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Geothermal energy: A multi-utility energy source

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ABSTRACT

Geothermal energy is the anomalous heat content in the interior of the earth, reported mostly along the plate boundaries, fault zones, volcanic terrains and deep seated igneous injections. Geothermal system is mainly established due to deep circulation of water through conduit zones. Hot water springs and steam emission are the main manifestations of geothermal resources. The geological investigation and exploration by drilling, helps in the development of such resources. The temperature of hot springs may vary from 30 to 97°C on surface. This hot water content is used for generation of electricity, mostly in USA, Japan, New Zealand etc. Geothermal energy being a renewable natural resource with very less carbon emission, is an environment friendly energy source. Besides electricity generation, geothermal resources can be used for direct heat uses like refrigeration, greenhouse cultivation, aquaculture, tourist attraction, spa and bath centers. It is a renewable, 24x7 source of energy, useful to control the pollution and greenhouse effects.

Key words: Hot springs, Renewable energy, Geothermal power plant, Space heating, Greenhouse

INTRODUCTION

The progress of civilization of any country depends on the social and economic growth. The economy is now directly dependent on the energy utilization, so every country is planning to produce maximum possible energy at affordable cost. Though the fossil fuels offer ready to use, convenient source of energy, there are other aspects like high emission of greenhouse gases, leading to global warming and thereby climate change. This warrants substitution of fossil fuels by renewable energy sources which are more eco-friendly. The non-conventional and renewable sources offer an alternate source of energy for power generation, which create less pollution, are user friendly and easily available for utilization.

Wind energy, solar energy, hydropower and nuclear energy have been common renewable energy sources. Besides, biomass energy, tidal energy, solar thermal and geothermal energy are upcoming energy sources which are getting acceptance. Electrical vehicles, hydrogen powered transport system are newly introduced modern energy substitutes. Systematic adoption of renewable energy will help in controlling the greenhouse gases and mitigation of climate change. Geothermal energy is an alternate renewable energy source available round the clock, having low carbon emission.

As the clean electricity supply continues to expand rapidly, the share of fossil fuels in global generation is forecasted to decline from 61% in 2023 to 54% in 2026, falling below 60% for the first time. Global CO_2 emissions from the electricity generation are expected to fall by more than 2% in 2024 after increasing by 1% in 2023. Renewables are set to provide more than one-third of total electricity generation globally by early 2025. The share of renewables in electricity generation is forecast to rise from 30% in 2023 to 37% in 2026 (IEA, 2024). The demand for energy in India is increasing very fast, with estimated demand of 243271 MW by 2024. The installed capacity of power generation is about 434195 MW in 2024 (CEA, 2024). The non-conventional energy sources in India contribute, hydropower 46928 MW, nuclear power 7480 MW, wind energy 45154 MW, solar energy 75576 MW, biomass 10262 MW, waste to energy 584 MW and small hydro 4995 MW to the power sector. The installed capacity of renewable energy sources was nearly 136570 MW in 2024, helping to reduce emission of greenhouse gases (Figure 1).

Geothermal energy is the renewable source of energy which is site specific, mostly located in hilly terrain, hence, can be utilised to fulfill the energy needs of remote areas where transmission of power is rather difficult. Considering the need to augment renewable energy sources, geothermal energy can play significant role in power supply by electricity generation as well as direct heat uses to save electricity. It is a heat source stored in the interior of the earth. The heat stored in rocks is brought to surface by the deep circulation of water moving through the rocks. It is a continuous source of energy as the heat is continuously generated in the interior of the earth and flushed to surface through hot water or steam. Considering the energy mix in power sector of India, geothermal energy has good scope to contribute to power sector in remote area and hilly terrain. Such energy sources are widely distributed along the plate boundaries and structurally disturbed areas. The igneous rocks like granite and basalt can also host geothermal energy sources. Its worldwide power production is about 16127 MW (Thinkgeoenergy, 2024) mostly located in USA, New Zealand, Iceland, Philippines, Japan, Italy, Indonesia, China, Kenya and Turkiye (Figure 2).

Besides electricity generation, upto107627 MW geothermal energy is popularly used to substitute electricity as direct heat uses, particularly in greenhouse, space heating, refrigeration, industrial uses, spa and aquaculture as shown in Figure 3 (Lund and Aniko, 2021).

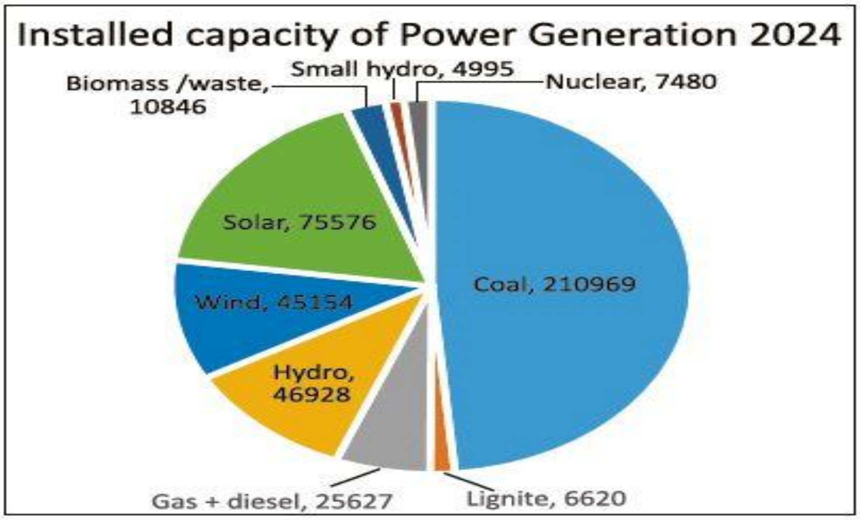

Figure 1. Installed power generation capacity in India (CEA, India)

