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GEOTHERMAL RESOURCES IN INDIA: POSSIBILITIES FOR DIRECT USE IN THE HIMALAYAS

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ABSTRACT

The Himalayan Geothermal Belt hosts nearly 150 thermal springs with temperature varying from 47 to 87 °C. The well known thermal provinces of Puga, Chumathang, Nubra geothermal provinces located in proximity to Leh and Manikaran, and other thermal locations in Kulu valley falls within HGB. Leh currently uses diesel to meet its major power demand for electricity and space heating. It is estimated that diesel generators are generating about 28,000 metric tones of CO_2 resulting in greater threat to the Himalayan Glaciers. It is reported that over the last 61 years, the Gangotri glacier has receded by a distance of 1,164 meters. The available geothermal energy can be utilized to generate power and for other direct applications and save the pristine ecosystem of the Himalayas.

1. INTRODUCTION

The Himalayas represents one the best areas of geothermal systems associated with continent-continent collision zone. The Himalayan geothermal Belt (HGB) extends from the north-western part of India (Ladakh) to the north-eastern part (Assam) over a length of 1,500 sq km and includes more than 150 thermal manifestations (Figure 1). The HGB is located between the Main Boundary Thrust (MBT) and the Indo-Tsangpo Suture Zone (ITSZ). The HGB includes the Himachal Pradesh geothermal provinces (Parbati, Tattapani, Alaknanda, Beas, Bhagirathi and Sutlej) and the Ladakh (Puga, Chumatang and Nubra) geothermal province in the NW Himalayas in India and the Tibet and Yangbajing geothermal provinces in China. Detailed geological, geophysical and geothermal investigations have already been carried out on these geothermal provinces. (Sehgal 1963; Gupta et al., 1976; Giggenbach et al., 1983; GSI, 1991; Alam, et al., 2004; Chandrasekharam, 2001a; Chandrasekharam, 2001b; 2002; 2003a,b; 2004a,b). The high heat flow (> 100 mW/m^2) along the HGB is due to shallow crustal melting along the subduction zone (Hochstein and Regenauer-Lieb, 1998) and also due to high radioactivity of the leucogranites (Varun and Chandrasekharam, 2007). The surface temperature of the thermal springs varies from 47 °C to 87 °C. The thermal discharge is saline due to mixing of magmatic fluids (Alam et al., 2004). The geothermal resources of the Himalayan region can be utilized for power generation as well as for direct applications (space heating, dehydration of agricultural products and refrigeration). In fact thermal springs, in several geothermal provinces in India, are being used for direct applications (cooking food, balneology and recreation). The current direct utilization of geothermal energy in India is 203 MWt and the geothermal energy utilization in HGB (within India) alone constitutes 134 MWt (Chandrasekharam, 2005). The thermal springs sites that are being utilised for direct applications are also the pilgrimage centres (Chandrasekharam, 1999, 2007). Direct applications of this heat source will reduce dependence on thermal power, there by preserving the pristine climate of the Himalayan region through reduction in CO_2 emission from diesel generators.

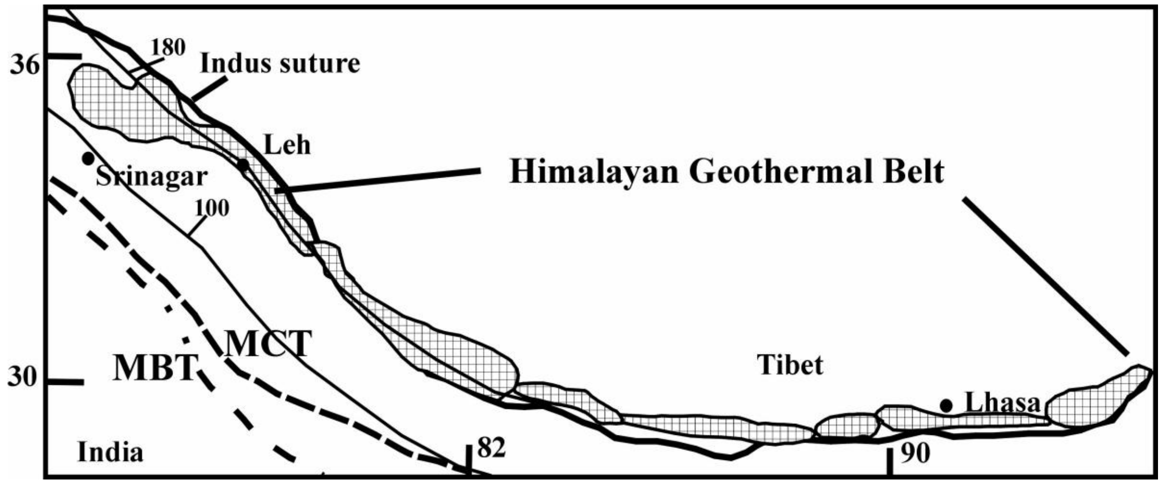

FIGURE 1: Himalayan geothermal belt showing the regional structure and heat flow values (Varun Chandrasekhar and Chandrasekharam, 2007)

