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# Geothermal Power Generation Possibility and Geothermal Sites in Bangladesh: A Review

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**Abstract:** Being a developing country, Bangladesh has to meet the huge energy demand for her massive population giving only 63% of total population the access to electricity. Due to her limited non-renewable energy resources like coal, oil, and others, she need to face the challenge looking forward to the scope for the renewable energy resources where Geothermal energy can be a good choice. According to the geographical position of Bangladesh, the north-western part has some potential sites for installation of geothermal power plants. Most of the analysis shows that the large geothermal gradient makes the regions like Barakupuria of Dinajpur district and Thakurgaon of Rangpur division the most favorable placefor extracting geothermal power. The Singra sub district of Bogra region is also favorable and the other parts are scattered in different parts of Bangladesh like Shitakund, Sylhet, Mymensingh, Panba, and Faridpur. Herewith, it is suggested in this paper that to meet the huge energy demand predicted by BPDB, it is high time for Bangladesh to look forward to install geothermal power plants to meet the huge energy demand for the upcoming days.

**Keywords:** *Geothermal energy; Geothermal sites; Bangladesh; Thermal gradient; BPDB*

**Introduction:** Bangladesh is a developing country with a huge energy demand. Electricity is a must for the recent development of Bangladesh. Electricity connection is available among only 10% of the rural households and it is predicted that some parts of Bangladesh which will not get the taste of electricity from the national grid within next 30 years [1]. Presently, 53% of the public sectors and 47% of the private sector organizations produce electricity in Bangladesh [2]. To meet the high demand, maximum 2087 MW generation in 1995-1996, which increased to 4037 MW in in next decade and could not remove power crisis in the country [3-4].

The power plants operating at this moment in Bangladesh make environmental pollution. In the recent days, biogas is a new technology and as Bangladesh is an agro-based country, it produces huge waste materials. A survey reports that 3,054 ton of wastes per day is expected to be collected in 2015 and cumulative disposal is about 9 million tones by the end of that year [5-6]. Energy resources like solar, wind etc. are also renewable but none of them gives much advantages. Each of them has some limitations. For example solar energy depends on sunshine, wind energy depends on air flow, and hydroelectric power causes lower flow rate of down rivers as we use dams, which is very harmful for our agriculture. So we need a safer but powerful renewable energy source where geothermal energy can play an important role.

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'Geo' is the term which means earth and 'Thermal' indicates something that is associated with heat. Geothermal means something that is related to earth heat or temperature. There are pores and fractures in the earth crust which contains heated rock sand fluid. The geothermal energy is originated in the deep of earth by radioactive decay, which exists as hot water, steam or hot rocks. It can also be called 'earth's energy' [7]. The power produced by this energy is called geothermal power [8]. It is energy with no limitation. Nonetheless, it causes no harm to the earth environment. Geothermal energy is used in bathing and cooking from the primitive age. In bath houses Romans used heated water by the earth [9]. Prince Conti tested the very first geothermal based power generator on July 4, 1904 in Larderello subdivision, Italy. As an experiment four bulbs were tested to be enlightened with the help of the geothermal based power generator. The very first geothermal power plant was installed in Italy in 1911[10].

**Geothermal power plant:** The power plant which is basically produces electricity using Geothermal Energy is called geothermal power plant. In a thermal power plant coal, natural gas is used as fuel whereas in geothermal power plant we use heat contained in the earth. Basically every geothermal plant is constructed to deliver sufficient steam to the turbine for generating electricity. So the primary target is to turn the turbine blades which can be done by various methods. The classification of geothermal power plants was done according to the fuel and thermodynamic cycle used. There are three types of geothermal power plants [11].

