Geothermal energy resource utilization: Perspectives of the Uttarakhand Himalaya

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The developing world community is struggling with scarcity of power. Most of its power is derived from non-renewable conventional energy resources which are decreasing day by day. Therefore, presently renewable energy resource utilization is the best solution to combat this problem. Geothermal energy is one such renewable energy resource which is still unexplored. Besides, there are other potential applications of this energy resource waiting to be explored. It is second to none in its applicability and environment-friendly aspects when compared to other contemporary energy resources. In the present article, attempts have been made to describe the multi-dimensional utilization of geothermal energy resource as far as India or in particular, the Uttarakhand Himalaya is concerned. This remote region is India's most promising geothermal province. The present energy scenario in India needs special attention to explore geothermal energy.

Keywords: Geothermal energy, renewable energy resources, utilization.

TODAY, most of our energy is drawn from conventional non-renewable energy resources, i.e. coal, biomass and petroleum products. At present, coal alone accounts for about 70% of India's electricity supply[1], but it is not environment-friendly. The main culprit behind conventional non-renewable energy resources is the uncontrolled emission of CO_2 which leads to global climate change. Recently, on the topic of global climate change[2], the G8 leaders agreed on the need for the world to cut carbon emissions by at least 50% by 2050. Environmental activists and leaders from the developing countries called it a 'toothless gesture'. Blind use of coal, biomass and petrochemicals leads to greater pressure on the earth's carrying capacity. Efforts are on in this respect; priorities are being given to such alternative options which are environment-friendly, economically viable, renewable and have vast practical functions. One such deserving and potential but quite unrecognized energy resource in India is geothermal energy, which needs to be explored for our common energy requirement. It is a clean energy source as it does not emit carbon or produce other harmful by-products. Extensive research in this respect showed it as having a good prospect for energy security with outstanding long-term potential[3].

The Geological Survey of India (GSI) in collaboration with UN organization explored[4] the geothermal provinces of India in the 1970s. The Himalayan province among others, constitutes high-temperature geothermal springs. Uttarakhand Himalaya is part of the Central Indian Himalaya which is endowed with a vast majority of geothermal springs, which contain medium to high enthalpy water that could prove to be a potential resource for various applications. Keeping the Uttarakhand Himalayan region in view, the present article sheds light on geothermal resource utilization, its availability and future prospects.

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Geothermal: The untamed energy resource

Geothermal (Greek: *geo* means earth and *therme* means heat) energy is the heat within the earth. This energy can be used to produce electricity, to heat buildings and to provide hot water for various purposes. There exists a considerable temperature gradient inside the earth which is found to be quite high in some geographical locations. Deep subterranean faults and cracks allow rainwater and snowmelt to seep underground. This water is heated by the hot rock and forms a geothermal reservoir beneath the earth. It circulates back up to the earth's surface and forms geothermal springs, geysers or fumaroles. Beside the natural geothermal springs, artificial ones can also be made by exploratory drilling. It is a common approach to search for geothermal gradients and reservoirs where natural geothermal springs are not found. High-temperature gradient exists in certain geographic locations on the earth, i.e. Ring of Fire area which surrounds the Pacific Ocean. India has about 400 medium to high-enthalpy geothermal springs, clustered in seven provinces. The most promising provinces are the Himalaya, Sohana, Camby, Son–Narmada–Tapi (SONATA) and the Godavari[5]. In India, a powerful geothermal gradient exists in the whole of the Indian Himalayan belt along the Main Central Thrust (MCT) and therefore the Uttarakhand Himalaya region is rich with high-temperature geothermal springs. The whole of the Himalayan region falls in the Indo-Eurasian plate boundary, which is a tectonically active zone. High temperature gradient in this region is due to Post-Tertiary granite intrusive.

Taming the untamed

Electricity production

Hot water or steam tapped from geothermal springs or exploratory drill holes (usually 121–371°C) can be used for electricity production. In such a power-generation system, hot water and steam obtained from geothermal reservoir is used to spin turbines to generate electricity. Various approaches used to generate electricity are as follows:

Flashed steam plant: The extremely hot water from drill holes when released from the deep reservoirs high pressure steam (termed as flashed steam) is released. This force of steam is used to rotate turbines. The steam gets condensed and is converted into water again, which is returned to the reservoir. Flashed steam plants are widely distributed throughout the world.