2. CO_2 EMISSION IN INDIA

Thermal power plants are the backbone of electricity in India with nearly 66% of electricity generated from thermal power plants (coal 55%, gas 10% and oil 0.9 %) and the remaining 34% is generated from various sources (table 1). The current power production is 123,668 MWe and India's target is to achieve 215,000 MWe by 2012 and make the country power surplus. At the current growth rate of 4.7 %, and keeping in view the United Nations Framework Convention for Climate Change (UNFCCC) mandate of reducing CO_2 emission by 5%, it will be difficult for the country to achieve the target unless additional thermal power plants are commissioned (Figure 2). The estimated CO_2 emission by the year 2012, at the current growth rate, is about 630 million metric tones of carbon (Figure 3).

This increase in CO_2 emission will result from the Government's liberalization of licenses to expand the existing coal mines and opening new ones. In order to achieve the target power generation of 215,000 MWe, 263 million tones of coal will be burnt creating a CO_2 flux of 870 million tones of CO_2 (Figure 3). Considering United Nations Framework Convention for Climate Change (UNFCCC) CO_2 reduction cap of 5%, it will be difficult for the country to achieve this target. The option left for the country is either to enter into "Carbon trade" agreement with the European Union or plan for an energy source mix by generating additional power from renewable sources like wind, solar, biomass and hydro (Figure 2).

TABLE 1: Energy sources in India (MOP, 2006)

Plant/Fuel Type	MWe	Generation %
Thermal (coal, gas, oil)	82,065	66.4
Hydro	32,135	26
Nuclear	3,310	2.7
Renewable	6,158	4.9
Total	123,668	100

Figure 2 represents the thermal power related carbon cycle in India. 870 million tonnes of CO_2 will be emitted due to additional burning of coal by 2012. The cycle will break due to the UNFCC cap on carbon dioxide emissions. Options to overcome this 5% cap are either to enter into carbon trade with the EU and/or depend on renewable energy sources like wind, solar, bio and hydro, as shown in the diagram. Although the renewable energy sources (wind, biomass, small hydro) have a potential of generating 54,000 MWe, the installed capacity is only 7,843 MWe and an additional 1,218 MWe is expected to be added in the future (Chandrasekharam, 2005). This is a very small fraction and these sources, with lower efficiency factors may not change the power scenario of the country. Geothermal energy is not considered as a viable option until recently. Geothermal energy resources as a renewable energy source can make a difference in the present energy mix context scenario. Direct application of this energy source for space heating will reduce the load on the air conditioners and hence reduces CO_2 emission from coal based thermal power plants.