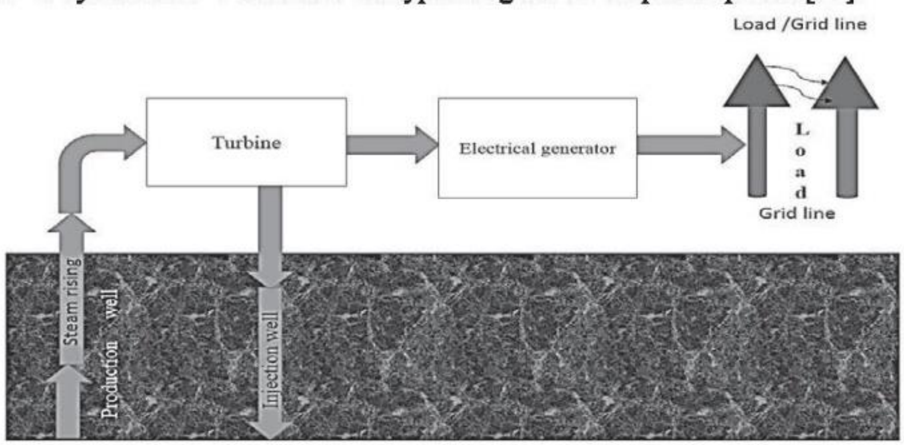



**Fig. 1:** Dry steam power plant

**Dry steam power plant:** This is the simplest and oldest designed power plant. Geothermal steam of 150°C or greater temperature is used here to turn turbines [12]. There are two wells drilled in the surface. One for steam rising and another for injecting water. This injected water come in contact with the solid rocks which contain high temperature and produce steam. Then it is pumped through the production well. Because of repeated injecting water, the shortage of water in the surface is recovered. Fig. 1 depicts the working of a dry steam power plant.

**Flash steam power plant:** Deep and hot water in high-pressure is pulled into the lower-pressure tanks by flash steam stations to drive turbines. Minimum temperature requirement is 180°C, or usually more [13-14]. Flashed steam drive turbines for generation of electricity. This is the most common type of station in operation around pacific ring of fire today. This plant is more effective than the previous one.

**Binary cycle power plant:** Binary cycle power plant transfers the heat to an organic fluid and then produces vapor to generate electricity. It can work on low temperature of geothermal fluid. As the working fluid is vapored in lower temperature than the steam's temperature, that is coming from production well. So there is always sufficient amount of steam of fluid to rotate the turbine. The steam is recovered again in heat exchanger. Fig. 2 shows a binary cycle power plant where a heat exchanger is used between the injections well and the production well [15].

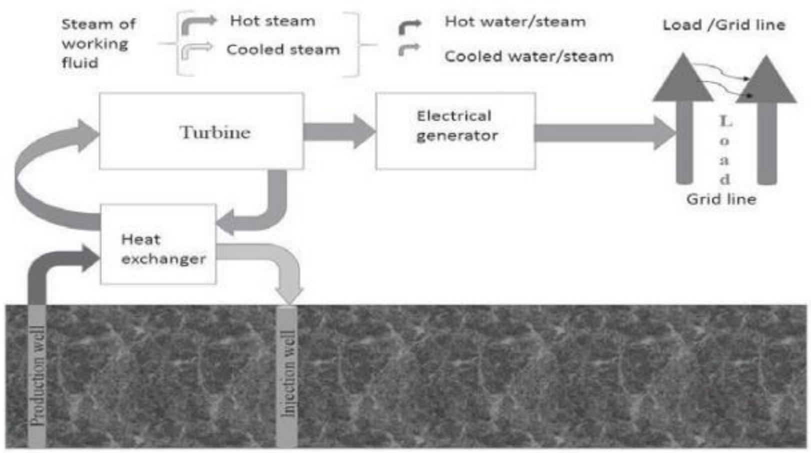
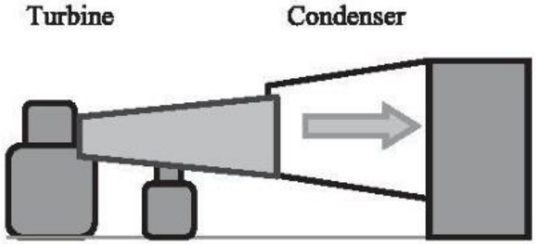



**Fig. 2:** Binary cycle power plant

The typical efficiency of a binary power plant is 10 – 13% [16]. Efficiency gets higher with the increase of temperature (around $180^0$) and gets lower with the decrease of temperature. It is the most developed geothermal power plant now. When the reservoir temperature is more than $220^0$ C and reservoir fluid is water or steam flash system or combined, binary and flash system can be used. When the reservoir temperature is between $100^0$ C -$220^0$C and reservoir fluid is water then Binary cycle is better. When the reservoir temperature is between $50^0$-$150^0$ C, water fluid, it is easy for direct use not for power generation. However binary cycle can be applied [17].

**Turbine and condenser combination:** Till now there are various processes to turn the turbine blades. But the road for electricity generation at a profitable quantity is still so far. While using long and large blade in turbines, it is found that a single flow turbine enhance the performance but makes the system more complex than a double flow turbine facility. In 2016 it is found that 'Combination of axial flow turbine and direct-contact condenser' shows highest speed of the turbine around 3600 rpm and a better exhaust direction [18]. Fig. 3 shows the combination of axial with surface condenser whereas Fig. 4 illustrates an axial with direct contact condenser.



