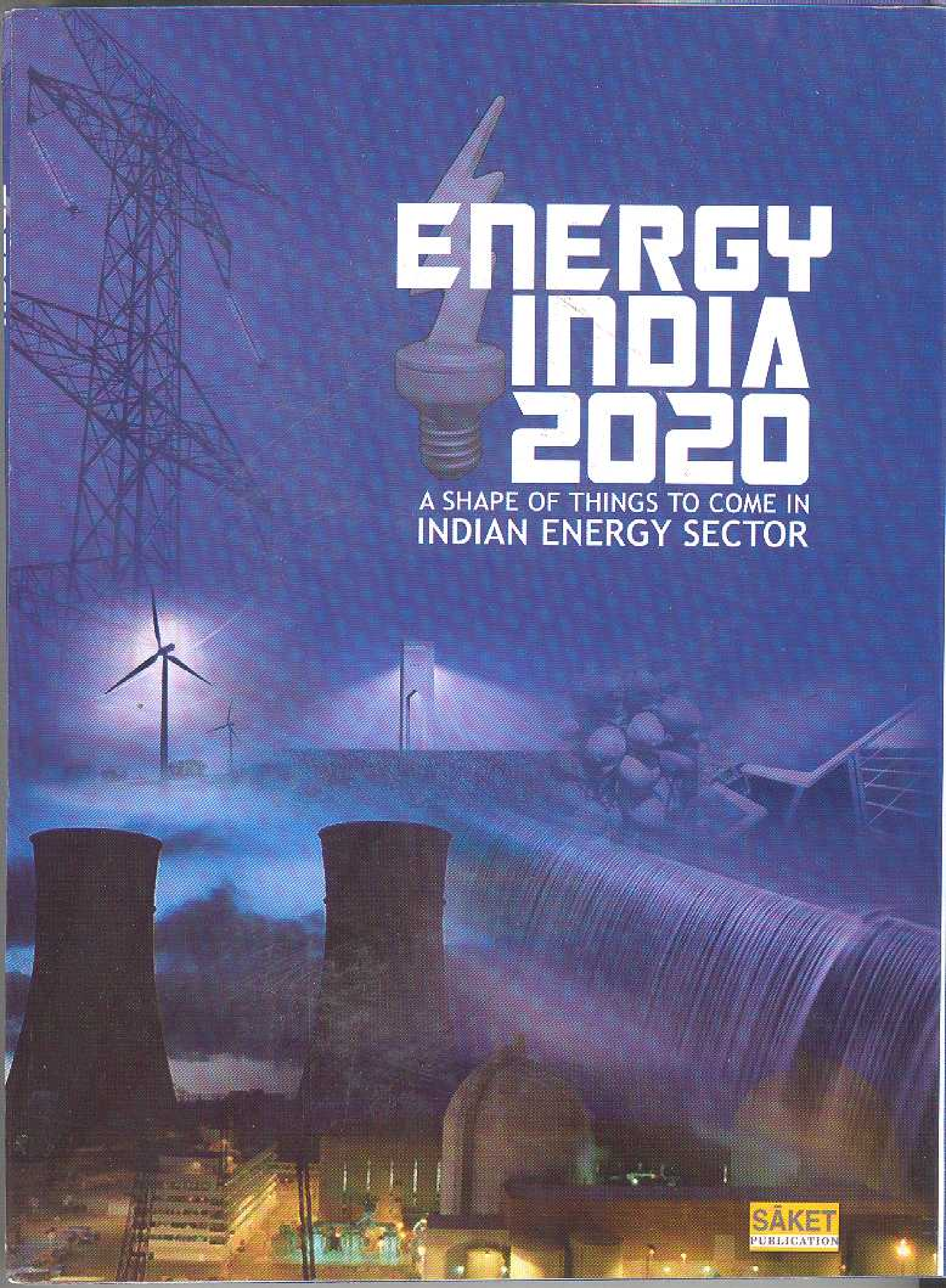
ENERGY INDIA 2020

A SHAPE OF THINGS TO COME IN INDIAN ENERGY SECTOR



SAKET PUBLICATION

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GEOTHERMAL ENERGY : VISION 2020

Dr. T. Harinarayana has significant contributions to the oil exploration upstream sector and geothermal secor in different parts of the country. Recently he was selected as an Independent Director of GSPC Ltd. He is the leader of various geophysical investigations in Gujarat such as Saurashtra, Kutch, Narmada, Camboy, and has been involved in various multidisciplinary mega-projects. Based on his recommendations, a few blocks have been carved out for exploitation of hydrocarbons in Narmada-Cambay region. Dr. Harinarayana is the Head of one of the major scientific projects of NGRI Magnetotellurics. He has spear-headed international collaboration projects with GEMRC, Moscow, Bulgarian Academy of Sciences, Bulgaria

Dr. Harinarayana's pioneering work in geothermal energy has opened up a new sector for power generation in Puga in Jammu and Kashmir, Tapovan - Vishnugad in Uttarakhand, Tatapani in Chattisgarh and Surajkund in Jharkhand. Deep crustal studies in Narmada-Son Lineament zone has provided a strong evidence for the existence of mantlewarping and magmatic under plating.

He has received the prestigious National Mineral Award from the Union Ministry of Mines, Government of India; Best Scientist Award by the Government of Andhra Pradesh. He has published more than 62 research papers in national and international journals with 20 technical research reports.

