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(Review Article)

Geothermal Energy: - A Prerogative for India to Solve the Energy Crisis

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Abstract

Energy consumption has always played a very important role in the social and economic progress of a country. Energy consumption can be managed by two factors energy requirement and energy conservation. Both these factors are influenced by the use of renewable and non-renewable energy sources. Due to easy availability and cheaper price, conventional methods had always been opted, but as the combustion of fossil fuels had posed threats to the environment as well as getting exhaustible after energy extraction, focus of many countries has been shifted to cleaner and greener options which include energy extraction from various non-renewable resources such as Solar, Wind, Biomass and Geothermal. This paper focuses on the geothermal potential of our country. The researches that had been done in the identification of geothermal regions and various activities undertaken in those regions to develop Geothermal Energy extraction in India as well as comparison of other sources of green energy has also been considered.

Keywords: Geothermal, Biomass, Energy per capita, Green Energy, GHG

1. Introduction

Countries are driven by the requirement and sustenance of energy. Growing population and rapid Industrialization are contributing factors for the ever increasing energy requirements and per capita energy consumption. The per capita energy consumption determines the economic progress of the countries, according to recent findings **[1, 2]** China has surpassed India & Pakistan in the per capita energy consumption**.**

Other countries such as UK, USA, and France are noted to have the highest per capita energy consumption which also helps in the economic progress of these countries **[3, 4].** The most popular form of energy utilized in the domestic as well as industrial sectors is electricity. Electricity had always been extracted by conventional methods, the global power generation capacity was estimated to be 22,668 TWh by the end of 2012**,** the primary sources were of fossil fuels (67.9%) and other resources included nuclear power (10.9%), hydro power (16.2%) and other renewable contributing to only 5%. The usage of fossil fuels had already been in use and is still in use to satisfy the growing demands of energy, this is so because it is a tried and tested form of energy extraction and is bound to be profitable but on the other hand this is also having a negative impact on the environment due to the emission of harmful gases such as CO_2, SO_X, NO_X, collectively known as the GHG's or the Greenhouse Gases**. [5, 6]**

According to scientific terms energy can neither be created nor be destroyed, but the question posed is the sources from which energy is extracted. The most common form of energy extraction comes from conventional methods. To solve the environmental issues as well as to reduce the greenhouse gas content in the atmosphere, adoption of Renewable Energy Sources (RES) is the best possible solution to meet the growing energy demand. The challenges faced while implementing Renewable energy sources are high capital costs, intermittency, difficulties in storage and complications in grid connectivity **[7].** Therefore due to these barriers the power sector around the globe relies heavily on fossil fuels, Lack of skilled manpower, Lack of funds for further research, makes the power sector over reliant on fossil fuels for power generation.

According to statistics, the three main countries i.e. China, India and Pakistan accounts for almost 40 % of the world population, the percentage of population also determines the growing energy demand, but these three countries contributes to only 29 % of energy consumption globally. With immense nuclear potential, as well as Solar & Wind energy resources at large in India, development and investigations on Renewable energy resources is definitely required. **[8].** After USA, China & Russia India is the fourth largest energy consumer. The electricity consumption is forecasted to raise around 2280 BkWh by 2021-22. **[9].** India became the third highest producer of electricity remaining behind by only Japan & Russia with a 4.8% of contributing factor to global power demand and per capita electricity consumption was approximately 917.2 kWh in the year 2013**[10].**

The Indian power sector is a combination of renewable and non-renewable energy resources. With India Topography and climate playing an important role, natural energy sources such as Solar, Wind, Geothermal, Water and Nuclear can be utilized to their full potential. Recent statistics shows that the total installed capacity of power plant in the country stands at 253.39 GW in which, Thermal power accounts for 69.5%, Renewable energy accounts for 12.5%, Nuclear energy accounts for 2% and Hydropower holds a 16%share.