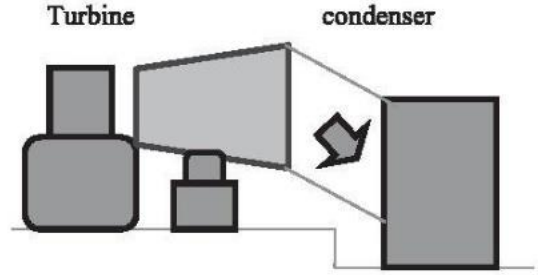




**Fig. 3:** Axial with surface condenser

**Fig. 4:** Axial with direct contact

**Efficiency of geothermal power plants:** Geothermal power engineering is flourishing now days. From 2010 to 2015 the installed capacity increased by 73% [19]. Though geothermal power plants have a lower efficiency compared with the Coal fired power stations, Natural fired power stations, Oil Fired Power Station and Nuclear power stations [20].

Table 1 shows the efficiency for different power plants and Fig. 5 shows the relative comparison among their efficiency [21]. Some researches indicates that only 10% of the energy produced from geothermal fluids are transferred as electric energy [22] whereas other thesis shows it may vary from 10-17% [23]. Though, the efficiency varies from country to country [24-25] like China and Indonesia [26-27] which are 1% and 20.7% accordingly.

**Table 1.** Efficiencies of different power stations

| Sl | Power Plants | Fuel | Efficiency (%) |
|---|---|---|---|
| 1 | Geothermal Power Station | Geothermal heat | 12 |
| 2 | Coal Fired Power Plant | Coal | 33 |
| 3 | Natural Fired Gas Power Plant | Natural gas | 39 |
| 4 | Oil Fired Power Plant | Oil | 37 |
| 5 | Nuclear Power Plant | Uranium | 32 |

The efficiency also depends on whether it is single flash [28] or double flash [29]. Different factors affects the conversion efficiency of geothermal power plants like Heat loss from different equipment, the gases which are non-condensable, efficiency of generator, parasitic loads of power plants like different exhaust fans, pumps , gas and fluid extraction system etc. [30-35]. Among all the factors, the non-condensable gas has most severe effect on the performance of turbine [36-38]. Hyungsul et al. [39] wrote a review on efficiency of all the geothermal plants worldwide and concluded that the overall efficiency is 12%.

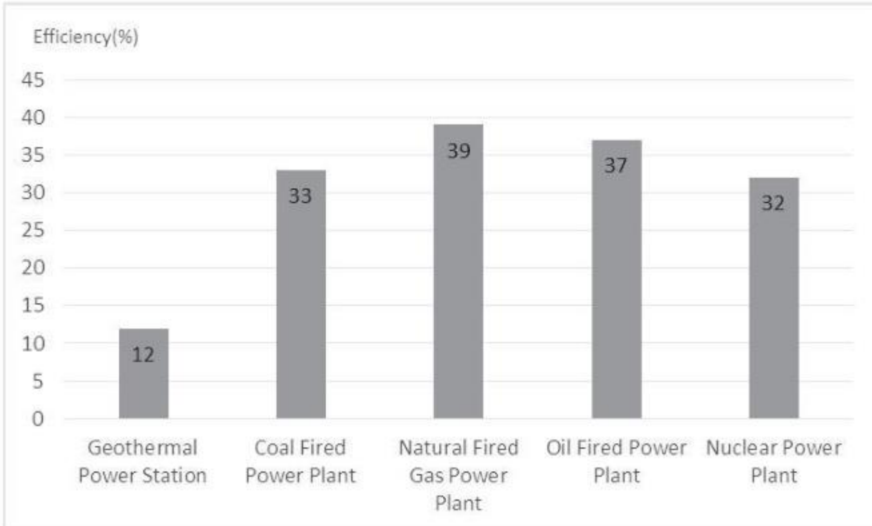



**Fig 5:** Comparison of efficiency of geothermal power plants and other type of power plants

**Environmental effects of geothermal power plants:** Geothermal energy was introduced at the beginning of 20th century in Lardello, Italy [40]. At present, the installed capacity of geothermal plants there is 882.5 MWe [41]. Some studies states that geothermal energy has less environmental effect than most other energy resources [42-43] though some study says that the emission of $CO_2$ from the geothermal power plants are higher than others [44] which can be balanced or reduced easily [45]. Bayer et al. says that sites influences for the environmental effect of geothermal power plants [46].