Dry steam plant: Usually geysers are the main source of dry steam. Those geothermal reservoirs which mostly produce steam and little water are used in electricity production systems. As steam from the reservoir shoots out, it is used to rotate a turbine, after sending the steam through a rock-catcher. The rock-catcher protects the turbine from rocks which come along with the steam.

Binary power plant: In this type of power plant, the geothermal water is passed through a heat exchanger where its heat is transferred to a secondary liquid, namely isobutene, isopentane or ammonia–water mixture[6] present in an adjacent, separate pipe. Due to this double-liquid heat exchanger system, it is called a binary power plant. The secondary liquid which is also called as working fluid, should have lower boiling point than water. It turns into vapour on getting required heat from the hot water. The vapour from the working fluid is used to rotate turbines. The binary system is therefore useful in geothermal reservoirs which are relatively low in temperature gradient. Since the system is a completely closed one, there is minimum chance of heat loss. Hot water is immediately recycled back into the reservoir. The working fluid is also condensed back to the liquid and used over and over again.

Hybrid power plant: Some geothermal fields produce boiling water as well as steam, which are also used in power generation. In this system of power generation, the flashed and binary systems are combined to make use of both steam and hot water. Efficiency of hybrid power plants is however less than that of the dry steam plants.

All the above-mentioned power plants are practically possible and are a part of the electricity generating system around the world. The United States is generating more geothermal electricity than any other country in the world, but the amount it generates is less than 1% of its total electricity production. Four states in the US have functional geothermal power plants: California (33 power plants), Nevada (15 power plants), Hawaii (one power plant) and Utah (one power plant). The Geysers', dry steam reservoir in northern California has been producing electricity since 1960. It is the largest known dry steam field in the world. The hybrid power plant provides about 25% of electricity to the island of Hawaii. Today, the total installed capacity of geothermal power plants in the US is almost 3000 MW. The total installed capacity from worldwide geothermal power plants[7] has reached up to 9732 MW in 2007, from 1300 MW in 1975. It is expected that this 9.7 GW installed capacity will increase up to 11 GW in 2010.

In India, the first 5 kW binary pilot power plant using R-113 binary fluid has been successfully constructed and operated by the GSI. Five 6 inches diameter production wells to commission a 3.17 MW pilot power plant have also been drilled at Tattapani, SONATA province by the GSI. However, the power plant is yet to be constructed. The geothermal reservoir has been reported at a depth of 2.5 km at Bugga and Manuguru thermal areas in Godavari province. It has been estimated that 38 MW power can be generated from this province[8]. Three exploratory drill holes have been put over a stretch of about 3 km upstream along the Dhauliganga river near the Tapoban geothermal spring. They are discharging hot water in the temperature range of 65–90°C. Besides, a thermal spring near Yamnotri shrine is discharging about 88–90°C hot water. A binary power plant can be constructed using this hot water. No further action has been taken to commission power plants till today by the government or private sector at any of the sites.

Other non-electrical uses

If the geothermal reservoir is either shallow or has low temperature, then it can be used for various other purposes, i.e. aquaculture, greenhouses, health spas, space or building heating, bathing, tourism or other activities involving low-temperature water. The related aspects are discussed in the following:

Aquaculture: High-altitude Trans Himalaya habitats come under the temperate region. Cold-water fishes (snow trouts, e.g. *Schizothorax* spp., *Mahseer* spp. and *Gliptothoroax* spp.) are mostly found in such habitats. It has been noticed that the success of cold-water fisheries is relatively lower than the tropical fisheries[9]. Therefore, to

Figure 1. Thermal springs of Tapoban geothermal area: (***a***) Soldhar (91°C) and (***b***) Ringigad (80°C).

meet the growing demand of fish food, tropical fish farming in such cold regions is a promising option. However, average low ambient temperature and high wind velocity create a harsh environmental condition for tropical fishes to be introduced. The geothermal water can therefore be used to heat the aquaculture pond. The optimum temperature can be accomplished using solenoid valves operated by means of temperature controllers. The valves are normally closed, but are actuated when the temperature sensors indicate that the water temperature in the pond has dropped below the optimum. The solenoid is opened to allow geothermal water into the distribution system until the pond temperature reaches an optimum value, and the valve is automatically closed again. The water level in the pond can be regulated by means of a sluice box or overflow pipe.