2. Renewable Energy Resources

2.1 Need for Green Energy Sources: Renewable energy is the energy that can be extracted from renewable resources, and the renewable resources are so called as they will never be exhausted unlike fossil fuels and gets replenished. India has the advantage of a variety of renewable energy sources, such as biomass, biogas, sun, and wind, geothermal, tidal and small hydro power. India's electricity sector is amongst the world's most active players in renewable energy utilization, especially wind energy. **[11].**The coal crisis faced by the country presently at an industrial level, as well as the emission of the greenhouse gases such as carbon dioxide, methane, nitrous oxides and chlorofluorocarbons, which are responsible for the ozone layer depletion and further degrading the environmental scenario are the main reasons towards opting for green energy**.** The greener & cleaner energy resources which can fulfill the growing demand of electricity in an economic and efficient manner. India is a country of diversified renewable energy sources containing solar, wind, geothermal, tidal and biomass. Renewable energy is becoming of ultimate Importance due to coal crisis occurring around the world. CO2, CH4, CFCs, halos, N2O gas emissions leads to ozone layer depletion and increase of earth's crust temperature **[20].** To meet the electricity or energy demand renewable energy's potential can inquire into and utilize appropriately.

2.2 Different forms of Renewable Energy:
2.2.1 Solar: Solar energy is the energy produced by sun rays. Solar energy possible energy producing is about 6000 million GWh of energy per year. Most parts of India's most regions gets 4– 7 kWh of solar radiation per square meter per day which includes 250–300 sunny days in a year **[21].** Solar energy requires a huge area of land for producing large quantity of energy for a specific condition or technology used. Solar Projects include GHG, mercury and cadmium emissions as they are used to make solar modules which pollute the environment.

2.2.2 Wind: India is 5^{th} in the world for wind power installed capacity with total capacity of 21136.40MW contributing to almost 75%. Gujarat, Rajasthan, Maharashtra, Karnataka states are providing development in wind energy sector [**22**]. Major hindrance is the lack of continuous constant wind affecting power production. Noise plays a prominent role in case of wind energy as noises are obtained by gearbox, generator and turbine.

2.2.3 Tidal: During low and high tides in the sea energy available in water is obtained due to rise and fall of water. For producing maximum power through tidal energy numerous sites are available such as Gulf of Kutch, Gulf of Cambay in Gujarat and Delta of Ganga in Sunderbans having potential of 1200MW, 700MW and 100MW. **[23]**

2.2.4 Biomass: Biomass is biological material derived from living organisms Total energy needs can be fulfilled up to 13% through biomass fuels. Biomass energy can be used through biogas, biodiesel, producer gas, vegetable oil and by burning biomass itself. 5000 million units or more of electricity can be generated by investing Rs 600crores every year providing yearly employment of 10 million men or more in rural areas **[24].** Biomass can be converted into suitable form of energy through different conversion technology.

2.3 Geothermal Energy: It is the thermal energy produced and stored inside the earth. Geothermal energy generates due to decay of radioactive isotopes of uranium, thorium and potassium. Geological survey of India estimates 10000MW potential of geothermal energy from 6.5% electricity generation potential around the world of geothermal energy playing a prominent role and leading contributor. Chandrasekharam estimates an installed capacity of 203 MW **[18, 19]**. As no fuels are combusted emissions while generating electricity are negligible. Geothermal power plants mostly re-inject used water back into the ground through wells instead of discharging the used water into surface waters thus preventing underground minerals or pollutants from being introduced.

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2.4 Geothermal Energy potential in India & its Utilisation: Dating back to the analysis done in the year 1988 regarding the status of geothermal energy resources and their utilization in India, certain important points came into picture, according to the research published by B.R.Moon & P.Dharam of Central Electricity Authority, barring one or two locations in India, the other geothermal sites are of low to intermediate temperature ranges, the sites of importance were Puga Valley, Parbati Valley, and the West Coast, analysis were carried out in these regions with the assistance of UNDP(United Nations Development Program).Besides the above stated locations exploratory drillings and survey was also carried out at certain other locations such as Tapovan in Alaknanda Valleys(UP), Salbardi in Narmada-Tapti basin(MP), Bhagirathi Valley(UP), Attri-Tarbola Area(Odisha), Lalsot-Toda Bhim Belt(Rajasthan).

Among these areas the Puga Valley was determined to have the best geothermal potential according to the Hot Spring Committee report of 1968, hot springs, hot pools, sulphur condensates and borax deposits were found in the area, a number of applications already existed in the puga valley such as space heating, extraction and refinement of salts, greenhouse cultivation was tried successfully utilizing the discharge from a geothermal well. Drilling was done up to a depth of 100meters where the temperature was ranging from 85-135 ^{0}C, studies indicated the presence of a deeper reservoir with temperature of at least 220^{0}C [**12**]**.** Setting up a power plant of 0.5-1 MW by drilling a shallow reservoir was also proposed.

