

Geothermal energy and its usage

Ashish Kumar

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Abstract

In physical world, Energy plays an important role. It is the property of objects which can be converted into different forms but It can't be created nor destroyed. There are various forms of energies like mechanical, thermal, nuclear, gravitational, kinetic, etc. depending on the motion, binding of nucleus, disordered equivalents, etc. In this paper, We are going to discuss about the most abundant form of thermal energy in the world named "Geothermal energy". In this report, We will discuss about various sources available in modern technology for extracting the energy from the earth. We will also look at the impact of geothermal energy on our ecosystem. We will try to explain about the application of geothermal energy for multiple purposes like electricity, paper making, refrigerations. We will also discuss some statistics and ongoing projects from the geothermal stats from gns website ^[2].

Introduction

In thermodynamics, thermal energy refers to the internal energy present in a system by virtue of its temperature ^[1]. There are various resources for thermal energy at microscopic level like disorderness, motion of particles in a large ensemble, etc. But Earth is the main source for this kind of energy as it involves large amount of radioactive decay of materials in its internal crust. Bursting or melting of rocks in earth's lower crust cause volcanic disturbance which can be used in an efficient manner in form of geothermal energy.

“Geothermal Energy” is the form of heat energy generated and stored in the earth. The heat is originated mainly by the decay of radioactive elements in rocks. Then heat conducts from lower level to upper level of earth continually and slowly along a temperature gradient. We can use pumps to send the water inside the earth and correspondingly get the steam from the earth which can be further used in different forms through turbine or generators ^[1].

Geographically, The geothermal heat flows are localised areas of higher heat flow associated with volcanic and geothermal activity. This occurs where tectonic plates are move apart, collide or in hot spots as in mid ocean volcanic islands.

Geothermal energy has certain advantages for our ecosystem, It is clean, pollution free hence low environmental impacts. It is abundant in the nature, We need to configure the resources to use it in convenient manner. It is renewable as any heat extraction is small as compare to the heat content in earth. Also natural heat does not flow in equilibrium and the planet is slowly cooling down on geological timescales hence minor outflow won't affect the acceleration of planet movement ^[1].

“The Earth has an internal heat content of 10^{31} joules ($3 \cdot 10^{15}$ TW·hr), approximately 100 billion times current (2010) worldwide annual energy consumption” ^[1].

Geothermal energy have an excellent potential for mitigation of global warming. It produces low carbon. Because of lower greenhouse gas emissions, Geothermal energy can be a good alternative of fossil fuels. Keeping in mind the environmental impacts of using coal and other fossil fuels, How they are deteriorating our current ecosystem, I think use of geothermal energy at large scale should become the need of current era.

Low Cost of geothermal energy, The major costs involves installing the well and pipes. After these the running costs for geothermal system is lower than for other source of energy and Also maintenance involves only manual labour. Economically, Also It is perfect form of energy which can be used in many household and industrial applications.

Sources of Geothermal energy:

Typically there are two kinds of sources for geothermal energy Conventional and Unconventional sources.

Conventional sources of geothermal energy are those sources which include high enthalpy geothermal systems in TVZ (Taupo Volcanic Zone) ^[3] and Ngawha ^[4] and hot spring systems ^[5] outside TVZ. It includes high enthalpy geothermal systems and hot spring systems.

Direct heat usage from geothermal sources involve bathing, drying, hot spring systems. New Zealand is one big geothermal system with geographically sustainable where heat can be extracted from circulating fluid or dry rock. A recent study in New Zealand shows that installed capacity of 448 megawatts thermal power is used as direct usage. About 62 percent of installed capacity is generated from outflows in power plants or wells ^[5].

Unconventional sources are those which are hardly exploited in warm to hot water in abandoned hydrocarbon, TVZ and Ngawha, natural heat in sedimentary basins and igneous terrain. These are not that much in current usage because of limited manual and tech support But In the coming year this source of energy is expected to play an important role in geothermal energy extraction.