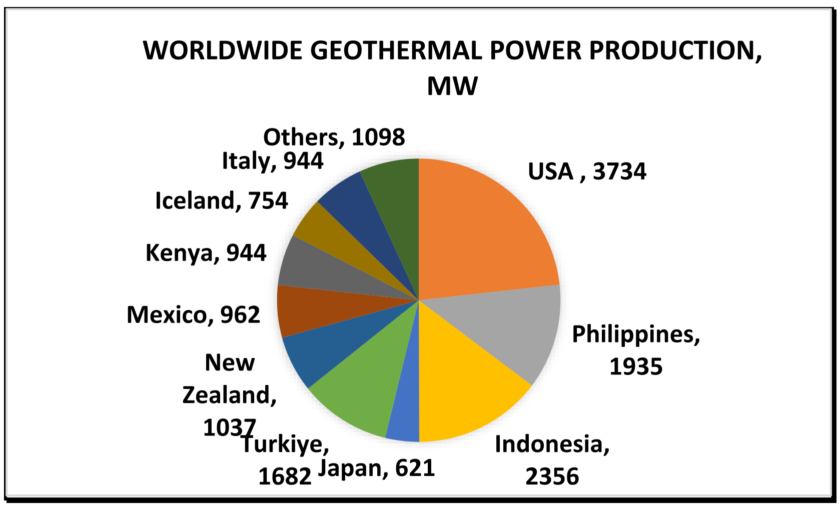

Figure 2. Main countries that are producing geothermal power (www.Thinkenergy.com)

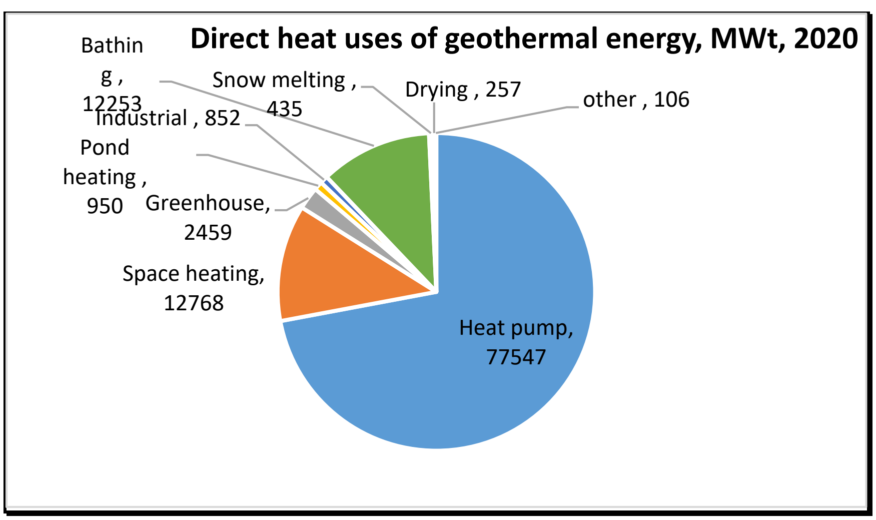

Figure 3. Direct heat utilization of geothermal energy worldwide (Lund and Aniko, 2021)

Geothermal energy is environment friendly as there is no burning of the fuel, and hence, the emission of polluting gases like CO_2, CO, NO_2, H_2S, CH_4 is in less quantity. The IPCC confirmed the environmental friendly nature of geothermal energy. The report on carbon emission of renewable energy sources and climate change mitigation by IPCC, indicated that the carbon intensity of electricity generation is around 1000 g CO_2 equivalent per unit by coal power, 840 g per unit by oil energy, 48 g per unit by solar PV and 45 - 65 g per unit by geothermal power (Figure 4).

Geothermal energy requires exploration to deep level >2000 m depth which is expensive. So the initial cost of geothermal power plant is more than the other solar or wind energy power plants. But it has very less cost on fuel and maintenance, hence in long period of time, geothermal power is also cost effective. A geothermal power plant can produce electricity 24x 7, whereas wind and solar power generation is during particular period depending on availability of the natural resource. Besides, geothermal energy saves cost of storage, as it can be transmitted directly. The estimated cost of geothermal power is around 4 cents /kWh in USA, as shown on X axis in dollars/ MWh (Figure 5). The levelised estimated cost of electricity generation depends on technology used, resource parameters and geographical conditions and it may vary from 80 to 120 US dollars/ MWh (Figure 6) (Cleantechnica, 2016).