It is important to know the chemical composition of the hot-spring water and soil before using it as pond water. The data obtained would be helpful to predict whether or not the geothermal water should be used in the aquaculture pond. Other options can be used if the water is of inferior quality or with harmful chemicals (i.e. Ar, B, F, Hg, etc.). Utilization of heat-exchanger system is a better option in this regard. Another important factor is the dissolved oxygen (DO). An aerator is often used to keep the required DO in the pond eater. It is also important to understand the actual stage and stocking density of the larva to be introduced in the pond. Apart from hatchery, other requirements are the suitable feed, storage area, a laboratory, a small brood tank set-up and medical kit to combat infection.

As far as the Uttarakhand Himalaya is concerned, there are numerous potential geothermal sites, namely Tapoban, Yamnotri, Gagnani, Badrinath, Garam Pani near Nainital, Kapkot and Gaurikund, which can be exploited for aquaculture (Figure 1). Establishing aquaculture for tropical fishes is an option to uplift the status of fish food in this remote area.

Building/residential area heating system: Residential area heating is also used throughout the world, but it is not popular in India. It is also called space heating system. Geothermal water, used in this heating system, is sent beneath the earth through pipes buried underground next to the individual building, commercial plaza or even entire community residential area. This system transfers heat from hot water into buildings in winter and can be injected back to the reservoir, where it is reheated and used again in the heating system.

It has vast applications at all the pilgrimage sites of Uttarakhand, where natural geothermal springs are found (Badrinath, Kedarnath and Yamunotri). This system can also be made available by exploratory drill holes at other pilgrimage sites which are devoid of natural geothermal springs. Space heating system has been successfully built-up by GSI in the Manikaran geothermal area.

Tourism and aesthetic value: Uttarakhand Himalaya is believed to be the abode of Hindu Gods and Goddesses and is known worldwide for pilgrimage and adventure tourism. Apart from Badrinath, Kedarnath, Gangotri and Yamunotri shrines, Uttarakhand Himalaya is endowed with high snow-clad peaks, glaciers, alpine grasslands, high-altitude lakes and dense forest. Millions of pilgrims and adventure tourists visit Garhwal Himalaya every year. Pilgrims usually consider these hot water springs as a holy place. Aesthetic value of geothermal springs put forth one of its important applications in tourism. Therefore, geothermal sites of Uttarakhand Himalaya may be developed to attract domestic as well as foreign tourists.

Bathing and cooking: It is the oldest and most common use of geothermal water. Geothermal springs of Trans Himalayan regions are used for bathing and cooking purposes. Eggs, potatoes and other food stuff such as rice are boiled directly in such high-temperature hot spring waters by under-privileged inhabitants. People also believe that the geothermal water has the capacity to treat eye or skin diseases. It is a popular practice in the upper reaches of Uttarakhand Himalaya. Therefore, they can be used as health spas. Community bathing systems as established in

Table 1. Characteristics of geothermal provinces of India[5]

Province	Surface temperature (°C)	Reservoir temperature (°C)	Heat flow (mW/m^2)	Thermal gradient (°C/km)
Himalaya	>90	260	468	100
Camby	40–90	150–175	80–93	70
West coast	46–72	102–137	75–129	47–59
SONATA	60–95	105–217	120–290	60–90
Godavari	50–60	175–215	93–104	60

Badrinath, Gaurikund and Tapoban geothermal areas, may also be developed over other geothermal sites.