**Table 2.** Environmental impact of geothermal gases

| Sl No. | Impact Category | Unit | Geothermal Gases produced | Impact(Global/ Provincial) |
|---|---|---|---|---|
| 1 | Global Worming | Kg $CO_2$ equivalent | $CO_2$,$CH_4$,$N_2O$, $SF_6$,$CF_4$,$C_2F_6$ | Global |
| 2 | Acidification | Kg $SO_2$ equivalent | $SO_x$,$SO_2$,$NO_x$,$NO_2$,$NH_3$, HCl, HF, $H_2S$ | Provincial |
| 3 | Human Toxicity | Kg 1.4 DB equivalent | $SO_2$,$NO_x$, As, Pb, Mn, Hg, Ni, Se | Provincial |

Armannsson argued that the emissions of $CO_2$ from the geothermal plants are negligible [47]. Frondini proposed that geothermal liquids are more emitted than volcanic degassing in Mount Amiata area at Italy [48] but these problems has been solved by urgent removal [49]. At the starting of 21st century, mercury and Hydrogen sulphide emitted in a great amount in Italy [50]. Geothermal gases which are emitted from the power plants also contain arsenic (As), antimony

(Sb), mercury (Hg), selenium (Se) and chromium (Cr) and the geothermal gases has regional and global effect which are shown in Table 2 [51]. Their findings alsoagrees with Brown and Ulgiati who says that geothermal energy and fossil power plants produces same amount of $CO_2$ [52].

**Geothermal power generation around the globe:** Geothermal power is currently used in many countries even in developing countries including the neighboring country India. Generation of electricity using geothermal power is an emerging concept all around the world. Data in Table 3 shows rapid growth of geothermal power plant around the globe according to 'Annual U.S. and Global Geothermal Power Production Report', March 2016. Fig. 6 indicates the quantity in a graph. It shows that the planned capacity of the geothermal power plant is highest for Indonesia and second highest in U.S.A but the operating capacity is highest than all other countries.

**Table 3.** Operating and planned capacity of geothermal plants around the globe

| Country | Operating capacity | Planned capacity |
|---|---|---|
| Iceland | 0.665 | 0.575 |
| Indonesia | 1.375 | 4.013 |
| Japan | 0.533 | 0.057 |
| Mexico | 1.069 | 0.481 |
| Kenya | 0.607 | 1.091 |
| Philippines | 1.93 | 0.587 |
| Turkey | 0.637 | 1.153 |
| U.S.A | 3.5378 | 1.272 |
| New Zealand | 0.973 | 0.285 |
| Ethiopia | 0.008 | 0.987 |
| India | 0 | 0.098 |

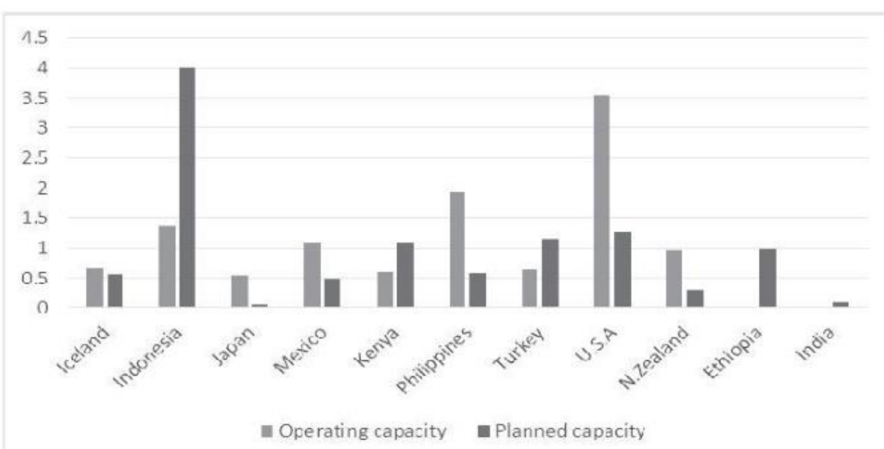



**Fig. 6:** Rapid growth of geothermal power plant around the globe

**Economic study of geothermal plant:** The economic study of the geothermal power plants from 2007 to 2021 is shown in Fig.7. It shows that the capacity is increasing exponentially every year. It's shown that in 2007 the plant capacity was lowest 9.731 Giga watts and it became 13.3 Giga watts in 2016. It's predicted that it will become 18.4 Giga watts in 2021[53].

