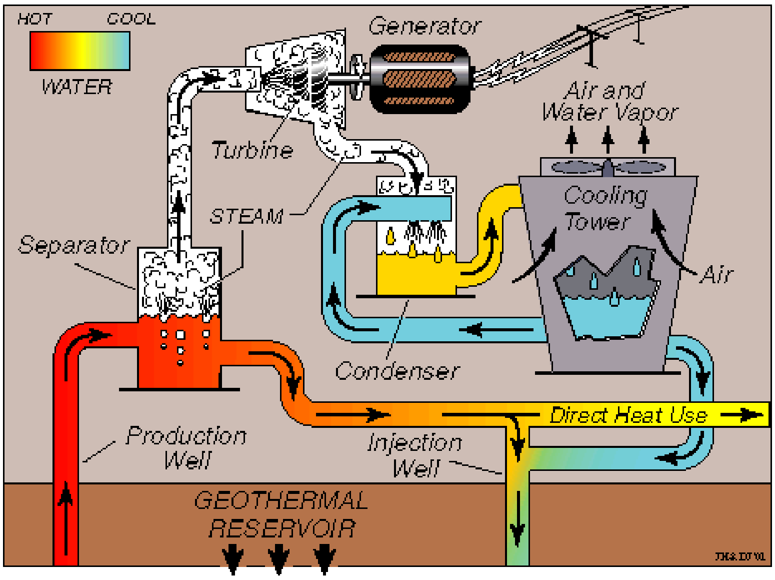
– 1) The rarest and most valuable systems are exemplified by those at The Geysers and Larderello. These vapour-dominated systems yield nearly pure, high-temperature (>235°C, or 455°F) 'dry' steam through production wells typically 1-4 km in depth The steam is processed to remove particulates and non-essential fluids and then is piped to turbines that spin generators to create electricity. In 1904 the first dry steam power plant was built in Larderello, Italy by Prince Piero Ginori Conti. This is considered the most spectacular historical advance in harnessing geothermal energy. Prince Piero Ginori Conti carried out a field experiment on July 15, 1904, by using a piston engine fed by pure steam produced in a small heat exchanger supplied with wet steam from a well near Larderello. The engine was coupled with a

10 kW dynamo, to which five bulbs of few watts each were connected.

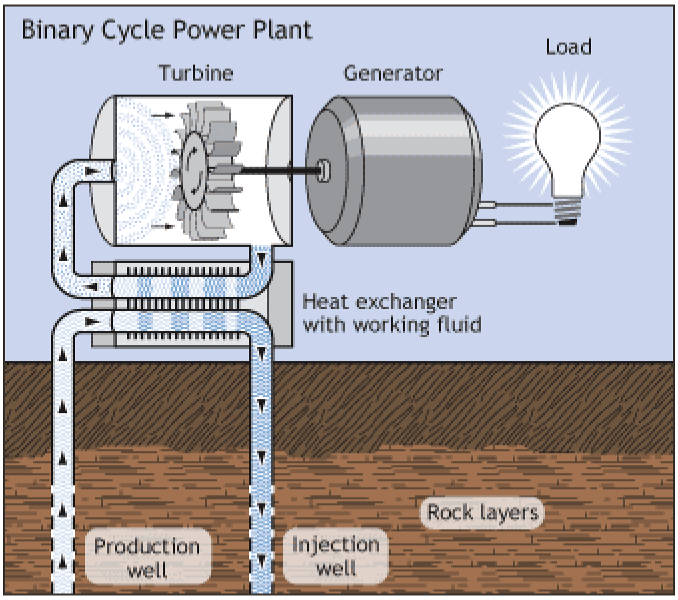
The success of the experiment led, in 1905, to the construction of a Cail prototype geothermal piston engine, coupled with a 20 kW dynamo, which enabled lighting for many years the palace and other residential buildings at Larderello. In 1908 the installation of a different prototype geothermal group followed; it was a Neville piston engine, still coupled with 20 kW dynamo, by which a few chemical plants in the area were electrified. Both the Cail and Neville groups were driven by pure steam obtained with heat exchangers fed by natural steam from nearby wells. Information on the behaviour of the production wells gathered through several years of safe operation of the two experimental groups, provided the electromechanical firm Franco Tosi with the basic elements necessary to design the first geothermal power plant in the world; it was an "indirect cycle" 250 kWe turbine that could be operated with a running pressure of up to 3 atmospheres at well head. Commissioned in 1913, this plant enabled electrification, between 1914-16, of all chemical plants and most villages of the boraciferous region, and of the main towns to the North of Larderello, including Pomarance, Saline and Volterra(4). The number of power stations has been constantly growing. There were 17 stations in 1975 with 420 MW; to which must be added the 15 – 20 MW so called unified units that increased the number to 25 plants in the '80s. In the '90s, beside the development of new areas, a plant renewal program was initiated, with new plant construction and dismantling of the old (obsolete) ones, for the Larderello area, and with the replacement of the machinery in other sites. This program, ended in 2003, brought the total to 34 plants and 862 MW installed capacity, with yearly production of over 5000 GWh[6].