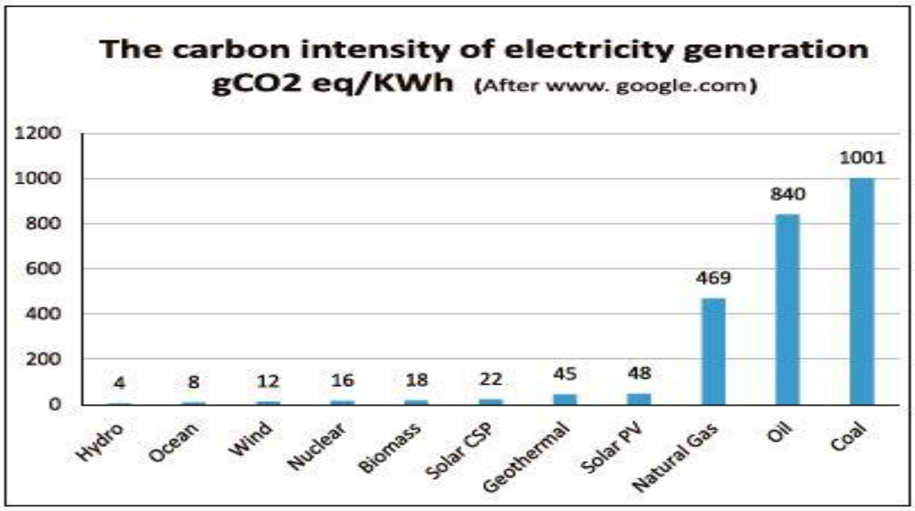

Figure 4. Carbon emission by different sources of energy

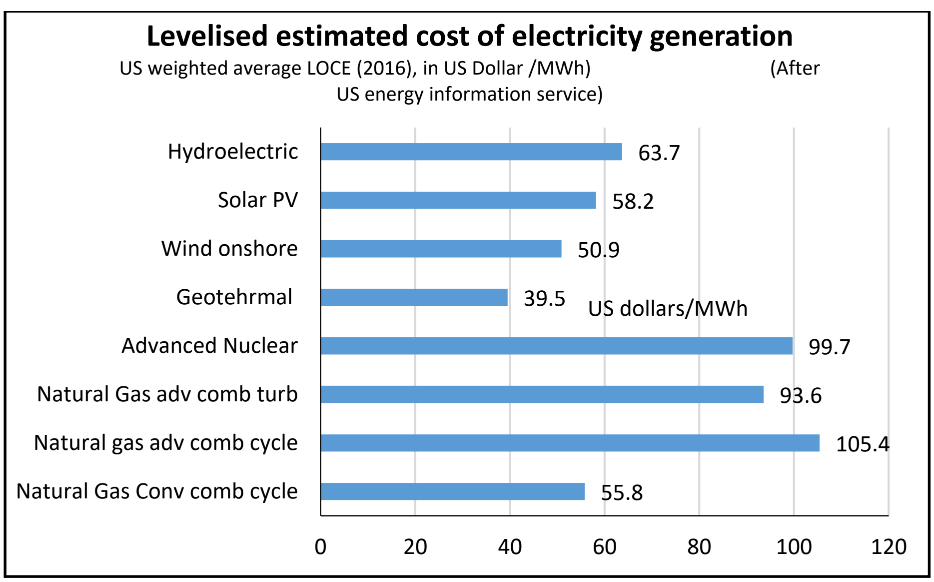

Figure 5. Levelised cost of geothermal power in USA. (US DEO, 2016)

But in India at initial stage the cost may be around 10 cents or more. The cost will substantially reduce with increase in production and availability of indigenous machinery.

The cost of power generation by different energy sources, including the renewable energy sources, indicate that the levelized cost of geothermal power is similar to nuclear energy and biomass energy. The cost of geothermal power depends on the temperature of resource, discharge capacity, method of power generation, and terrain conditions.The cost is inversely proportional to discharge, temperature of resource and capacity of powerplant. The cost of steam based power generation is less than binary cycle power geenration. (Nathwani and Mines 2015). A steam based large capacity power plant may have cost of power generation from 0.04 to 0.10 USD per unit depending on resource temperature (Nathwani and Mines 2015). Thus, geothermal power plants using proper technology and good discharge parameters are commercially viable.

For example, the geothermal power plant at Wairakei, New Zealand, is running for the last 50 years, indicating that the geothermal power is a sustainable energy source. The exploration and power generation of geothermal power resource needs investment at various stages. The general fund requirement for a 200°C resource with 30 MW flash geothermal power plant installation is suggested in Figure 7 (Nathwani and Mines, 2015). The graph on Y axis, shows variation in capital cost of geothermal power plant with base temperature by binary cycle method and flash plant and levelised cost of electricity generation (LCOE) per MWh in US dollars. This indicates that higher base temperature is required for flash plant than the binary cycle method, hence, the cost of power generation based on flash method is marginnaly less than the power generation by binary cycle method. Thus, the cost of electricty generation is controlled by the temperature of the resource and the method of power generation.

The geothermal exploration and power project installation requires funding at every stage of investigation. Geothermal exploration, field confirmation, field completion and power plant installation are main activities requiring major cost input (Nathwani and Mines, 2015). The cost component of various activities in geotehrmal power palnt development, as shown in Figure 8, indicates that the major proportion of cost input is for field devlopment and power plant installation. Hence, the production cost of a geothermal power generation depends on cost of field completion and capacity of the power plant.