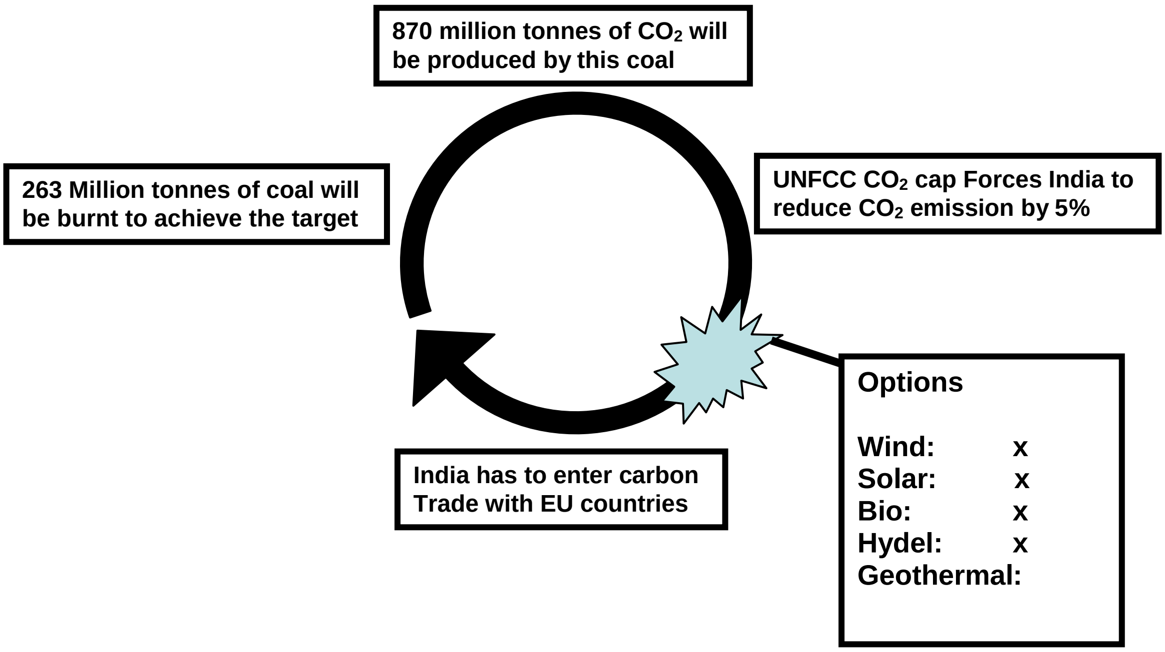

FIGURE 2: Thermal power related carbon cycle in India

The efficiency factor for other energy sources, except geothermal, is far less and these sources can not sustain base load and supply power without breaks. Furthermore, fuels like biomass, generate particulate matter and smoke that is detrimental to the environment and human health. Recent study indicates that in rural areas more than 50% children get affected by respiratory diseases due to smoke in the rural house holds. Environmental considerations is a set back for hydro electric projects. This does not mean that these sources should be discarded. In Indian rural settings these energy sources are a vital life line to millions of families. Where ever there is a possibility of utilizing geothermal energy sources, this should be exploited to the fullest extent. Geothermal sources, besides generating electric power, can be utilised to reduce carbon emission from coal based thermal power plants by direct applications like space heating and cooling (replacing air-conditioners and heaters) , refrigeration (cold storages), dehydration (for preserving agricultural products) etc. A large amount of power generated from coal based power plants are at present used for the above purposes and offsetting coal power by geothermal for such uses in fact controls carbon dioxide emission to a large extent. Rural regions like Leh, in Ladakh, in spite of the available geothermal source still depend on other energy sources like diesel, kerosene, biomass, cow dung and wood.

Figure 3 represents past, present and future carbon emission by thermal power plants in India. Carbon emission will nearly double by 2012 if additional thermal power plants operate to meet the energy demand of the country.

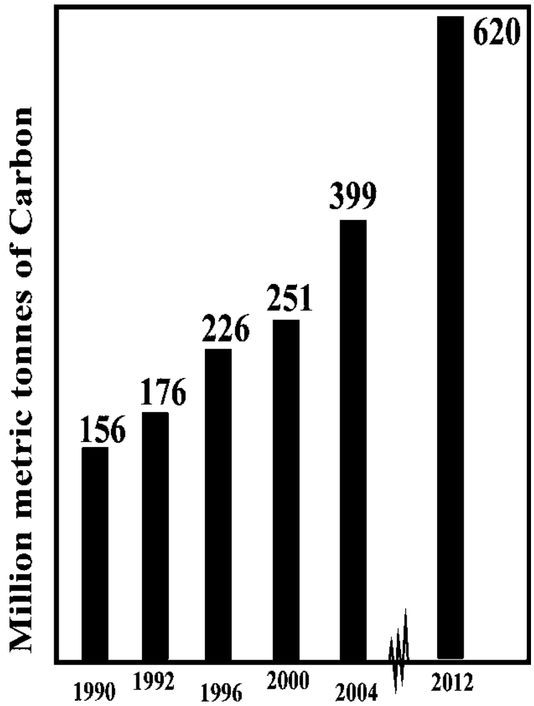

FIGURE 3: Past, present and future carbon emission by thermal power plants in India.