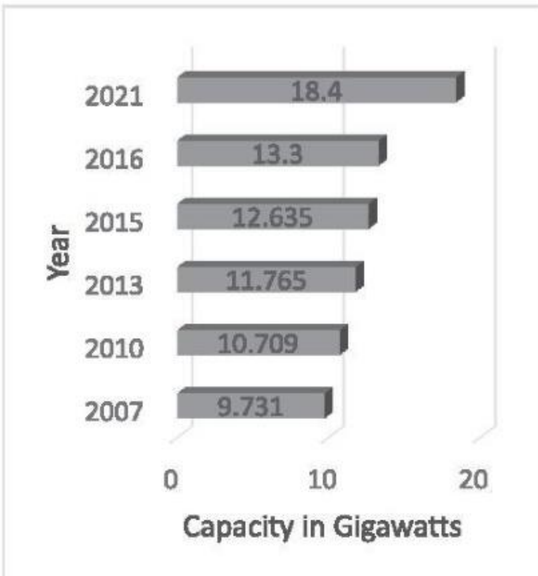



Fig. 7: International geothermal power production

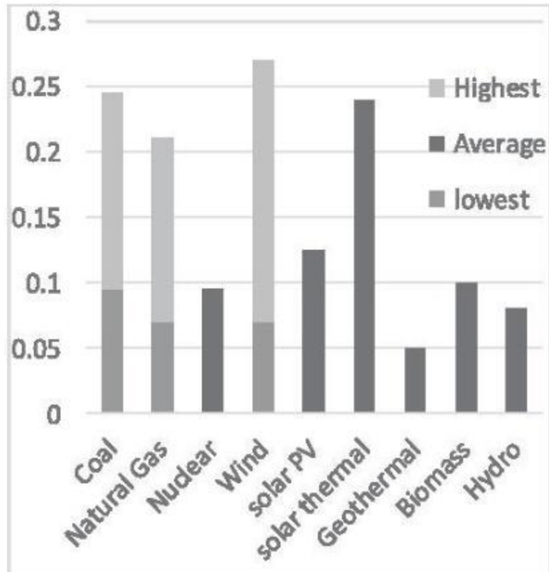



**Fig. 8:** Cost of different plant in $ per MWh

While considering a dual flash reasonable geothermal power plant of 50 MW, it may cost $88 per MWh. Up gradation can be made in its long life time, ensuring more efficiency as well as lower cost [54]. Fig. 8 shows the cost of different plant in USD per MWh.

**Present power generation capacity in perspective of Bangladesh:** Only 63% of population has the access to electricity till now and most of them are living in the rural areas and farmer by profession. So there is a random shortage of electricity considering some recent approved projects.

The Ministry of power and Energy, Bangladesh has been mobilizing BDT 400 billion to generate 5000 MW of electricity so that it can reduce load shedding into a tolerable level within next four and half years during the term of the present government. Fig. 9 shows the installed and derated capacity of Bangladesh Power Development Board (BPDB) power plants on March 2017 and Table 4 shows the relative data. Fig. 10 shows the installed capacity of different type of plant in Bangladesh [55].

**Table 4.** Installed and derated capacity of power plant s according to BPDB on March, 2017[55]

| Fuel Type | Installed Capacity(Unit) MW | Total (%) | Derated Capacity(Unit) | Total (%) |
|---|---|---|---|---|
| Coal | 250.00 | 1.9 % | 200.00 | 1.6 % |
| Oil | 0.00 | 0 % | 0.00 | 0 % |
| Naturtal Gas | 8267.00 | 62.97 % | 7844.00 | 62.61 % |
| HFO | 2800.00 | 21.33 % | 2743.00 | 21.89 % |
| HSD | 1032.00 | 7.86 % | 961.00 | 7.67 % |
| Hydro | 180.00 | 1.37 % | 180.00 | 1.44 % |
| Imported | 600.00 | 4.57 % | 600.00 | 4.79 % |
| Total | 13129.00 | 100 % | 12528.00 | 100 % |