Other places of interest included the space-heating of tourist huts in Kasol, in Parbati Valley of Himachal Pradesh; hot water was used for bathing purposes using geothermal application. Geophysical Surveys in the west coast, found no significant conductive zones at deeper levels, therefore the usage was restricted to hot baths and other religious purposes. Due to financial constraints, the investigations were not carried out to the full extent in many regions, however the Puga Valley and Alaknanda Valley showed good promise as geothermal areas which also has its own set of problems such as Puga Valley which is located at an altitude of 4400 meters, and is scarcely populated, it has a short working season of 5 to 6 summer months.

India has a geothermal potential of 10,600 MW. According to the Geothermal Atlas of India created by the Geological Survey of India, our country has a total of 340 hot springs, out of which 20 hot springs are in J & K alone, and at least 7 key geothermal provinces of India. These hot springs can be seen in the lesser/central Himalaya, the Kashmir valley and the high Himalaya region, and at least three localities in the Ladakh region are estimated to have a geothermal power potential of 3 to 20 MW. One of the main geothermal activated area is the Puga Valley, previous researches have highlighted the potential of this region but challenges faced by this area is that it is located at a higher altitude, the population is scarce and geophysical surveys indicate the presence of an active magmatic system, 34 wells have been drilled in the Puga Valley region, out of 17 wells have faced mixed steam and water blowouts **[13].** The main problem faced by the people of Jammu and Kashmir is the shortage of electricity and power failure especially in the mountainous region of Ladakh, during the winter season most of the hydro-power stations are either shut down or work with reduced efficiency. It was estimated that more than 5000 MW of energy can be generated from the Puga region which can be used for greenhouse cultivation, heating and also in the generation of electricity which can solve a lot of problems in the state.

The Cambay Graben is one of the known geothermal provinces in the Gujarat state in Western India [**14**]. The Chabsar Valley is located at the base of the Cambay Basin. At a depth of 3.5km below the earth's surface temperature ranges between 100 and 150^{0}C had been recorded in the area. To understand the geoelectric structure as well as the presence of hot water springs at different location of Chabsar, Magnetotelluric (MT) investigations have been carried out at Chabsar which is located at a distance of 50km southwest of Ahmedabad, at 24 sites with an inter site spacing of 1.5 km. The good quality high frequency MT data has been acquired to better resolve the image of shallow subsurface of the region. In view of the large heat flow values of waters entering into the Cambay basin, we infer that the zone is presumably filled with fluids which may have a heat source at deeper levels.

Dholera, located in the state of Gujarat, is one of the potential geothermal areas in India. Although it is potentially sound as a geothermal site, the scarcity of water continues to be a major problem in the area [**15**]. With less surface water resources and limited freshwater supply from the Narmada Canal due to government norms, need arouses for the demand of freshwater to be utilized for residential and industrial purposes, therefore this lead to the testing of groundwater that was found below the surface in the aquifers. Dholera has a low enthalpy geothermal reservoir[**16]** along with the presence of hot water wells and hot springs which can be utilized by industries and other applications such as geothermal space heating & cooling**[17],** which will decrease the demand for electricity. The analysis of water chemistry or the presence of different metals or ions in the water content was also done to check whether this water is consumable or not. This research was also conducted to analyze the suitability of water for irrigation, aquaculture and other direct applications. This study has proved beneficial in the reliable management of water sources as well as reducing pollution related problems**.**

Parameters like Sodium Adsorption Ratio (SAR) and Na % were calculated, the high sodium content signified that

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groundwater was unfit to be used for irrigation purposes, cannot be used in industrial use as well. Results of the chemical analysis suggest that seawater content in the aquifers, as the Gulf of Khambhat is located nearby this region. This further implied the non-utilization of groundwater for irrigations and industrial applications. Apart from generating geothermal power in the area, certain desalination activities should be implemented in the region**.**

2.5 Geothermal Power Plants in India:- Present & Future Status: Indian states Gujarat, Chhattisgarh, Andhra Pradesh and West Bengal are the first states to set up geothermal power plants targeting power capacity in the range of 3MW to 5MW. Exploratory & Preparatory work has been started with the assistance of National Thermal Power Corporation (NTPC). The company had also been in talks with ONGC (Oil & Natural Gas Corporation) and other international organizations to discuss drilling operations.