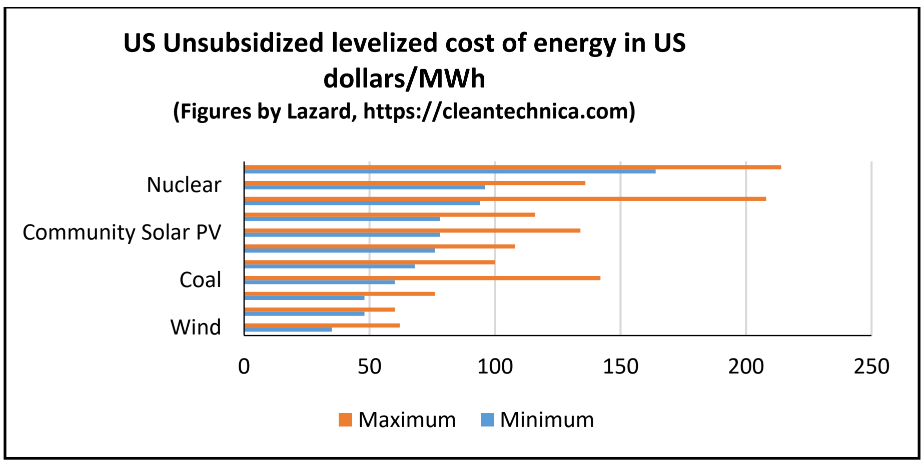

Figure 6. Estimated levelised cost of power generation (after Cleantechnica, 2016)

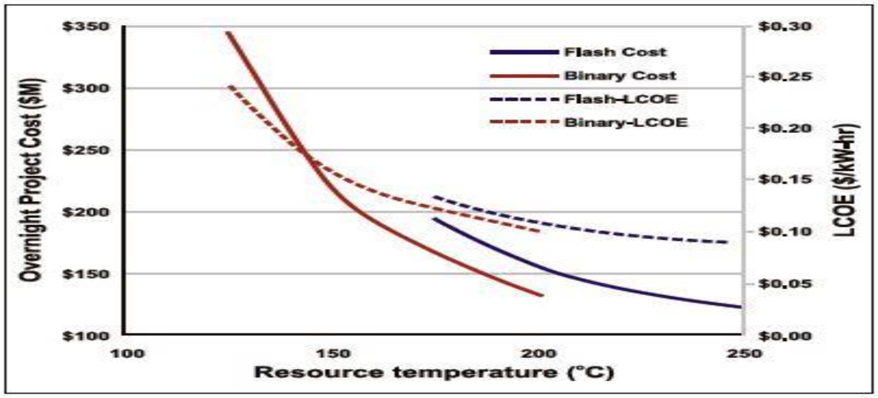

Figure 7. Cost estimation of different methods of geothermal power generation (After Nathwani and Mines, 2015)

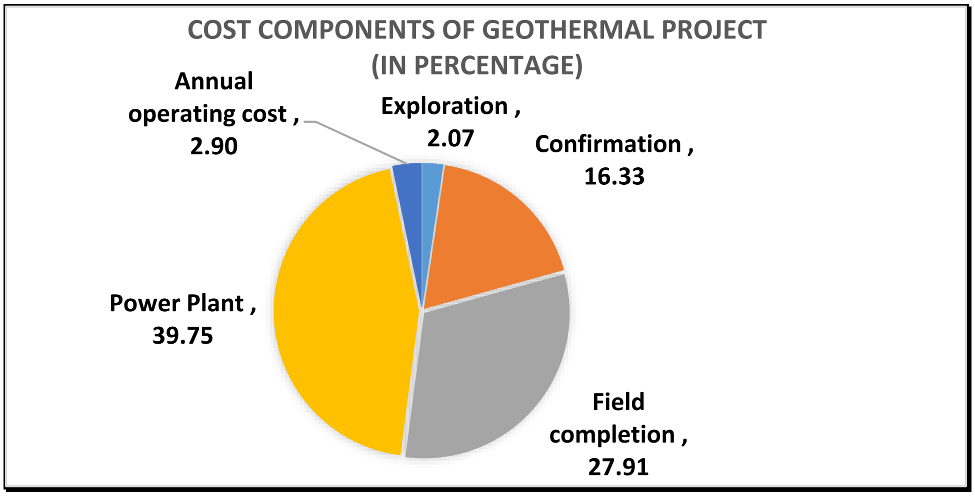

Figure 8. The percentage wise cost of various components in exploration and development (Nathwani and Mines 2015)

GEOLOGY OF A GEOTHERMAL REGION

Most of the geothermal fields are structurally controlled, located along faults, plate boundaries or near volcanoes or active volcanic zones. The rock types may vary depending on local geology. Most common geothermal basement rocks are granite, basalt and sometimes sandstone. Geothermal reservoirs are commonly reported from granites, basaltic lava, calcareous rocks and sedimentary rocks, like sandstones. A geothermal circulation cycle mostly sets in porous and permeable rocks with good inter connectivity. In places where granitic basement or volcanic rocks are present, but a hydrological recharge cycle is not developed due to lack of permeability, the geothermal system is called as hot dry rock geothermal prospect. In hot dry rock system, there is high heat flow without any hot water discharge.