Abstract

Although, we could overcome the food problem through green revolution, we are starving for energy. The gap between demand and production is widening year after year. Our industrial growth is suffering due to lack of energy supply, which in turn affecting our economy. Time has come now to look and explore in all directions to meet our energy demand.

Among the various new and renewable energy sources, geothermal energy is known to be one of the clean energy without smoke and also without environmental hazards. Although it's importance is realized long back in other countries, it's exploitation is still far away in our country mainly due to lack of knowledge on the deep subsurface structure and deep drilling technology in high pressure, high temperature conditions. Geological Survey of India (GSI) and National Geophysical Research Institute (NGRI) have made concerted efforts in identifying these resources in different parts of our country for possible exploitation of the energy source. The details of geothermal energy, with estimated potential in our country, its importance and usage in other countries are discussed. Concrete plans and directions are also provided to develop this untapped resource.

Energy is a basic requirement by all the countries. One can visualize 3 types of countries - developing, developed and over-developed countries. The over-developed countries are consuming 5 to 10 times (per capita) more energy than other countries and contributed with a major share to global warming.

India is a country occupying 2% of the land mass and generating about 2% of the global electricity, mostly using low grade coal, of which it has about 5% of the world reserves. India has, however a share of large amount of world's population, only second to China. As per the integrated Energy Policy of Government of India, power generation capacity must increase to nearly 8,00,000 MW by 2030. However, the present installed capacity is only 1,43,061 MW comprising 35,909 MW from hydro, 91,907 MW from thermal (including coal, gas, diesel), 4,120 MW from Nuclear and 11,125 MW from renewable energy sources. The power supply position in the country for the period of April 2007 to March 2008 is given in the table below:

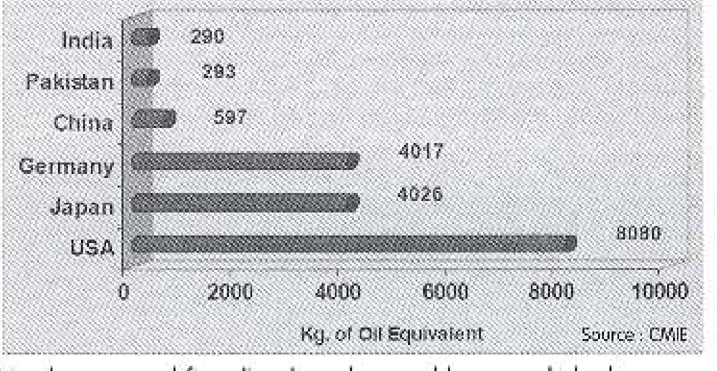
Peaking (MW)				Energy (MU)			
Req (MW)	Avail (MW)	Shortage (MW)	% shortage/ surplus	Req (MU)	Avail (MU)	Surplus	% Deficit
108866	90793	(-)18073	(-)16.6	737052	664660	(-)72392	(-)9.8

Source: Ministry of Power, Government of India

The likely addition of energy in the country during the 11th Plan (2007-12), as per assessment made by Central Electricity Authority (CEA), is of the order of 78,600 MW comprising 15,700 MW from Hydro 59,500 MW from thermal Projects (including coal, gas, diesel) and 3,400 MW from Nuclear Projects. In addition, renewable capacity addition, including wind, solar, biomass etc of about 14,000 MW is estimated for the 11th Plan. All the above data indicates that our present growth in energy production is insufficient and demands to generate more power.

India is planning to have a quantum jump from a developing country to a developed country. Its' energy consumption is directly linked to industrialization and the living standards of its population. Fig.1 shows the per capita consumption of energy by different countries. Our consumption is less than 1/10th as compared to developed countries, say Germany or Japan. The rapid economic development of our country coupled with population growth in recent years has been driving energy demand growth. But the gap between the production and demand is still large. Although India is blessed with vast potential in the form of new and renewable resources such as solar, wind, bio-mass, hydro, gas hydrates, geothermal etc., their utilization is not near its maximum potential. Several articles can be seen on the development of geothermal energy in developing countries (Chandrasekharam, 2002).

Figure 1 : Per capita energy consumption



Thus electricity demand is remarkably increasing due to economic growth and progress of electrification. Target of the 10th five year power development plan (2002-2007) was 41,110 MW, but actual result was only 21,180 MW (corresponding to 51.8% of the target). In India, major organizations such as National Thermal Power Corporation Ltd (NTPC), National Hydro-Power Corporation Limited (NHPC) and also private companies supply electric power. Target of the 11th five-year power development plan (2007-2012) is aimed for the total installed capacity of 215,000 MW. Major sources of power in this plan are coal fire, diesel, nuclear and large-scale hydropower (MNRE report, 2008). In view of this, we need to look for other sectors from non-conventional and renewable energy sources in a big way.