According to India Energy Portal India is said to have a geothermal potential of 10,000MW. The Tattapani geothermal field is the most promising geothermal resource in central India according to governmental reports. The Tattapani resource has been an area of research and investigation since many years in India. India had been one of the frontrunners in the development of geothermal units in the early 1970s and 80s, but recently not many investigations has been in progress. Thermax, a capital goods manufacturer based in Pune, has entered an agreement with Icelandic firm Reykjavík Geothermal in the year 2014. Thermax is planning to set up a 3 MW pilot project in Puga Valley, Ladakh (Jammu & Kashmir). Reykjavík Geothermal will assist Thermax in exploration and drilling of the site.

The start for drilling of explaratory bore will soon be started by the assistance of NTPC in the Tattapani Geothermal reservoir located in the Balaram District of Chattisgarh For resource assessment of geothermal reservoir at Tatapani, measurement of geological parameters like Magneto-telluric studies, DRS studies are also in progress. The Project work had been undertaken by Chhattisgarh Renewable Energy Development Agency (CREDA) in association with Geological Survey of India and National Geographic Research Institute, Hyderabad. In its quest to increase its renewable energy portfolio, India proposes to harness 10,000 MW (10 GW) of geothermal energy by 2030 through active international collaboration with countries such as the US, Philippines, Mexico and New Zealand. India had agreed for active collaboration with countries such as New Zealand, Philippines and Mexico to harness 10,000 MW of Geothermal Energy by 2030. A draft policy has been prepared by the Gujarat Government regarding the geothermal norms in the country, according to the norms, geothermal energy will have to make an important contribution towards energy supply in India in the long run by developing a sustainable and environmentally safe energy industry, thereby creating ample of employment opportunities. The target is to produce 1000MW of geothermal energy by 2022 and 10000 MW by 2030.India is at nascent stage in terms of exploitation of geothermal energy, primarily because coal is cheaper. But with increasing environmental problems associated with coal based projects, India is now also looking at developing clean and eco-friendly energy sources. Coal is easily available in or country and also it is cheaper, that is the main reason for harnessing conventional methods rather than going for non-conventional methods. But with the increasing environmental restrictions from the government our country is slowly progressing towards renewable sources, even the renewable energy sector has made interesting developments in the recent years. The central government has been assisting and actively conducting research in geothermal energy for over two decades. Systematic efforts to explore geothermal energy resources first commenced in India in 1973 and several promising sites were finalized. Some of these are Cambay Graben in Gujarat, Puga and Chhumathang in Jammu and Kashmir, Tattapani in Chhattisgarh, Manikaran in Himachal Pradesh, Ratnagiri in Maharashtra and Rajgir in Bihar.Gujarat, Chhattisgarh, Andhra Pradesh and West Bengal are the first Indian states that had planned to build geothermal power plants with capacities ranging from 3 MW to 5 MW.

A modify Rankine power cycle utilizing a combination of ocean thermal energy and geothermal waste energy has been proposed in a recent study and it is known as a GeOTEC (Geo-Ocean Thermal Energy conversion) power cycle.

Closed cycle systems can be divided into organic Rankine cycle (ORC) and absorption power cycle **[25].** A research work by Wei et al. showed that ORC operates best in higher grade heat source of heating temperatures between 280^{0}C and 300^{0}C **[26].** Efforts to increase the temperature difference between the hot source and cold sink would lead to a better plant performance and higher cycle efficiency.

OTEC technology generates electricity by utilizing natural thermal energy found within the ocean **[27].** OTEC power cycle uses the temperature difference between warmer surface seawater and cold deep seawater to produce electricity. Surface sea water between 100 and 200 meters depth have a temperature range between 25 to 30^{0}C: Cooler deep sea water found beyond 600 m depth ranges between 3 to 5^{0}C, which yield a temperature difference of 10 to 25^{0}C with higher differences occur in tropical and equatorial waters **[28-33].**

In 1881, J. D'Arsenoval, a French scientist, developed OTEC technology [**34**]. In 1930, his student, G. Claude was the first to build a simple experimental OTEC power plant of 22 kW in Cuba **[35].** From this significant effort, scientists

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began to show interests in OTEC, and some designs of OTEC power plants were developed and run experimentally.