An investigation for geothermal resources involves (i) Geological mapping, topographical survey, petrography, XRD and fluid inclusion study, (ii) Geochemical study, water quality and geothermometry, (iii) Geophysical surveys including MT studies, (iv) Drilling and borehole geology, and (v) hot water discharge, steam content etc. In geothermal exploration, MT method is used for detecting earth layers with different resistivity (or conductivity) of various rock materials and fluids below the Earth's surface (Subbarao et al., 2023).

GEOTHERMOMETERS

The temperature of the hot springs may vary from 30°C to 97°C while the sub-surface reservoir temperature may go 100°C to >250°C. The sub-surface temperature is estimated based on the composition of water. The solubility of quartz with temperature and the equilibrium ratio of Na- K is popularly used to infer the possible temperature of deep geothermal reservoir (Giggenbach, 1997). The content of silica in hot water and Na-K ratio are used to decipher the water temperature as suggested by Fournier (1979) and Giggenbach (1997). It is assumed that the silica content does not vary during up flow and Na- K ratio remains stable in saturated geothermal water. There are other indicators based on Ca-Mg and K-Mg ratio also. Besides this, alteration, mineral content, fluid inclusion study and gas analysis is also used to infer temperature of geothermal reservoir. The actual temperature at reservoir can be finally verified by drilling to the desired depth.

GEOPHYSICAL SURVEY

Geophysical survey is a useful tool to decipher subsurface configuration of rock types and structure which can give inference about water bodies also. Resistivity and magneto-telluric surveys are mainly used methods in geothermal investigation. Geophysical methods try to measure relative variation in following properties of the rocks.

1. Density- Gravity method
2. Magnetism- Magnetic survey
3. Seismic susceptibility- Seismic survey
4. Electrical properties- (i) Self-potential survey, (ii) Resistivity Survey, (iii) Magneto-telluric survey, and (iv) Borehole logging

RESERVOIR CONFIGURATION

The preparation of planar and 2D / 3D section of geothermal resource is part a of reservoir configuration. Geological data, lithology, structure, topography and drainage pattern, geophysical survey interpretation, temperature data, available sub-surface data are taken into consideration to prepare reservoir configuration. Based on these data, surface area of geothermal anomaly is marked, coupled with sections prepared with geophysical inferences and thermal gradient data that help in suggesting the reservoir configuration.

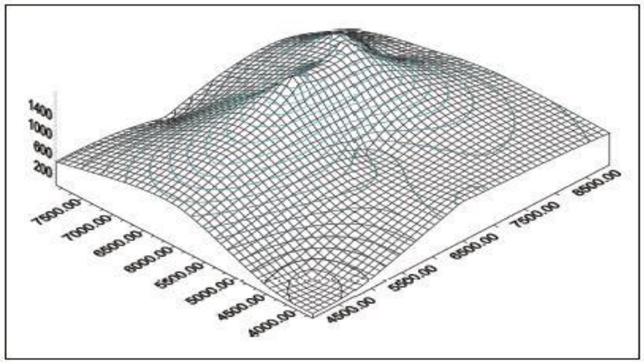

Figure 9. Surface configuration of 100°C isotherm at 1500 m depth, Tatapani geothermal field, (Chhattisgarh, India)

Figure 9, depicts a possible surface configuration of 100°C isotherm interpreted based on thermal logging and bore bole data suggesting a conical structure with peak near Tatapani village, Chhattisgarh, while the outward slope of isotherms indicate that the geothermal reservoir continues to a depth below 1500 m (Sarolkar et al., 1999). Exploration for geothermal resources is planned considering the reservoir configuration, and sub-surface characters.

POWER GENERATION METHODS

The type of power generation method is decided based on discharge temperature, steam content and flow. A plan is prepared for effluent water discharge or reinjection. A closed cycle production plan ensures good recharge of reservoir, less loss of resource and less environmental pollution. Geothermal power uses heat stored in water to generate electricity. In geothermal resource of high temperature > 200°C, the power generation is similar to steam turbine where steam separated from water is used to drive the turbine. This is called steam based geothermal power plant. In high temperature resource areas, depending on temperature, the water is flashed one or two times to separate the steam. This is called as single flash and double flash geothermal plant. The steam based geothermal plant generally has higher efficiency of power generation. When the temperature of geothermal resource is <180°C, the heat in water is used to vaporize an organic liquid of low boiling point. This organic vapour is used to drive the turbine. This method is called as Binary Cycle power plant. In binary cycle method, the efficiency of power generation is less as compared to steam turbine, and have relatively more cost of production.

FUNDING NEEDS

Geothermal exploration is an expensive activity because the drilling requires heavy machinery for drilling boreholes >2000 m deep, to control hot water flow and completion of production well. Besides cost of exploration and field preparation for steam production, the power plant costs are similar to steam based power plant while the binary cycle power plant has less output hence may require more cost of production. In geothermal power plant, the cost of hot water or steam is much less but the cost of exploration and power plant combined makes the project expensive. Considering this, initially the project looks expensive inhibiting the investors to consider it as a business proposal. Thus, funding for geothermal development is a major issue. This requires a firm policy regarding incentive for exploration and investment through public private partnership and FDI through international co-operation. (Sarolkar, 2015).