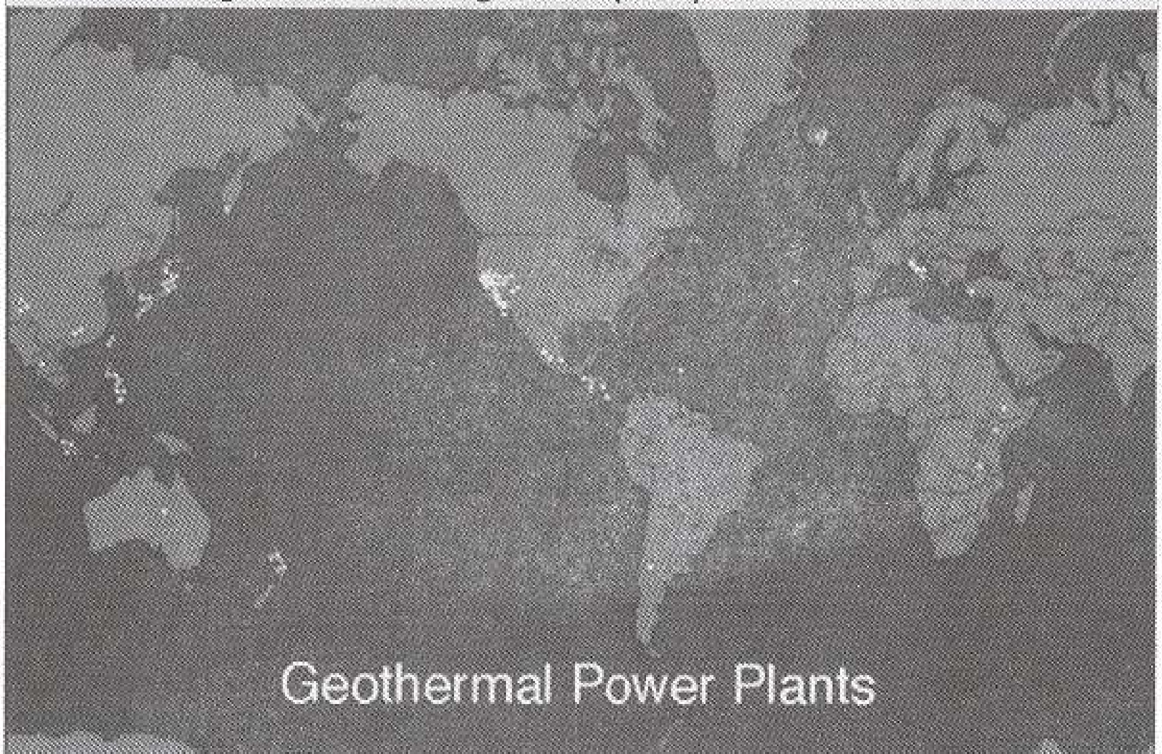
The heat, in the form of geothermal energy, constantly flows outward from the core, heating the surrounding area. Nearby rocks melt at high temperature and pressure. They transform into magma. Magma sometimes comes up to the surface as lava during volcanic eruptions, but most of the time it remains below the earth's crust, heating nearby rocks, where trapped groundwater in fractured or porous hot rock is heated up forming as a reservoir of steam and hot water below the earth's surface. These reservoirs of geothermal energy can be tapped for generation of electrical energy or for many other direct uses. The surface manifestations of geothermal energy occur in the form of volcanoes, geysers and hot springs.

Geothermal is a source of energy which requires special mention. Geothermal energy is renewable if proper techniques are used for exploration and utilization. Geothermal energy is a liquid energy - Hydrothermal - and also as a solid - Hot Dry Rock - which can be recycled. Government of India has formulated a National Mineral Policy for exploration and mining of mineral resources. Similarly a policy of exploration and exploitation of oil and gas as well as atomic minerals and thermal power generation is released. As the mandate for exploration of geothermal energy resources on a national scale was primarily bestowed on Geological Survey of India (GSI), most exploration and drilling activities were carried out by them, with complementary efforts from the National Geophysical Research Institute (NGRI) and a few other organizations. Also, the utilization of geothermal energy was pending due to non-availability of both robust estimates of potential for different geothermal fields as well as appropriate machinery and equipment for deep drilling and exploitation. For these reasons, a formal policy on Exploration and Development of Geothermal Energy Resources need to be initiated. With the advent of the worldwide progress in geothermal energy utilization, private entrepreneurs have started taking initiative in geothermal energy exploration. The increase in demand for power in rural sector has necessitated the exploitation of site specific energy sources as a substitute to fossil fuel energy. Hence, it has become imperative to formulate guidelines and policy for exploration of the geothermal energy resources and their further utilization for power production and direct heat utilization.

Geothermal energy offers number of advantages over traditional fossil fuel based sources. From an environmental standpoint, the energy harnessed is clean and safe for the surrounding. It is also sustainable because the hot water used in the geothermal process can be re-injected into the ground to produce more steam. In addition, geothermal power plants are unaffected by changing weather conditions. Geothermal power plants work continually, day and night, making them base load power plants. From an economic point of view, geothermal energy is extremely price competitive in some areas, particularly in case of remote located demand and reduces reliance on fossil fuels and their inherent price unpredictability. The price variations in the global oil and natural gas pose a great problem to our 'Energy Security' considerably. With wide network of research and development of premier organizations such as Council of Scientific and Industrial Research (CSIR), Directorate of Science & Technology (DST) and also the premier energy oriented organizations such as Oil and Natural Gas Commission (ONGC), Oil India Limited (OIL), Reliance, National Thermal Power Corporation Ltd (NTPC), National Hydro-Power Corporation Ltd (NHPC), etc are playing a significant role in planning for the strategic energy research towards the sustainable development.