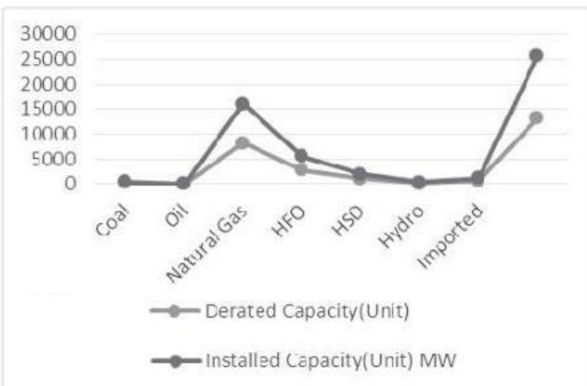



**Fig. 9:** Installed and derated capacity of BPDB power plants on March 2017

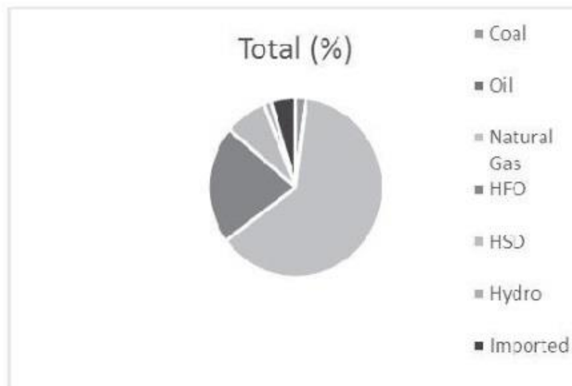



**Fig. 10:** Installed capacity of different type of plant in Bangladesh

**Present Scenario of Renewable Energy resources in Bangladesh:** Through rural household based solar energy, Bangladesh has 15 MW capacities and through wind power in Kutubdia and Feni she has 1.9 MW power generation capacity. It's estimated that Bangladesh will produce 10% by 2020 from renewable energy sources like wind, waste and solar energy. Solar energy is also a popular renewable resource which is clean, economical, and less polluted [56]. Though the efficiency is lower in fixed solar panels, an arrangement of LED sensors and camera can be used to increase efficiency [57]. But here the difficulty is the initial cost of the solar tracker. Solar is not economic for our atmosphere especially in rainy season. Remarkable progress isn't significant to increase the renewable energy resource capacity both in govt. and private sectors. Though govt. has introduced law, to form a big industry or project one must have the said amount of own power generation capacity including solar energy; investors avoid costly solar panels. Solar, wind, wave resources always depend on weather. Once a geothermal system is planted, the operating sustainable geothermal heat is always available. Geothermal power plant provides a primarily carbon free, secure and continuous source of energy. Besides it has one of the lowest leveled unit costs among many energy types.

**Favorable Geothermal Power plant sites in Bangladesh:** Bangladesh is located at the head of the Bay of Bengal. Two great rivers Padma and Brahmaputra form successive delta systems. Because of collision with the northward wandering Indian plate, the Himalayan mountain ranges were uplifted. In Bangladesh, Indian platform is subdivided into four parts [58] i.e. The Dinajpur Slope, The Rangpur Saddle, The Bogra Slope, and The Hinge Line.

**Table 5.** Possible Geothermal sites recommended by Guha et al. [59]

| Sl | Divisions | Subdivisions | Comments |
|---|---|---|---|
| 1 | Sub-Himalayan Foredeep | • Salbanhat<br>• Panchagarh District<br>• Northern Slope of Rangpur Saddle | • Relatively low thermal gradients<br>• Barely feasible |
| 2 | Rangpur Saddle and the Garo – Rajmahal Gap | • Rangpur District<br>• Dinajpur District<br>• Malda<br>• Western part of the Rangpur Saddle<br>• Barakupuria<br>• Thakurgaon | • High surface Temperatures<br>• Reasonable drilling depth |
| 3 | Bogra slope | • Singra<br>• Kuchma<br>• Bogra | • Potentially favorable |
| 4 | Deep Sedimentary Basin | • Sylhet<br>• Mymensingh<br>• Panba<br>• Faridpur Trough<br>• Barisal<br>• Chandpur High<br>• Madhupur | • Loaded with cool sediments<br>• Geothermal gradients are very low.<br>• Barely feasible |
| 5 | Folded Belt | • Sitakund-5 | • Geothermal Gradients relatively high<br>• Feasible |

Guha et al [59] divided the geographical area of Bangladesh in four divisions and analyzed their special features which are shown in Table 5. They divided the geological map of Bangladesh in five different divisions named sub-Himalayan Foredeep, Rangpur Saddle and the Garo – Rajmahal Gap, Bogra slope, Deep Sedimentary Basin, ands Folded Belt. They also subdivided the zones in subdivision. Sub-Himalayan Foredeep has relatively low thermal gradients and is not feasible for geothermal power generation. The Rangpur Saddle and the Garo -Rajmahal Gap has huge potential for geothermal power generation because Northern Slope of Rangpur Saddle has been included in the Himalayan Foredeep [60]. Thakurgaon region also offers good opportunity for installation of Geo power plant because warm water up to 36 $^{0}$C has been observed in irrigation wells at depth of 80 meters [61]. Barakupuria coal mine situated at Dinajpur district of Bangladesh has a temperature of 50 $^0$C at the depth of 400 m. The High surface Temperatures can lead to a reasonable drilling depth for geothermal power plant.The change of temperature per kilometer in the term of geology is called geothermal gradient. With the assumption of a linear increase in temperature with depth, temperature of any depth can be measured.