ENVIRONMENTAL ASPECTS

The best environmental policy consists in preventing the creation of pollution or nuisance, at the source rather than subsequently trying to counteract the effect. Pollution by substances which are capable of causing harm to man or any other living organism supported by the environment has to be controlled. Similarly, the greenhouse gas emission has to be checked to avoid adverse effect of climate change. Geothermal energy is clean energy as it causes much less pollution as compared to fossil fuels. The gas emission from geothermal energy comprises H_2O, CO_2, CH_4, NO_2, H_2S, H_2, Argon and Helium. CO_2 emission of geothermal power is around 65 mg /kwh compared to the CO_2 emission from 950 mg/kwh by coal based power plant (www.IPCC,ch).

Thus, use of geothermal energy is a good tool to arrest greenhouse gas emission. Besides gases, the water quality has to be monitored to avoid adverse effect on local environmental. The geothermal water contains mostly Na, K, Cl, HCO_3, SO_4, which needs to be monitored during production to avoid corrosion effect in turbine and production line. The water composition of some geothermal fields in India, given in Table 1, shows the hot water of Tatapani Chhattisgarh, Chumathang Ladakh, Manuguru Telangana, and Bakreshwar West Bengal are mostly sodium- bicarbonate type, while the Tural hot spring is sodium- chloride type. The hot water composition is suitable for industrial production purposes.

Table 1. Water composition of some geothermal fields in India

	WHO limit (Lund and Herbert, 1971)	BIS limit ppm (CPCB, 2019)	Tatapani geothermal field (Borehole 23, 1996) (Sarolkar and Mukhopadhyay, 1996)	Chhumathang geothermal field (GSI, 2022)	Manuguru geothermal field, borehole MGR-4, (Sakhare et al., 2020)	Bakreshwar Geothermal field, WB/123, (GSI, 2020)	West Coast, Tural hot spring, (GSI, 2020)
pH	6.5 to 9.2	6.5 -8.5	8.6	8.1	8. 4	7.8	7.5
Conductivity @25°C	1400	1400	642	1491	641	769	1445
CO3 ppm	-	300-600	16	76	52	NA	NA
HCO3	-	--	151	398	327	292	54
Cl	600	1000	72	95	32	86	365
SO4	400	400	65	225	15	30	70
Ca	200	200	2	16	13	67	47
Mg	150	100	1	2	5	22	2
CaCO3	500	400	8		52	262	122
Na	--	--	125	250	148	48	271
K	-	--	11	2	10	9	11
B	--	1	0.5	31	NA	NA	NA
F	1.78	1.5	16	10	1.2	0.8	2.01
As ppb	0.05ppm	.05	<10	NA	NA	NA	NA
Hg	0.002ppm	0.001	NA	NA	NA	NA	NA
SiO2	-	--	118	87	60	43	70
TDS	1500	2000	520	1010	320	385	725

The geothermal exploration and development may have some effect on terrain conditions, physiography and ground water conditions. The following effect can be observed in geothermal areas.

PHYSICAL ENVIRONMENT

Geothermal manifestations

Continuous flow from hot sprouts cause a large area into a marshy land. The marshy patches are observed near hot springs and borehole discharge create stretches of waste land showing patches of secondary deposition and sometimes hot ground.

Ground subsidence

In the hard rock area like granite, granite-gneiss and biotite gneiss, the ground is stable but in sedimentary rocks continuous production of hot water may cause ground subsidence locally. Continuous flow of the thermal water opens up the channels and fractures in the boreholes. The breccia zones cause caving and block the bore wells with loose pebbles and debris.

Drainage

Generally the geothermal plant does not require clearing of land except for power station. Hence, there is less damage to the landscape and drainage. It is necessary to monitor any effect on ground water table.

Noise

A typical noise exposure level is 85dBA for an average day of 8 hours with a peak level of 140 dBA (Cleantechnica, 2016). The noise level of the turbine and separator of effluent water may locally cause inconvenience to humans.

CHEMICAL ASPECTS OF ENVIRONMENT

The effect of pollution can be judged by the content of contaminants in the water e.g. arsenic, fluorine, mercury, calcite and silica. The damage to organism and environment may be minimized by maintaining the composition of the chemicals in water within the limit of human tolerance and industrial parameters.

Calcite scaling

Calcite scaling is a major problem in geothermal fields e.g. Kizildere, Turkiye and Te Aroha, New Zealand. Calcite or aragonite is deposited in the wells at the level of first boiling (Arnorsson, 1989) causing blockage of boreholes and large areas of white terraces near hot springs as observed in Yellow Stone Geothermal field, USA.

Silica scaling

Silica precipitation is a major problem in high temperature geothermal fields. The silica is deposited around hot springs and may also deposit in boreholes blocking the boreholes.