In the last few decades, there has been an increase in the use of geothermal energy all over the world. Geothermal energy has been found to be a reliable and flexible renewable energy resource, which is economically competitive with other forms of energy. Geothermal power plants are modular and can be installed in incremental units as needed. Very small-scale kilowatt level geothermal power plants are also feasible. Geothermal energy has a large net positive impact on the environment and power from these plants is available continuously. Besides, the low heat geothermal sources can be used directly for green house, space heating, refrigeration and for various industrial uses.

Figure 2 : Distribution of geothermal power plants around the world



Courtesy : Geothermal Education Office

Source : http://geothermal.marin.org/GEOpresentation/sld069.htm

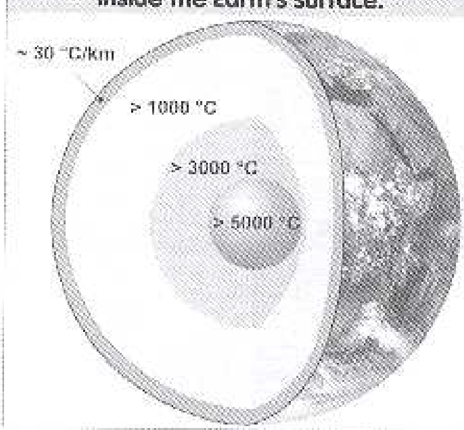
Energy and thermal transfers in geothermally active regions can play an important role in controlling their dynamism depending on the superficial hydrothermal state. Major part of geothermal energy is released through the groundwater circulation, hot gas emission and thermal conduction. Therefore, it is important to know the hydrological and thermal environments, as well as the superficial and deep structure, associated with active regions.

If we study the geothermal power plants in the world, it can be observed that only a limited number of locations are being exploited (Fig.2). This is not due to the reasons that other regions are not suitable. In reality, it is mainly due to lack of information about the subsurface structure suitable for geothermal potential. For example, let us see the case of India. No geothermal power plant in the whole country. In high Himalayan regions, the only source of power may be geothermal. The conventional power plants face many problems in this region such as transportation problem of the fuels for thermal power plants, freezing temperature problem for hydroelectric power plants etc.

Towards this direction, the present article reviews the geothermal potential in India along with our present day knowledge on the geothermal fields of India and also discusses the future programmes and plans to develop geothermal energy with a vision for the year 2020.

What is Geothermal Energy?

Figure 3 : Natural heat available inside the Earth's surface.



Geothermal energy is the earth's natural heat stored inside the earth. This thermal energy contained in the rock and fluid that filled up fractures and pores in the earth's crust that can profitably be used for various purposes. It is believed that ultimate source of geothermal energy derived from the earth due to radioactive decay occurring within the earth at deep crustal depths. About 0.1% of the energy stored in the Earth's crust could satisfy the world energy consumption for 10,000 years. At all locations, the heat reaches the surface of the earth in a defusing manner. The earth's heat increases with depth at a rate of 30 °C per km and this way the centre of the earth is estimated to have about 5000 °C (Fig.3). However, due to geological processes and tectonic disturbances, heat sources become relatively shallow at certain locations. Greater the temperature near the surface of the Earth higher will be its utility. For example, the heat source of high temperature (>200 °C) is generally used for electric power generation. As on today, geothermal electric power generation in US is approximately above 2800 MW. This is equivalent to 4 large nuclear power plants. The low and moderate temperature resource can be used for direct applications and also using ground source heat pumps. Application of direct use involves heating of the buildings, industrial processes, greenhouses, and aquaculture and in holiday resorts.

Ground heat source, uses the groundwater as a medium of transport that can be used to transfer the heat from the soil down below to the surface. As on today, the current world production of geothermal energy for both direct and indirect uses has occupied third place among the various renewable energy sources such as hydro, biomass, solar and wind. Although its potential is impressive from various users in different countries, its utility in India is near zero. The success of geothermal use depends on the technical information about the various geothermal provinces. Table 1 gives worldwide contribution to geothermal power generation showing the installed capacity in various countries.

Global Scenario

Geothermal reservoirs constitute one of the important renewable sources of energy currently being used to meet the energy demands. Near the surface of the earth various mega geological and tectonic features associated with geothermal energy are spreading ridges, transform faults, subduction zones etc. They form a vast network that divides our planet into distinct lithospheric units. For example, the plate boundaries correspond to fractured zones of the earth and characterized by large heat source that can be seen on the surface with many number of volcanoes, frequent seismic activity, etc. These typical regions can also manifest itself on the surface such as geysers, hot springs etc. Figure 4 provides the world wide technical potential of various renewable energy sources that can be used per year. The geothermal potential stands out with the availability of large potential. However, the technology needs to be developed to harness this energy source.

Through geological and geophysical investigations, geothermal source buried at certain depth can be delineated for exploitation as an energy source. For example, pacific plate boundary, all along the western coast of north and South American continent, geothermal provinces such as Imperial Valley, Cerro Prieto, the geysers, Ahuachapan, Eltatio etc. can be observed. Similarly, the subduction zones and along the Indian plate boundary, the geothermal reservoir systems of Philippines, Himalayan belt regions can be seen. Apart from these regions, major rift regions on land, for example Kenya rift system in Kenya, Narmada rift system in Central India are also considered to be the sources of geothermal energy.

Geothermal energy is being used for various purposes worldwide, for the last few decades by several countries. Among these uses, a few of them are being used for electric power generation. The table-I gives a summary of the countries and installed electric power capacity.