In New Zealand case studies ^[5], The heat in place for unconventional sources of energy is estimated using below equation:

$$\begin{aligned} \text{Total heat in place} &= \text{Heat in fluid} + \text{Heat in Rock} \\ &= [V(1 - \Phi)C_{rock}\rho_{rock}(T_f - T_o)] + [V\Phi C_{water}\rho_{water}(T_f - T_o)] \end{aligned}$$

Where V = volume in m^3

Φ = porosity

C_{rock} = Rock's heat capacity (kJ/kg)

C_{water} = Water's heat capacity (4.18 in kJ/kg)

ρ_{water} = Water's density (1000 kg/ m^3)

ρ_{rock} = Rock's density in kg/ m^3

T_o = base temperature (approx 15°C)

T_f = source temperature for extraction of geothermal energy

Porosity is a measure of how much rock is present in open space. So where the rock is dry and circulating fluid is low we would assume the porosity as low of the order of 0.01.

Conductive heat flow is based on the area in which geothermal system is operating.

In the study of geothermal systems in New Zealand, It is concluded that direct usage of heat from geothermal are enormous and widespread. However most of the Unconventional sources are inaccessible. But We can't rely on the direct usage as It may be limited due to various factors which includes, Abundance of various other energy sources like solar, wind, etc., General lack of knowledge, Limited legislation and support from government, Advanced technologies, etc.

From the study of New Zealand, It was mentioned that 14.4 MWe of binary cycle plant uses about 264kg/s waste water. We should use this waste water for further cycles in

geothermal systems. As recyclation would produce much optimum output for the geothermal systems. In Wairakei, It had been done where this waste water are reinjected or used by the prawn farm. We can use this unused energy for multiple purposes like agricultural business complex, freezing, refrigeration of vegetable or fruits, distillation of certain chemicals like ethanol, etc. ^[6]

Application of geothermal energy ^[8]:

According to different case studies mentioned on the gns website We get to know the applications of geothermal energy varies according to temperature.

Temperature (F\C)	Usage (Application)
356/180	Digestion in paper pulp (Kraft)
338/170	Drying of diatomaceous earth
320/160	Drying of fish meal and timber
284/140	Drying farm products, Food Canning
266/130	Evaporation in sugar filtering, Extraction of salts by evaporation and crystallisation
230/110	Drying and curing of light aggregate cement slabs
194/90	Drying of stock fish, Intense de-icing operation
176/80	Space heating (buildings and greenhouses)

158/70	Refrigeration
140/60	Animal husbandry
122/50	Mushroom growing,
104/40	Soil warming, Biodegradation, Fermentation

Taken from lindal diagram for geothermal resources

Source: http://www.gns.cri.nz/var/ezwebin_site/storage/images/media/images/lindal-diagram2/31871-1-eng-GB/lindal-diagram.jpg

Limited efforts have been made to develop new geothermal resources due to economic and availability constraints.

Low-temperature geothermal resources can occur in rock other than volcanic and may results naturally from percolation of warm rain water or seawater to the depth. These warm water rises back to the surface in form of warm springs and diffuse into the environment. These resources can also be the result of outflows from high-temperature geothermal system. Water heated by shallow magma chambers resulted into high-temperature geothermal system. This hot water rises, diluted by shallow cold groundwater and then emerges from the distance of these high-temperature systems due to topography. These type of outflows occur in TVZ and Ngawha in Northland. These systems have been widely used in industrial and household applications like bathing, heating greenhouses, de-icing, aquaculture, melting, and numerous others. ^[7]

Generation of electricity through geothermal energy:

Major part in using geothermal energy is the site selection. It is based on various parameters like fluid content, permeability of rock, heat content, etc. Binary cycle, flash steam and steam power stations are the technologies used in generating electricity from the earth.

In thermal power stations for generating electricity, typical methods of electricity generation are followed. Water is transferred from the stations to certain ground level through pumps and then earth's core performs as a fuel source to extract heat from the water, then This heat is passed through turbine of a generator which as a result produces electricity. The main advantages of these power stations are that It uses the same heat coming from the turbine and passed to the ground by cooling it with the help of condenser. In case of binary systems, water is fed into heat exchanger where heat is transferred to a fluid which have lower boiling point than water like isopentane or isobutane. This fluid then turns into energised vapour using earth's crust and this vapour is passed through turbine to generate electricity which is further passed to the earth through condenser.