WATER COMPOSITION

The thermal water contains moderate amount of Cl, SO_4, Na, HCO_3, SiO_2, while K, Ca, Mg, B are low in content. Arsenic is mostly within permissible limits while fluorine content may be high. If released into a river or lake, these contaminants may cause damage to aquatic life, plants or humans, hence the need for an environmental impact assessment (Webster and Timperley, 1995). High values of TDS in geothermal water sometimes interfere with the usefulness of water as source of energy (Srivastava et al, 1996). According to the Intergovernmental Panel on Climate Change (IPCC), geothermal energy source is recognized as a competitive energy source (with a carbon footprint around 50 gCO2eq/kWh over its lifetime) compared to conventional energies such as coal or oil (with a carbon footprint around 800 g CO2 eq/kWh) (Marchand et al., 2015).

Fluorine

The fluoride content in thermal water may be high and if used for irrigation, may cause harm to the ecosystem. Fluorine content of 0.7 to 1.5 ppm is acceptable for drinking water (Deshmukh et al., 1995). Solubility experiments carried on fluorite in distilled water by Ramamohana Rao et el. (1993), revealed that addition of Ca ions to solution in contact with fluorite caused decrease in fluorine concentration.

Arsenic

Arsenic released into the river may be embedded in plants and sediments. Excess intake of arsenic is poisonous and carcinogenic to humans (Chanlett, 1973). Hence, it is desirable to remove arsenic from effluent water by bio-degradation processes.

Boron

Boron is present in geothermal water in small quantity around 1 ppm and 0.5 ppm in Tatapani, Chattisgarh. Sometimes the water contains high boron as in Puga Ladakh, which is extracted as a byproduct.

Mercury

Mercury readily combines with chloride, iodide and bromide or may be present as a mercurous ion in thermal water. Mercury may occur in steam fraction also. Hg can bind to carbon and may accumulate in the food chain. Hg has tendency to accumulate through the food chain (Webster and Timperley, 1995), hence it is necessary to monitor Hg in water.

GASEOUS CONTENTS

H_2S

H_2S occurs in a dissolved and gaseous state in thermal water. The dissolved H_2S is oxidized rapidly in the presence of oxygen to colloidal sulphur as observed in a few springs at Tatapani (Shivastava et al., 1996). The dissolved H_2S needs to be treated for extraction of native sulphur which may improve taste and odor of the water and reduce corrosion of installations.

CO_2

CO_2 is the most common gas in geothermal exhausts. Besides causing carbonate scaling in bore wells, CO_2 is highly toxic for humans and cattle. The CO_2 is colour less and odour less, heavy gas which accumulates in pits and depressions. Though less in quantity, it is essential to monitor regularly at the geothermal site to avoid the CO_2 accumulation.

UTILISATION

The most important use of geothermal energy is power generation. Besides power generation, geothermal energy is used for many other ancillary uses depending on the local conditions. The effluent water from power plant or hot water with low temperature is used for substitution of conventional energy sources for industrial purpose. The important uses of geothermal energy are discussed below (Lindal, 1973).

Binary cycle power plant (Temperature 140°C to 100°C)

In binary cycle power plant, the hot water is used to vapourize a fluid of low boiling point, which is used to generate electricity. The water and working organic liquid flow in separate closed loops so that there are no or little air emissions (US DOE, 2016). At Hussavik, geothermal heat utilization, 90 l/s hot water of 125°C with outlet temperature of 80°C, was used for generation of electricity by binary cycle power plant (Eliasson, 2001). Geothermal power plants come small (300 kW to 10 MW), medium (10 MW to 50 MW), and large (50 MW to 100 MW and higher) sizes. A geothermal power plant usually consists of two or more turbine generator 'modules' in one plant. Extra modules can be added as more power is needed (DOE, 2004). As such geothermal power production can be modified as per the demand.

Refrigeration and cold storage (80°C to 180°C)

This is a very popular use of geothermal water by ammonia absorption or isobutane method or using similar organic fluids. The geothermal energy is used to substitute part of the electricity required for refrigeration. Geothermal heat pumps (ground-water and ground-coupled) have become popular in the U.S. and Switzerland, used for both heating and cooling.

An example of space heating and cooling with low-to-moderate temperature geothermal energy, is the Oregon Institute of Technology in Klamath Falls, Oregon. In addition, a 541 kW (154 tons) chiller requiring up to 38 L/s of geothermal fluid used to produce 23 l/s of chilled fluid at 7°C to meet the campus cooling base load (Boyed, 1999). Dholera Swaminarayan Mandir is the first to utilize geothermal energy for air conditioning and cooking. The 50°C hot water is also used for bath (Deshgujarat.com, 2016).

Snow melting (Temperature <80°C)

The sprinkling of groundwater over roads or circulating groundwater in heating pipes embedded in the pavement are popular methods in areas which are not much cold. As for the utilization of geothermal heat, the outflow hot water from spas, has been used in the same manner as groundwater for snow melting (Morita and Togo, 2000).

Space heating (Temperature >60°C)

Space heating is most popular use of hot water. Hot water is circulated through specially designed pipes in a building for heating purpose. Geothermal energy is used in Kamath falls, USA and Tianjin,China for space/ house heating substituting large amount of electricity. Heat pump systems use groundwater aquifers and soil temperature typically in the range of 5-30°C. The extensive use of geothermal heat pumps for heating and cooling of buildings in North America and Europe is a relatively recent development (Roy and Sarolkar, 2022).