2) More common are systems dominated by hot water at temperatures in the range 150-300°C (300-700°F). For these systems, flash-steam power plants are required. Again, the geothermal fluids are brought to the surface through production wells as much as 4 km deep. At these depths, the hot waters are highly pressurized, but as pressure is reduced in transit to the power plant, 30% to 40% of the water flashes (explosively boils) to steam. The steam is separated from the remaining hot water and fed to a turbine/generator unit to produce electricity. The residual water is returned to the reservoir through injection wells to help maintain pressure and prolong productivity.

Flash-steam power plant



3) For lower-temperature geothermal reservoirs (those between

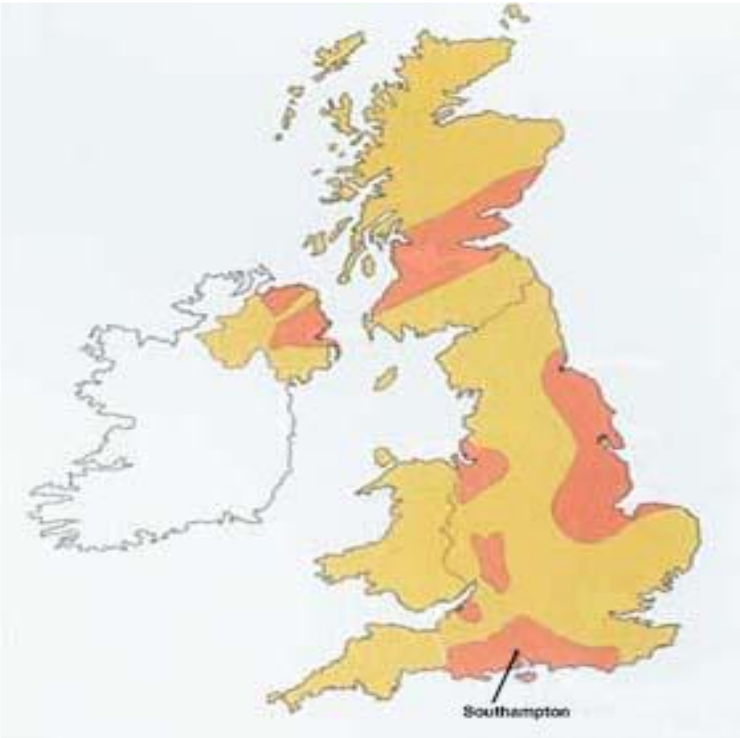


approximately 100°C and 150°C), binary-cycle power plants are the preferred installations. In a binary plant, geothermal waters are passed through a heat exchanger to heat a secondary working fluid (for example, isopentane) that vaporizes at a lower temperature than water. In a closed-loop cycle, the working-fluid vapour spins the power-producing turbine/generator unit, and then is condensed back to liquid before being re-vaporised at the heat exchanger. As in a flash-steam cycle, the spent (heat-depleted) geothermal water exiting a binary plant is injected back into the reservoir.