3. ENERGY SCENARIO IN LEH

Ladakh is one of the largest provinces of Jammu & Kashmir, India and falls within the HGB (Figure 1) and includes Kargil and Leh. Leh district has a population of 117,000, spread over 112 villages. The district is located at an elevation of 4,500 m and experiences extreme temperatures of -30 °C (winter) to 35 °C (summer) and enjoys the most pristine atmosphere. Besides the civilian population, army establishments are present both in Leh and Kargil. A large number of tourists visit the area (25,000 per year) and the Hill Development Council is increasing financial loans to travel agencies to increase the taxi service to Leh to enhance tourism *(http://www.jktourism.org).*

The Chumathang, Puga and Nubra geothermal provinces in Leh district, are well known for their high temperature geothermal manifestations GSI, 1991; Chandrasekharam, 2000). More than 150 thermal springs are in this province with surface temperatures varying from 80-87°C (boiling springs). At several locations steam discharge (2 to 3 kg/cm^2) can be seen. Considering the geothermal gradient (100- 200° C/km)(Ravi Shanker, 1988; Chandrasekharam, 2000; 2001b), heat flow values (140-468 mW/m^2), geochemistry of thermal springs and gases and the local geological formations (Chandrasekharam, 2001a,b) there is high probability of striking high temperature (>250° C) thermal reservoir at depths between 1 to 2 km (Chandrasekharam, 2000, 2001b). Similar depth temperature estimation of the reservoir was made based on magneto-telluric investigation (Harinarayana et al., 2004). Reservoir parameters, oxygen isotope data and melting frequencies and volumes of the Himalayan glaciers suggest that these geothermal systems have a long life span. These systems resulted due to the closure of the Tethis Sea during Indo-Asian plate collision at about 65 Ma. Besides the wet geothermal systems, HGB has excellent sites for developing enhanced geothermal systems (Chandrasekharam, 2001b; Varun Chandrasekhar and Chandrasekharam, 2007). Apparently the potential of geothermal energy is not quite known to the population and even if it is known, this source is considered as a sacred pilgrimage and recreation site (Chandrasekharam, 1999).

The entire population in Leh district depend on a meagre 2 MWe of electricity generated from the Stakna hydro electric power plant and a large number of diesel generators. Solar lamps provide electric power to a small section of the population in Leh during winter. In summer the consumption of diesel is less compared to winter. In winter electricity from the hydro electric power plant ceases and diesel generators are the only energy source that meets both electricity and space heating requirements. The present electricity generated by diesel generators is 13 MWe. There are a few villages in Leh that have not seen an electric bulb even to day! Thanks to the scientific advancement made by the country. According to a report prepared by the Chief Executive Councillor of Ladakh Hill Development Council, the present demand of power for Leh is 59 MWe and is expected to grow by 94 MWe by the year 2010 (Chandrasekharam, 2004b). This demand includes both electricity and space heating requirements only for the Leh population**.** Power generation through diesel generators is an expensive method of meeting power demand since diesel is air lifted to Leh from Delhi or Chandigarh. The cost of diesel in Leh is twice compared to the cost at Chandigarh. Subsidized cost of power in Leh is about Rs. 7.50/kWh. This subsidy can not sustain for a long period of time and will not improve the socio-economic problem of Leh population (Chandrasekharam et al., 2004a).

In winter all the above sources, except diesel generators, fail to generate power as a result the population depend on traditional methods (wood, chulas and animal dung etc.) for cooking and space heating purposes. Traditionally "bukharis" (wood, dung, and kerosene based heating appliance) are extensively used for space heating during winter both by civil and army personnel (Figure 4). Those children living in the Tibetan residential schools have to brave the cold of winter as they have no means to heat their bedrooms (Figure 5).

FIGURE 4: A typical 'Bukhari" traditionally used in Leh for space heating during winter. Kerosene from a storage tank (T) is pumped into a closed hollow cylinder (C). Kerosene burns continuously in the cylinder radiating heat into the space outside. The exhaust (mostly CO_2) is released into the atmosphere through an exhaust tube connected to the cylinder.

FIGURE 5: Tibetan orphan children in a residential school near Puga geothermal site. The building has no provision for space heating (even by traditional methods) and the children sleep in the bunker beds, braving the cold, (see insert) using only blankets during the harsh winter season.