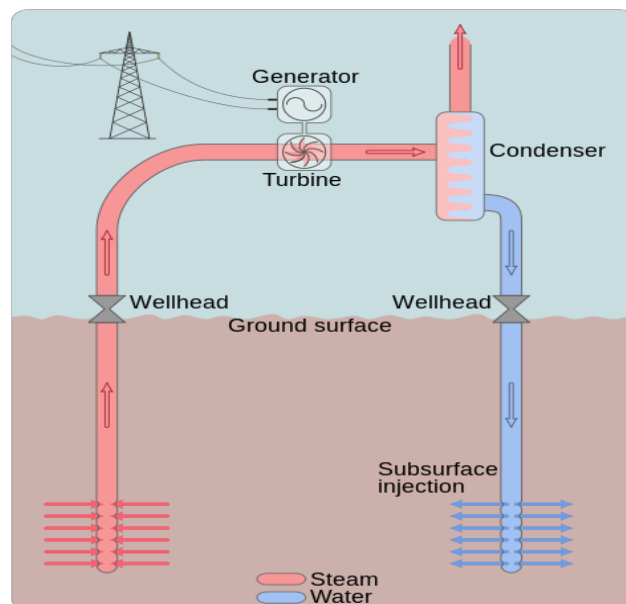


Figure: Dry steam station cycle

Source: http://en.wikipedia.org/wiki/File:Diagram_VaporDominatedGeothermal_inturperated_version.svg

Usage in paper making process:

In paper making process, the steam generated from geothermal plants needs to be cleaned. Cleaning process involves heat exchanger, stripping plant, separation plants, etc. This clean steam is used in 'yankee'. Yankee is the large steel cylinder used in paper machine. In the tissue making process, Yankee dryer evaporates the moisture. Usage of geothermal energy in paper making process have reduced the CO₂ emissions by 39 percent.

Usage in aquaculture:

Geothermal energy can also be used in aquaculture. It helps in growing aqua living beings like prawns. For this geothermal plants are modified such that geothermal fluid is passed through a heat exchanger to heat water for grow-out ponds and tanks in the hatchery and nursery as part of the process of growing prawns. By virtue of this application, tourism venture is getting economically stronger. Via this method we are able to do controlled optimal growth temperature for aqua living beings.

Space cooling:

Lake water at low temperature around four degree celsius is pumped from a depth of around 80 meters which is three meters from the lake surface through a stainless steel plate heat exchanger. The lake water cools the water because of temperature gradient at the surface and the bottom. Through this application, we can make the environment cooler in hot conditions. Use of diffusers enhance the back water mixing at the lake which in turn makes the process much simple. Lake space cooling is environmentally and economically positive. Also It would help in saving the electricity upto 80 percent on cooling systems.

Future of geothermal energy ^[9]:

Geothermal energy plays a significant role in making our ecosystem more clean and sustainable. It is one of very few technologies which are based on the supply of base load and continuous power. Unlike other energy plants of nuclear and coal, Binary geothermal plants[described above] can be used as adaptable source of energy which balances variable supply of renewable resources like solar and wind

The costs of electricity through geothermal systems is also becoming competitive, sustainable and reliable. According to EIA new geothermal plants will be <5 cents per kWh as compare to 9 cents for new conventional coal and 6 cents of new natural gas. So There is a bright future for geothermal energy in household and business source.

EGS system has a great potential of providing electricity in gigawatts of electricity as It generates electricity without the use of convective hydrothermal resources.

Ongoing work

- Fingerprinting geothermal fluids: Tracking the magmatic signature

Magmatic fluid plays an important role in extraction of heat from the earth. In volcanic regions, It becomes very difficult to find the sustainable place for geothermal plants. If we are able to find a way to track the flow of magmatic fluid under the earth then our task of establishing a geothermal system plant would become much more easier. Approach to track the magmatic fluid involves tracking of magmatic fluid signature in geothermal systems by characterising its fingerprint. This approach influences the magmatism under the TVZ. ^[10]

- Various Research programmes

Various research program are being conducted in New Zealand and various other countries for enhancing the use of geothermal energy in various activities. Like hotter and deeper. This program aims to use geothermal energy such that 20 percent of electricity in the region should be fulfilled by the heat extracted from earth. ^[11]

References:

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