In 2002, a floating 1MW OTEC plant known as Sagar Shakthi was built by the National Institute of Ocean Technology in corporation with Saga University Japan in India**. [36]**

Another alternative and innovative way to improve the cycle efficiency has been proposed by Yamada et al. and Kim et al., by using an external heat source to increase the temperature difference. Yamada et al. proposed an addition of solar collector into the OTEC cycle. Yamada et al. concluded that the addition of external heat source by solar collector enhanced OTEC thermal efficiency by 2.7 times higher compared to that of conventional OTEC operation. [**37]**

2.5.1. GeOTEC power system description: The proposed GeOTEC power cycle utilizes both energy sources from warm seawater and raw natural gas from offshore gas production platform. Warm seawater is pumped into the evaporator to evaporate ammonia as the working fluid into a saturated vapour. The geothermal waste energy is used in GeOTEC cycle to superheat the saturated ammonia vapour before it enters the turbine to generate electricity. The turbine exhaust gases enter the condenser to be cooled by cold deep seawater and condensed back into liquid ammonia. The schematic of GeOTEC power cycle which includes geothermal water heating system (GWHS), heat exchanger, Geothermal super heater, evaporator, turbine, condenser, and pumps is shown in Fig. 1 **[38]**

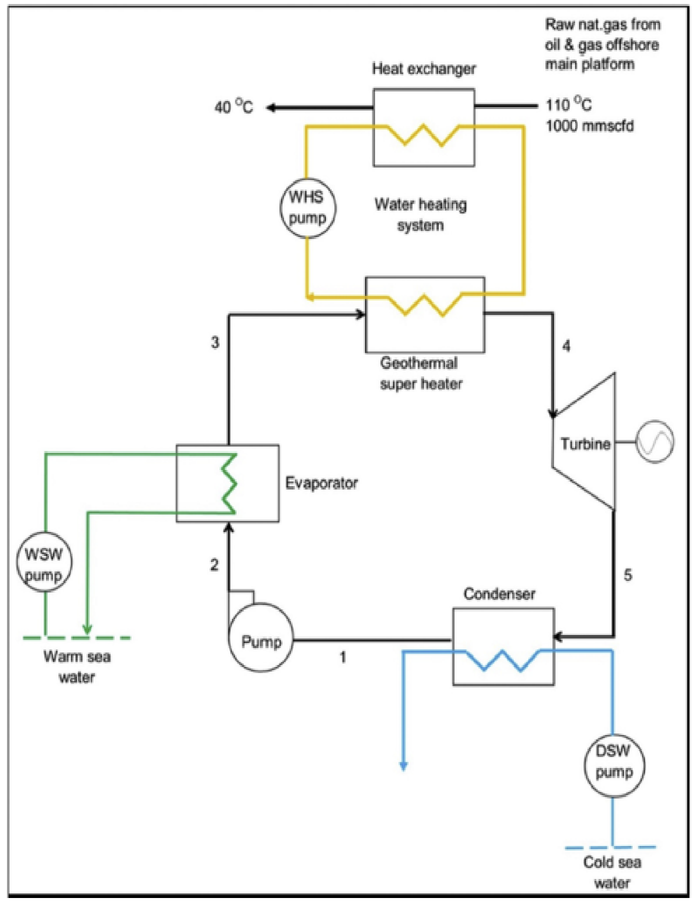

Figure 1. Schematic diagram of GeoTec Power Cycle [38]

3. Conclusions

This paper presents some prominent reviews and research done on various geothermal fields in India, where does India stand in the global power scenario and the various renewable energy potential that our country possesses. India is a tropical country and based on its climatic conditions and topography, it has Geothermal active areas, these areas had been identified decades before, but India is still at a budding stage on geothermal development. Solar and Wind energy extraction has already been started in various areas and geothermal power projects has already been initiated and are currently in their early development stages. The state of Gujarat had drafted a policy on geothermal energy which enlists the use and need of geothermal energy and the contribution of this source in fulfilling the energy requirements of our country. A step towards this source of energy extraction is not only fulfilling the country's energy requirement, but also creating a healthy environment, ample of employment opportunities, and preparing our nation to be energy independent. The recent developments in setting up of geothermal power plants in the nation for energy extraction have also been discussed**.**

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