Table 1

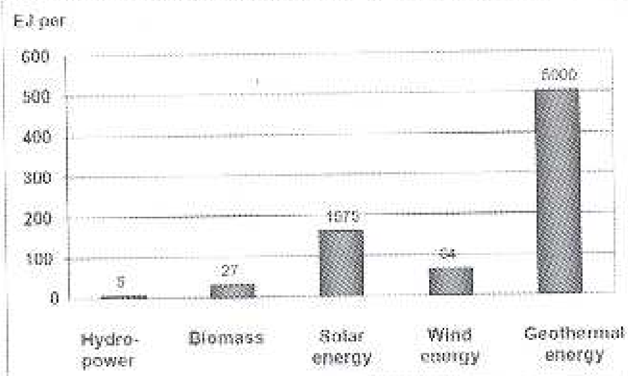
Name of the Country	Installed Geothermal Capacity, MW
United States	2850
Philippines	1848
Mexico	743
Italy	742
Japan	530
Indonesia	528
New Zealand	364
El Salvador	105
Nicaragua	70
Costa Rica	65
Iceland	51
Kenya	45
China	32
Turkey	21
Russia	11
Azores	8
Guadalupe	4
Taiwan	3
Argentina	0.7
Australia	0.4
Thailand	0.3
India	0.0
Total	7,953

Source : World Geothermal Congress, 2000

Geothermal Provinces of India

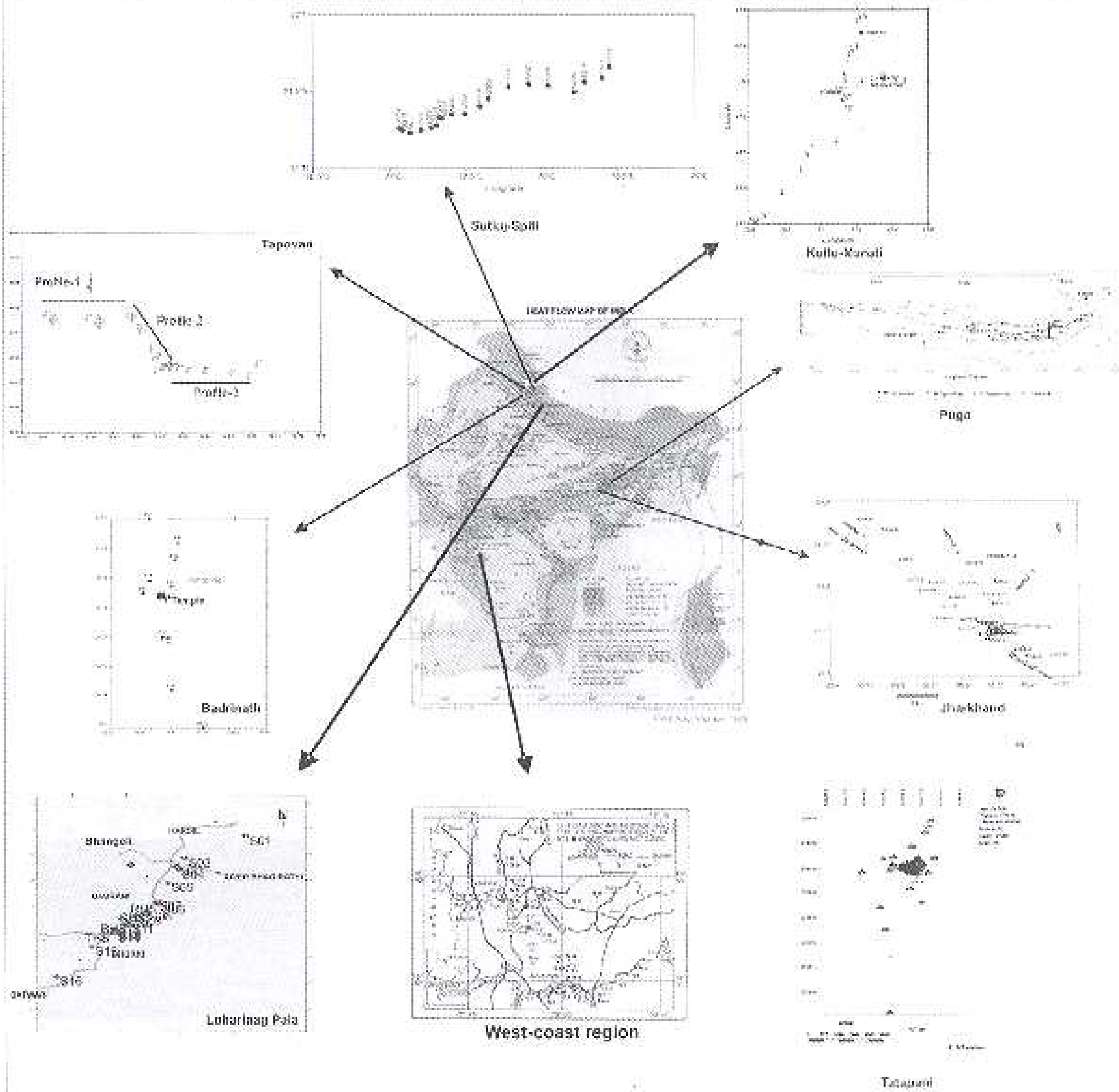
Rocks covered on the surface of India ranging in age from more than 4500 million years to the present day and distributed in different geographical units. The age of the rocks comprise of Archean, Proterozoic, the marine and continental Paleozoic, Mesozoic, Tertiary, Quaternary etc., More than 300 hot spring locations have been identified by Geological survey of India (Thussu, 2000). The surface temperature of the hot springs ranges from 35°C to as much as 98°C. These hot springs have been grouped together and termed as different geothermal provinces based on their occurrence in specific geotectonic regions, geological and structural regions such as occurrence in orogenic belt regions, structural grabens, deep fault zones, active volcanic regions etc., Different orogenic regions are - Himalayan geothermal province, Naga-Lushai geothermal province, Andaman-Nicobar Islands geothermal province and non-orogenic regions are - Cambay graben, Son-Narmada-Tapi graben, West Coast, Damodar valley, Mahanadi valley, Godavari valley etc., Figure 5 shows different geothermal provinces of India along with regional heat flow values (Ravishanker, 1988). The deep geophysical studies carried out by NGRI at different locations are also shown.