4. EFFECT OF DIESEL GENERATORS IN LEH

Ladakh has no resources of fossil fuels whatsoever. Energy based on such fuels, is therefore, not the answer to Ladakh's energy requirements. In recent times, Ladakh's needs for power have witnessed a sharp increase, as the people of the region have started adopting a lifestyle that is more and more in line with the outside world and in addition to this lifestyle, as mentioned above, tourism, being a revenue for the local population, is given priority *(http://www.jktourism.org)*. This spurt in power requirements has mostly been met by importing fossil fuels from outside the state – a system that is not reliable and the population in Ladakh has to depend heavily on outside sources. Currently, 8,000 litres of diesel is needed to generate sufficient power for a day's consumption in Ladakh, and all of this fuel is imported from other states. Clearly, this is an unsustainable arrangement, economically as well as environmentally. At present 300,000 litres of diesel is burnt to generate 13 MWe of power annually. At the prevailing cost of diesel, 120 million Indian rupees are spent annually to generate 13 MWe. A rough estimate shows that 28,000 metric tones of CO_2/ MWhr are generated from the diesel generators (Chandrasekharam, 2004b). The effect of CO_2 on the Himalayan glaciers is already felt and the Gangotri glacier, during the period between 1936 and 1996, has receded by a distance of 1,164 m amounting to an average receding of 18 m per year during this period (Naithali et al., 2001).

5. SOLUTION TO THE PROBLEM

In this context it is appropriate to utilize the available geothermal energy source for direct applications as well for power generation and preserve the pristine atmosphere of Leh and reduce the impact of

CO_2 on the local Himalayan glaciers. This will provide sufficient energy for the Leh population for the next decade and meet their internal power demand for electricity and space heating requirements. This energy source will improve the socio-economic status of the Leh population including the Tibetan children located in the orphan schools. Besides the civilians, the army personal will also greatly benefit by the geothermal sources. In addition to space heating and power generation, geothermal energy in Leh can be utilized to grow a large volume of vegetables through greenhouse cultivation thus providing employment to Ladakhis (Chandrasekharam, 2001a). At present considerable amount of vegetables are also imported (together with diesel and kerosene) from neighboring states like Chandigarh and Delhi both by the civilians and army personal.

It has been demonstrated that using geothermal energy instead of conventional energy for food processing and green house cultivation saves about 80% fuel cost and about 8% operational cost (Lund, 2002). Even though this energy can be utilized by the rural community and army personnel in these provinces (Chandrasekharam, 2001a, b; Chandrasekharam, 2003a), serious attempts have not been made to utilize this free energy source. As an initiate to utilize geothermal energy of the Himalayan belt, M/s GeoSyndicate Power Private Ltd., a recent offshoot of the Indian Institute of Technology Bombay is setting up a 50 MWe power plant in Puga for generating power as well for direct applications like greenhouse cultivation and space heating (Chandrasekharam, 2005; Lund et al., 2005). Initially, in 2005 the company planned to install two HPs, each capable of recovering 50-75 kWt of heat from the existing thermal springs in Puga valley for space heating (for space heating purpose of Tibetan schools) and greenhouse cultivation and subsequently integrate this system with sealed turbo-generators for co-generation of 10-15 KWe of power (Chandrasekharam, 2005). Now with available detailed geological, geophysical database, the company has taken a major initiative for setting up the above mentioned power system.

Utilizing geothermal energy source in the Himalaya province will not only provide clean energy for lighting, space heating and green house cultivation but also reduces carbon dioxide emission and protect the pristine ecosystem of the Himalayas and also the glaciers. With the currently available drilling, heat exchanger and design technology even low enthalpy geothermal resources (especially in high altitude regions like Himalayas) can best be utilized for sustainable development and promote clean development mechanism in several developing countries like India (Chandrasekharam and Bundschuh, 2002, 2008). In addition to space heating, the geothermal energy in the entire Himalayan region can be utilized for dehydration of agricultural products.

Himachal Pradesh geothermal provinces (Parbati, Tattapani, Alaknanda, Beas, Bhagirathi and Sutlej), have varied agro-climatic conditions suitable for growing a variety of fruits like apples, pears, peaches plums, walnuts etc. The total area under fruit cultivation in this region is about 2,000 km^2 with a production of about 5,000 tonnes of fruits annually (Chandrasekharam, 2005). Apple is the main fruit cultivated accounting for more than 40% of total area under fruit cultivation and about 80% of total fruit production in Himachal Pradesh. The current existing fruit processing units have a combined processing capacity of 20,000 tonnes per year. But then, the region depends on other states for other farm food. If the available geothermal energy is utilized in the entire HGB, this province can become one of the major food producing and processing regions in the country. Relatively rural location of most of the geothermal sites in HGB offers advantages in terms of providing clean air, fewer diseases, clean water, warm homes and stable employment to the local population and enhances the living conditions of women of this hilly region.

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