$$T_z = T_g \times \frac{z}{1000} \qquad \text{eq.1}$$

Equation 1 signifies the relationship between the Temperature gradient and bottom hole temperature. Where, $T_z$ is the bottom hole temperature at depth Z (meters).$T_0$ is a mean surface temperature and $T_g$ signifies the geothermal gradient $^0$C/Km [62]. Significant sites in Bangladesh with remarkable temperature gradient are shown in Table 6[63] which is depicted in Fig. 11.

**Table 6.** List of possible geothermal sites in Bangladesh with relative temperature gradient

| Sl | Favorable Sites | Gradient ($^0$C/km) | Remarks on Gradient |
|---|---|---|---|
| 1 | Kuchma | 28.5 | Medium |
| 2 | Salbahanhat | 20.8 | Lowest |
| 3 | Jaipurhat | 25 | Medium |
| 4 | Bogra | 29.5 | Medium |
| 5 | Singra | 34.1 | Higher |
| 6 | Madhyapara | 31.6 | Higher |
| 7 | Thakurgaon | 34.2 | Second Highest |
| 8 | Barapukuria | 48.7 | Highest |

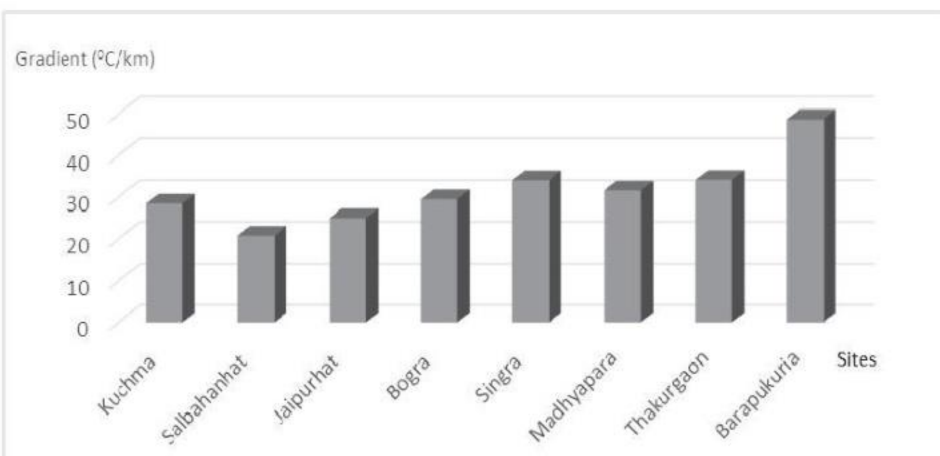



**Fig. 11:** Significant places in Bangladesh with remarkable temperature gradient

If Bangladesh builds a geothermal power plant here in Bangladesh for the very first time, she will become the 26th country in the world to use this source of renewable energy. According to Energy Anglo MGH, various northern districts of Bangladesh show favorable condition for exploitation of geothermal resources.