Figure 4 : World energy potential assessment of various renewable energy sources



The geothermal potential fields can be broadly divided into three types. High temperature fields, medium

Figure 5 : The heat flow map of India showing different heat flow zones from zone-1(highest) to zone v (lowest)



temperature fields and low temperature fields. High temperature fields (>200 C) can profitably be used with conventional geothermal systems, where in a deep bore hole is drilled usually to a depth of about 1-3 km directly to the permeable hot rock below wherein the hot fluids from below escapes to the surface through the bore hole and thus it can be utilized for electric power generation (Fig.6). In the case of medium range geothermal fields, wherein the temperature is of the order of 120-200 C the fluids can be used using binary cycle power plants. In this case, the fluids after getting cooled on the surface need to put back to the subsurface through injection wells at different location in order to get recharged. The technology for generating power from low temperature fields is not yet developed, however, they are being used for direct application such as space heating, balneology, spa etc., Fig 7 shows a typical schematic diagram showing the use of geothermal heat for power generation in a medium temperature field.

Geothermal Potential and Resources of India

From geological, geochemical, shallow geophysical and shallow (<500 m) drilling data it is estimated that we have about 10000 MW of geothermal power potential that can be harnessed for various purposes. To exploit the geothermal energy source, we need to map the deep subsurface structure and to demarcate the area of geothermal heat trapped inside the surface such that decisions regarding deep drilling, estimation of it's potential, number of years that can profitably be used etc parameters can be estimated. This can be carried out with the help of geochemical and deep geophysical techniques. Geological survey of India has made concerted efforts in this direction by using shallow geophysical technique, geochemical sampling with shallow (<500 m) bore hole drilling in several geothermal fields in India. The data base generated by GSI is a valuable document with which heat flow map of India, geothermal atlas of India have been prepared (Ravishanker, 1988). National Geophysical Research Institute (NGRI) has also made concerted efforts in different geothermal regions of India (Gupta and Roy, 2006). In order to map the deep structure of geothermal regions, NGRI, for more than a decade, has been using a deep geophysical technique - magnetotellurics (MT) - to map the anomalous deep geothermal fields. The regions covered by MT are Talapani, Chattisgarh, Puga, J&K, Tapovan-Vishnugad-Badrinath in Uttarakhand, Surajkund in Jharkhand, Kullu-Manali-Manikaran in Himachal Pradesh etc., (Harinarayana et al 2000, 2003, 2004 and 2005). These studies have provided valuable information and have identified the locations for deep drilling for possible exploitation of geothermal energy for power generation. The estimated temperatures of these geothermal fields based on shallow drilling and deep geophysical studies are shown in Table-2.

Figure 6 : Schematic diagram showing the use of geothermal energy for power generation

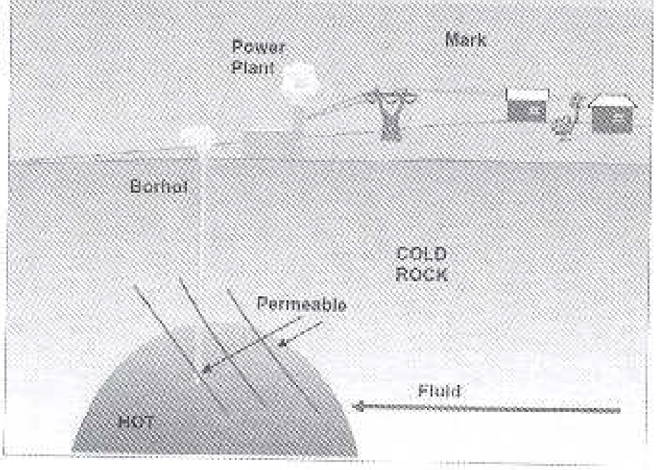
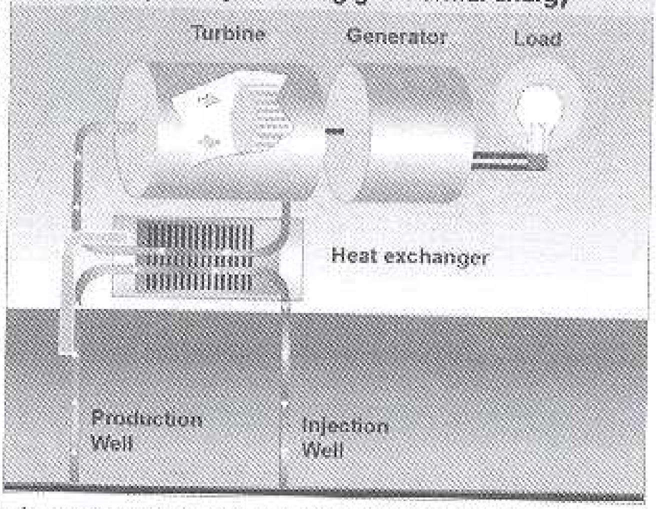