Soil warming (Temperature >40°C)

Warm water is used for soil warming in cold climate, to improve water flow and water retention in the soil. The soil warming helps in improving agricultural output. Geothermal water of low temperature, is used for soil warming and snow melting in cold terrains. The heating coils are filled with working fluid consisting of a glycol water mixture. The geothermal energy is supplied to heating system through the use of pipes, directly from circulating pipes, through a heat exchanger or by allowing water to flow directly over the pavement. The benefit of this system is that they eliminate the need for snow removal, provide greater safety for people and vehicles, and reduce the work of slush removal (Lund, 2000).

Industrial uses (Temperature 80°C-180°C)

The hot water can be used for digestion in paper mill, cement block curing, drying of vegetables, metal part cleaning, fish drying, wool processing and timber washing (Lindal, 1973), depending on the temperature. One of the first was Bloteca, a construction block factory that started using geothermal steam in curing process of concrete products. At Agrioindustrias La Lagnna, a fruit dehydration plant was set up as an experimental and demonstration project (Merida, 1999).

Aquaculture, agriculture and crocodile farming (Temperature <60°C)

The hot water is used to keep the water conditions congenial for crocodiles and fishes by regulating the temperature. Geothermal heat allows better control of pond temperature, which optimizes growth of fishes. The use of geothermal energy for raising cat-fish, shrimp, tilapia, eels, and tropical fish has produced crops faster than by conventional solar heating. Using geothermal heat allows better control of pond temperatures (Lund and Aniko, 2021). In vegetable dehydration process of onions, garlic, geothermal water flowing through heat exchanger warms the air to temperature ranging from 38°C to 104°C, which is blown over the sliced vegetables as they proceed along a conveyor belt (www.ThinkGeoenegry). In fact, the cost of dehydrating fruits by geothermal source is 15 -25% of the cost by using conventional energy (Lund and Rangel, 1995). In Utah, during winter, the geothermal water keeps the temperature in greenhouse space at about 21°C, even when outside temperature drops below freezing point. Fog cooling and ventilation system help maintain a moderate temperature during summer when outside temperature can reach 35°C (Lund and Rangel, 1995). Most greenhouse operators estimate that using geothermal resources instead of traditional energy sources, saves about 80 percent of fuel costs and about 5 to 8 percent of total operating costs (DOE, 2004). Milk pasteurization with geothermal energy has been tried at two locations, Klammath Falls, Oregon and Oradea, Romania. A geothermal water of 87°C was pumped into the building and through a 3 plate heat exchanger, to heat cold milk at 3°C to a temperature of 78°C, at the rate of 0.84 l/s (Lund, 1997). Besides electricity, geothermal heat can be utilized for dehydration of agricultural produce. Dehydrated agricultural products have a high export potential supporting the economic structure of the country as well as the rural population that depend on the agricultural income (Chandrasekharam, 2001a).

Tourism, spa and swimming pool (Temperature >40°C)

The hot water with controlled temperature is used in bathing tanks, spa and swimming pools. Bathing centers and skin care centers are popular tourist attractions. In India, geothermal water has been used for bathing purposes at Ganeshpuri, Thane, Tural, Ratnagiri, Yamunotri, Ganganani, and Badrinath in Uttarakhand. A very popular tourist place has been developed at Tatapani, Chhattisgarh and Chhumathang in Ladakh. More than 200 resorts and spas in the United States offer their guests the use of hot springs for bathing, swimming, or therapy. Geothermal water has been used for recreational purpose since long time.

Extraction of rare metals and mineral water industry (Temperature >30°C)

Geothermal water contains many rare metals like lithium, cesium and helium (Chandrasekharam, 2001b), and also borax which needs to be recovered as byproduct. Similarly, sulphur, calcite and borax are easily recovered from geothermal springs. The inert gases like nitrogen and helium are also recovered from geothermal discharge.

Desalination of water

In areas of water scarcity, the geothermal energy can be used for desalination purpose. Geothermal wells deeper than 100 m can be used for desalination, but the use of geothermal energy for thermal desalination requires cheap geothermal resource and decentralized applications focusing on small-scale water supplies in coastal regions, provided that the society is willing to pay for desalting (Goosen et al., 2010). The direct geothermal brine with temperature up to 60°C can be used in desalting by adopting membranes distillation technology (Gryta and Palczynski, 2011). The desalination of geothermal water using membrane distillation is a feasible process.

CONCLUSIONS

Geothermal energy is a natural source of non-conventional energy, useful for generation of electricity and ancillary uses. Geothermal power plant technology is a proven technology which is being utilized in developed counties like USA, Japan, New Zealand. The geothermal prospects can be used for industrial applications to substitute conventional sources of energy. The geothermal resources in India are poised for development now, contributing to the power sector in Himalayan belt, and interior parts of the country as an alternative energy to substitute the electricity in projects like cold storage, green house cultivation, aquaculture and for tourist attraction places, contributing to improve local economy. Government of India may encourage installation of demonstration geothermal power plant as a show case for feasibility of geothermal resources for utilization as a sustainable energy source.

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Author Credit Statement

Conceptualization, data collection and manuscript writing

Data Availability

No new data was generated for this study

Compliance With Ethical Standards

Author declare no conflict of interest and adhere to copyright norms

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