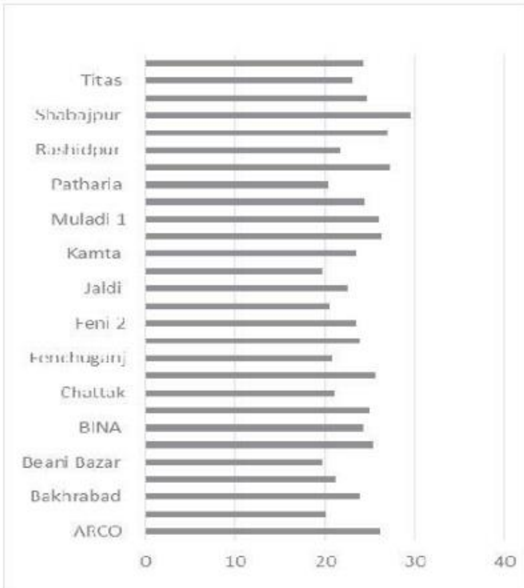



Fig. 12: Different well name versus gradient

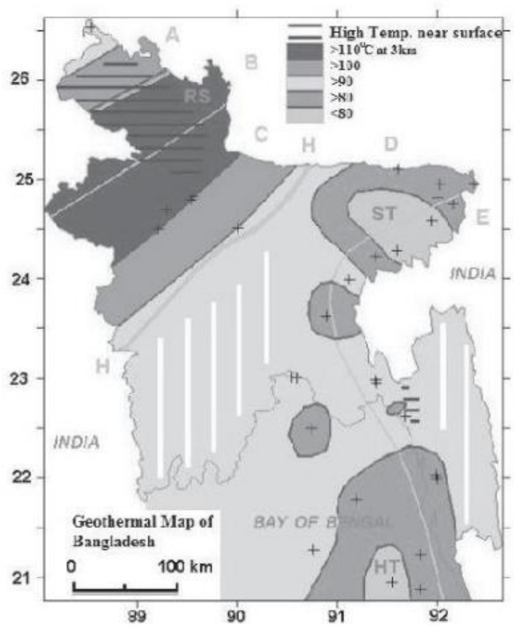



Fig. 13: Geothermal map of Bangladesh [59]

Subsequent research discovered high anomalous temperature gradient in some groundwater wells in some parts of the Thakurgaon and Dinajpur District area. Fig. 13 indicates the significant places in Bangladesh with remarkable temperature gradient [64]. Different well name versus gradient are shown in Fig.12 and geothermal map of Bangladesh is shown in Fig.13.

**Results and Discussion:** Bangladesh has already introduced with renewable energy however lately like the other countries. Among them geothermal power have high efficiency, weather independent, and safe for environment. When searching for geothermal power plant sites in Bangladesh, the Bogra slope embodies the southern part of the Rangpur district. Singra is a sub district of Natore and this place has also offers a good scope for geothermal power plant. The place is less favorable compared to the Dinajpur-Rangpur region. The other two regions Deep Sedimentary Basin and Folded Belt are scattered in different part of Bangladesh like Sylhet, Mymensingh, Panba, Faridpur Trough, Barisal, Chandpur High, Madhupur and they have relatively lower temperature gradient. So, these places should not be so much favorable for building geothermal power plant as the drilling cost will be high. Fig. 14 shows the favorable places for building Geothermal power plants in Bangladesh.

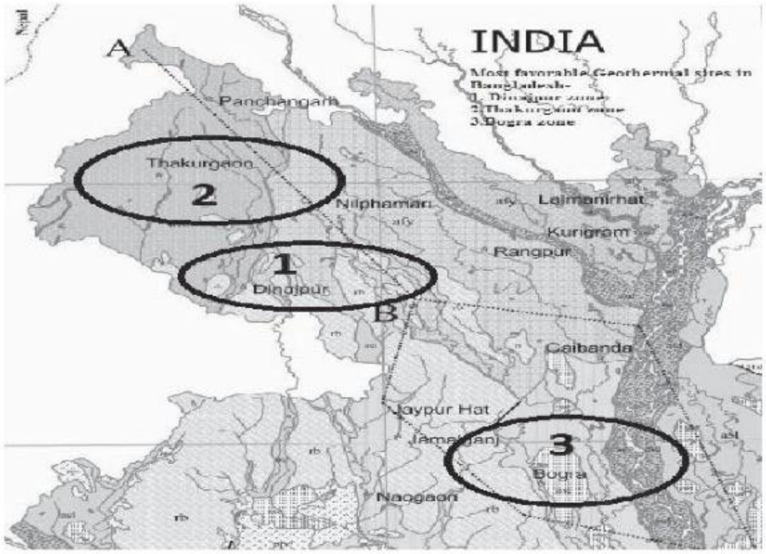



**Fig 14:** Most favorable Geographical sites in North Western part of Bangladesh [65]

When considering cost, it is about equal to natural gas based power plant but natural gas is a limited resource. However geothermal electric plant's production of 13.380 gram carbon dioxide per KWh while this emission are 453 gm./KWh for natural gas, 906 gm./KWh for oil and 1042 gm./KWh for coal [66].

**Conclusion:** As electricity generation scenario is very poor here in Bangladesh, geothermal power plant is a perfect solution to her for this time being with no doubt. Despite a lot of advantages, it's to say that geothermal power plants also produces small amount of $CO_2$ compared to other power plants but this problem can be overcome by proper maintenance and control which are stated clearly in this paper with necessary data analysis. All the things interrelated to geothermal power and power crisis in Bangladesh are tried to bring in one frame in this review paper and successfully it does. Bangladesh has remarkable gradient temperature in Boropukuria, Dinajpur and Thakurgaon district of Rangpur division. Geothermal power plant may have high drilling cost but in the long term it will be generating electricity at a low cost around to natural gas without harming the environment and causing no fear of resource limitation. The world is going after the earth's energy and so should we.

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