Figure 7 : Typical set up of various basic components of a power plant using geothermal energy



Direct Uses of Geothermal Heat Energy

As has been indicated earlier, in India, there are more number of hot springs that are medium enthalpy and low enthalpy geothermal systems. Puga geothermal field, Chummathang geothermal field, Ladakh, J&K, Tattapani geothermal field, Sarguja, MP fall under high enthalpy system and other areas in Maharashtra, Himachal Pradesh and Uttar Pradesh fall in the medium enthalpy system. The high enthalpy waters could be utilized for either primary cycle power production (Puga geothermal field) or binary cycle power production, (Tattapani, geothermal field, MP) using different types of freons. Majority of the thermal waters at other places, although grouped in medium enthalpy system could be utilized for non-electrical applications at present. It is, therefore, pertinent to point out that the thermal water discharging from majority of geothermal fields in India have better scope for non-electrical application. It is, therefore, felt that until the deep reservoirs with sizeable discharge and temperatures are located and proved with deep drilling operations, the present day discharge from shallow bore holes can be put to non-electrical uses. The following table gives a broad utilization pattern of the thermal waters ranging in temperature between 20°C and over 200°C.

In India, utilization studies have been carried out at Puga, Chhumathang geothermal fields, Ladakh, J&K and at Manikaran in Parbati valley geothermal field. The utilization studies carried out are discussed below:

Puga-Chhumathang Geothermal System

Puga geothermal fields are the only field capable of producing either primary cycle electrical power or binary cycle power at present, though on a very small scale. The thermal fluids have been utilized for space heating,

Table 2

Geothermal Field	Estimated (min.) Reservoir Temp (Approx)	Status/work program
Puga geothermal field, Ladakh, J&K	240°C at 2000m	Deep subsurface structure investigated by NGRI, shallow structure, geological, geochemical studies, shallow drilling (<500 m) by GSI
Tattapani, Sarguja District (Chhattisgarh)	120°C - 150°C at500 meter and 200 C at 2000 m	Deep subsurface structure investigated by NGRI, shallow structure, geological, geochemical studies, shallow drilling (<500 m) by GSI
Tapoban, Chamoli Dist (Uttarakhand)	100°C at 430 meter	Deep subsurface structure investigated by NGRI, shallow structure, geological, geochemical studies, shallow drilling (<500 m) by GSI
Cambay, (Gujarat)	160°C at 1900meter (From Oil exploration borehole)	Shallow structure, geological, geochemical and shallow drilling (<500 m) by GSI.
Badrinath, Chamoli Dist (Uttarakhand)	150°C estimated	Deep subsurface structure investigated by NGRI, shallow structure, geological, geochemical studies, shallow drilling (<500 m) by GSI
Surajkund, Hazaribagh Dist (Jharkhand)	110°C	Deep subsurface structure investigated by NGRI, shallow structure, geological, geochemical studies, shallow drilling (<500 m) by GSI Heat flow 128.6 n/w/m^2
Manikaran, Kullu Dist (H P)	100°C	Deep subsurface structure investigated by NGRI, shallow structure, geological, geochemical studies, shallow drilling (<500 m) by GSI Heat flow 130 n/w/m^2
Kasol, Kullu Dist(H P)	110°C	Deep subsurface structure investigated by NGRI, shallow structure, geological, geochemical studies, shallow drilling (<500 m) by GSI
Bakreswar, (W.B.)	120°C	Deep subsurface structure investigated by ISM, Dhanbad, shallow structure, geological, geochemical studies, shallow drilling (<500 m) by GSI

processing of borax, sulphur and extraction of salts. Extraction of rare metal Cesium is under experimentation. Poultry farming and green house cultivation are the other industrial applications for which the geothermal energy has been used. The thermal waters have been used for hatching poultry and for the growth of mushroom in a hut, 500 sq.m in area by the Regional Research Laboratory (RRL) of Council of Scientific & Industrial Research (CSIR), Jammu & Kashmir. The experiment has been a success. Green house cultivation has been successfully tried at Chhummathang.

Parbati Geothermal System

Thermal waters have been utilized for developing a 7.5 tonne capacity cold storage plant based on ammonia absorption system at Manikaran. A 5 kWe binary power plant has also been test run successfully. In addition, these waters are at present utilized for bathing.

Beas Geothermal System

Thermal waters have been utilized at Bashisht and Kalath. The waters at Kalath could be utilized for mineral water bottling.