Agriculture: Usually the cold ambient temperature, high wind velocity, foggy atmosphere and short day length are detrimental weather conditions for crop production. Hot spring water is used to warm greenhouses or even open fields to increase flower, vegetable or other Himalayan crop yields. Using geothermal water important medicinal and flowering plants may be grown in poly-houses.

Industry: Heat from geothermal water is used for drying fruits and vegetables, dying clothes, pasteurizing milk, drying timber products and manufacturing paper. It is also being used in the extraction process of gold and silver from ore. However, such practices are not feasible in the upper reaches of Uttarakhand Himalaya, since it is totally devoid of industries.

Research and development: Geothermal springs are excellent biotopes with controlled environmental conditions round the year, which can be useful for ecological and evolutionary studies. Hot-spring biodiversity is also a thrust area which is drawing attention of the scientific community worldwide. There are a number of by-products[10] which have been isolated from thermophilic microorganisms inhabiting geothermal springs. Research is being carried out on related aspects throughout the world. Geothermal systems also put forth possibilities for advanced studies on geology and geography-related problems. The Indian Institutes of Technology, GSI and some Indian universities are working on various aspects of geothermal energy.

Impediments and future prospects

Blind use of conventional non-renewable energy resources for short-term gain creates critical damage to the global environment. It is therefore important at this stage to explore non-conventional renewable energy resources of our country. The efficient use of geothermal energy maintains high environmental standards. It is a clean energy that does not emit any CO_2 and produce other harmful by-products. Because of its sustainability, it is as superior as solar and wind energy resources. As it is close to our reach it needs to be fully exploited.

Geothermal springs have been a part of our culture since ancient times. Recently, they have received significant attention worldwide for their potential in the field of electricity generation and other non-electrical uses. India has an enormous but completely ignored potential of non-conventional energy resources. It is surprising that even underdeveloped poor countries like Kenya (129 MW), Ethiopia (7 MW) and Papua New Guinea (56 MW) have shown some positive endeavour, but India is still avoiding geothermal power plants[7]. It has been estimated that India has the capacity to generate 10,600 MW of power using geothermal energy resources[11]. The geothermal characteristics of all the Indian provinces (Table 1) show that they may be exploited for different beneficial uses applying advanced technology. But why is such a large geothermal potential still unexplored? The possible answer lies in the availability of large recoverable coal reserves (about 192 billion tons) and a powerful coal lobby[5]. Inadequate government policies, available technology, construction cost and funding are some additional hurdles. It also needs enormous funding for research and development. Firm decisions should be taken keeping in view the long-term interest of the nation and policies should be made by the Ministry of New and Renewable Energy, Government of India.

The prominent energy resources of the Himalayan region are forest and hydroelectricity. Because of the fragile ecosystem, forest resources are being conserved and any interference with them is strictly banned. Inhabitants of this remote area break the law because they are completely dependent on the forests for their energy requirements. Hydroelectric projects provide several benefits, but are detrimental to biological diversity and are a major cause of human displacement[12]. Therefore, utilization of forest as energy resource and construction of hydroelectric projects have been a matter of conflict between the inhabitants and the government. Inaccessibility to remote regions is another big problem which obstructs frequent transport of other conventional energy resources, namely LPG and kerosene. Keeping these obstacles in view, it will be a great achievement if the indigenous energy resources, namely geothermal energy is trapped to generate electricity exclusively for its inhabitants. Uttarakhand Himalaya is embodied with numerous geothermal springs which may be exploited for electricity generation and other non-electrical uses as described above. Apart from the existing geothermal discharge sites, more suitable reservoirs can also be identified using exploratory drill holes. Preliminary efforts of such exploitations in the Himalayan region have been carried out for Puga, Chhumathang (Jammu & Kashmir), Manikaran (Himachal Pradesh) and Tapoban (Uttarakhand) geothermal fields[13], but it is negligible compared to the expected potential of geothermal energy.

This brief discussion clearly indicates that geothermal energy resources utilization needs a multi-dimensional approach, inventing interactions among engineers, geologists, biologists, social scientists and local inhabitants. Since the Trans Himalaya is a remote and cold region, exploitation of geothermal resources will help in the capacity building of its underprivileged inhabitants.

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