Flash and binary cycles can be combined in sequence for the most efficient conversion of thermal to electrical energy. In these hybrid power plants, hot water from production wells is first flashed to steam that is used to rotate a primary turbine/generator unit. Steam condensate from the flash cycle is then mixed with the residual, fresh water and routed to a binary unit for further generation of electricity. Geothermal electric-power plants are typically available for generation 95% of the time.

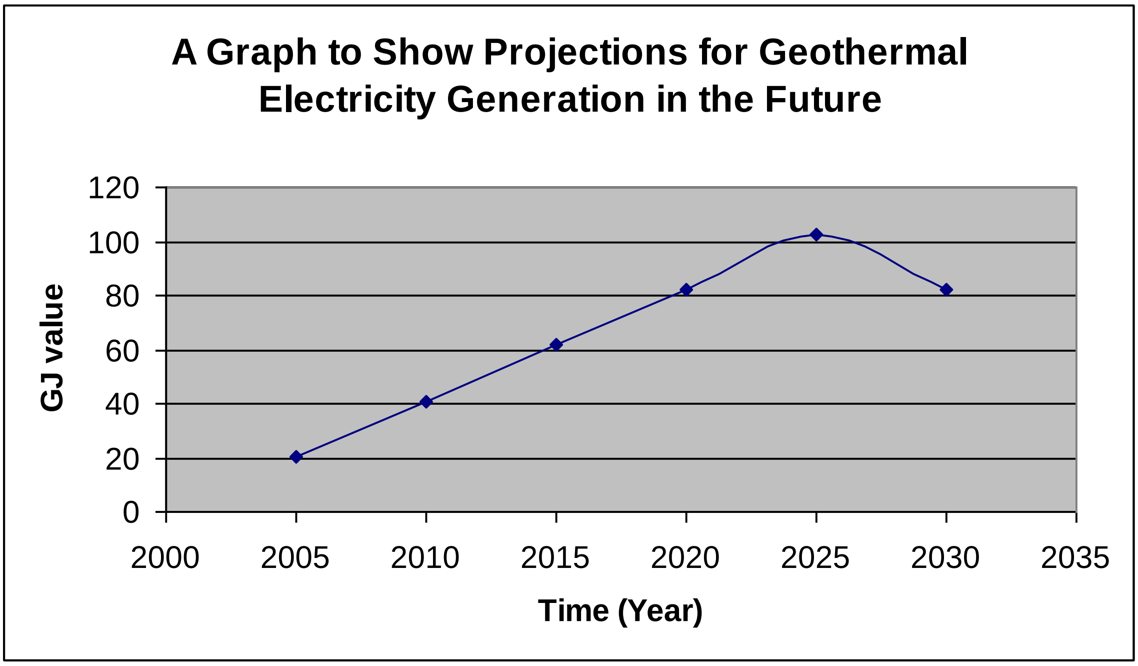
Where does the UK Stand with Geothermal Energy?

The trouble with geothermal energy in this country is that we are only on a semi-thermal heating zone. Semi thermal fields are more common than hyper thermal fields. The hot water entrained in the aquifer of a semi-thermal field seldom reaches 100°C[8].



As can be seen in the map above, the red areas are semi-thermal regions of the United Kingdom that are available to use geothermal plants. The yellow areas are cold areas with no ability to use geothermal energy. The red areas are just areas where the groundwater has retained its heat by virtue of an insulating "blanket" of Tertiary sedimentary deposits over the aquifer. There is no exceptional heat *source* underlying the regions, simply an exceptional amount of the 'background heat' from the Earth's interior is retained. Because of this, accessing that heat is considered to be "heat-mining"; i.e., once used, it is only replaced on geological timesscales. It is thus not "renewable", as are volcanically-active sources of geothermal energy[9].

This basically means that all three of the electricity production techniques are unusable, and any use of geothermal energy in this country would only be in programmes like that of Southampton. So an optimistic projection for the use of geothermal energy in this country by the year 2030 would be as followed on the graph below:



Notice that the values are not very large and would not contribute at all to the countries energy demands. This is also a really optimistic value; a reasonable value would be 0 Peta joules. It is for this reason that I conclude that geothermal energy has no ability to help us achieve our energy needs and other sources of renewable energy will need to be looked at to help us achieve the target.

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