Tattapani Geothermal System

No experimental utilization studies have been carried out in Tattapani area. Installation of a pilot binary cycle power plant is under consideration by Chattisgarh government in collaboration with private industry partnership. The thermal fluid discharge from the bore holes drilled by geological survey of India being used by local people for therapeutic purpose. Tattapani geothermal waters could also be used for non-electrical purposes. Other potential uses of geothermal energy could be in the following fields:

Temp °C	Possible Utilization	
200		Electric power generation (Primary cycle)
190	Deep fat frying	
180	Evaporation of highly concentrated solutions Refrigeration by ammonia absorption, in paper Pup, Craft.	Binary cycle electric power generation
170	Heavy water via hydrogen sulphide process Drying diatomaceous earth	Binary cycle electric power generation
160	Drying fish meal, drying timber.	Binary cycle electric power generation
150	Beet sugar processing, alumina via Bayers process	Binary cycle electric power generation
140	Drying farm products at high rates, food canning	Binary cycle electric power generation
130	Evaporation in sugar refining, extraction of salts By evaporation and crystallization.	Binary cycle electric power generation
120	Fresh water by distillation	
110	Drying and curing light aggregate cement slabs Saline solution for intravenous injection.	
100	Dehydrated potato processing, drying organic material, seaweed grasses, vegetables etc washing and drying wood.	
90	Drying stock fish, intense de-icing operations	
80	Space heating-domestic green houses, milk Pasteurization.	As pre-heated fluids.
70	Refrigeration by low temperature	
60	Animal husbandry, space heating, hot bed heating, Manure processing, poultry processing	
50	Poultry hatching, breeding-mushroom growing.	
40	Soil warming	
30	Biodegradation, fermentation, deicing	
20	Fish hatching farming	

Source: Potential of Geothermal Energy, Arizona, 1978

Silviculture
The region is rich in developing raw material for Kosa silk. Silk does not require water at hih temperature water for extracting thread from the coccons. There is no plant for coccon processing and making of threads in Tattapani area. It may be mentioned that the silk industry could be developed in this remote area, using these waters very effectively.

Hard Board making
These waters could be used for making hard boards utilizing agriculture and forest waste mixed with local soil. The thermal water could fruitfully be used as digester and these blocks could be used for construction work.

Development of Tourist and Health Resort
The waters from the discharging boreholes could be used for developing 'Sauna baths' and other entertainments areas like parks etc.

Agriculture
The thermal water after utilizing for both electrical and non-electrical uses could be used for agriculture purposes.

West Coast Geothermal System
No attempt has been made to use the thermal waters in the West Coast area. Only a few places (Eg. area around

Ganeshpuri, north of Mumbai) are being used for bathing and therapeutic purpose. Although eighteen thermal spring locations occur along West Coast, only three areas have potential for use and that too for non-electrical purposes. These are Unhavre-Khed and Tural of the Southern sector. The thermal waters at these places could be used for:

i) The development of health resorts, sanatorium, tourist and holiday resorts, in view of the proximity of these areas to Bombay, Ganeshpuri hot springs are already attracting large number of tourists for hot water bath.
ii) Development of green houses on a large scale for increase in the production of vegetables and mushrooms under controlled conditions through multiple cropping.
iii) Development of animal husbandry, poultry farming, fresh water fish farming etc.

The following uses could also be considered:

Canning, bottling and pup making plants; Fish drying, under controlled conditions; Washing and drying wool and other fibers; drying and curing light aggregate cement slabs, mass refrigeration, milk pasteurization; Brewing of low percentage alcoholic beverages.

After attaining success in the above areas these studies could be taken up in other areas of West Coast where temperatures are low. This would enable saving of a sizeable amount of fossil fuels like coal, natural gas and petroleum products.

Summary

It is evident that our country is putting all the efforts to increase our power production. Since our demand is not being reached from the conventional sources, concerted efforts are being made by government of India in other sectors - namely, solar, wind, bio-mass etc., and more recently on nuclear energy. However, as evident from the present study, the geothermal energy also needs to be taken into consideration for generation of electric power and also for other direct uses which can reduce our dependence on the conventional sources. This energy considerably helps in reduction of CO_2 to our environment. From the present day knowledge of our geothermal sources, the high temperature fields like Puga in J & K, Tattapani in Chattisgarh can profitably be used for development of power using conventional energy generation systems and others like Tapovan, Badrinath, Kullu-Manali, Jharkand etc, binary power plant systems can be attempted in a staged manner.

In order to give a boost to this untapped energy resource, Ministry of New and Renewable Energy (MNRE), Government of India need to initiate and coordinate the following steps on priority basis such that utilization of geothermal energy can see the light of the day at least by 2020:

- During the coming year (2010-11) clear policy and guidelines to develop geothermal energy need to be released.
- Tax holiday for 5 to 10 years to all the industries developing geothermal energy.
- Zero tax and zero duty on all the equipment and its accessories being imported for the development of geothermal energy.
- Participation in Power Purchase Agreement (PPA) with concession on tariff similar to solar power.
- Initiation of experimental deep drilling (2-3 km) in all the geothermal fields by 2012 and completion by 2015.
- Initiation to develop low/medium geothermal fields for tourism, health resorts/holiday resorts, spas etc on BOO (build, own and operate) basis through global tendering process by 2015.
- Initiation of power generation through a pilot plant/demonstration through government/private partnership.

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Acknowledgements : I wish to thank the Director, National Geophysical Research Institute (NGRI) for his kind permission to publish this article in a book by SAKET, Ahmadabad. I also wish to thank Sri Arvind Kumar Gupta and Sri Sreeramulu who have helped me in preparation of the manuscript.

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