

Applications and potentials of geothermal energy: Indian scenario

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Abstract

Energy is essential for all activities in and around us. It provides comfort, increases productivity and allows us to live as we want. Presently most of our energy demand is derived from conventional fossil fuels such as coal, petrol, diesel, natural gas, kerosene etc. According to an estimate oil would run out in about 40 years and natural gas soon after. Additionally, they're degrading environment by releasing harmful byproducts and contribute to global warming and greenhouse gases. Keeping in view of the limited store of fossil fuels and ever increasing gap between the demand and supply of energy, it has become necessary to switch to new and renewable sources of energy. It is a fact India has one of the highest potentials for effective use of renewable energy. During the last one decade, there has been a visible impact of renewable energy in the Indian energy scenario. Apart from contributing to about 12.5 per cent in the national electric installed capacity, renewable energy based applications have benefitted millions of people in the Indian villages by providing for their energy needs in an environment friendly manner. India is the world's fifth largest producer of wind power after Denmark, Germany, Spain, and the USA.

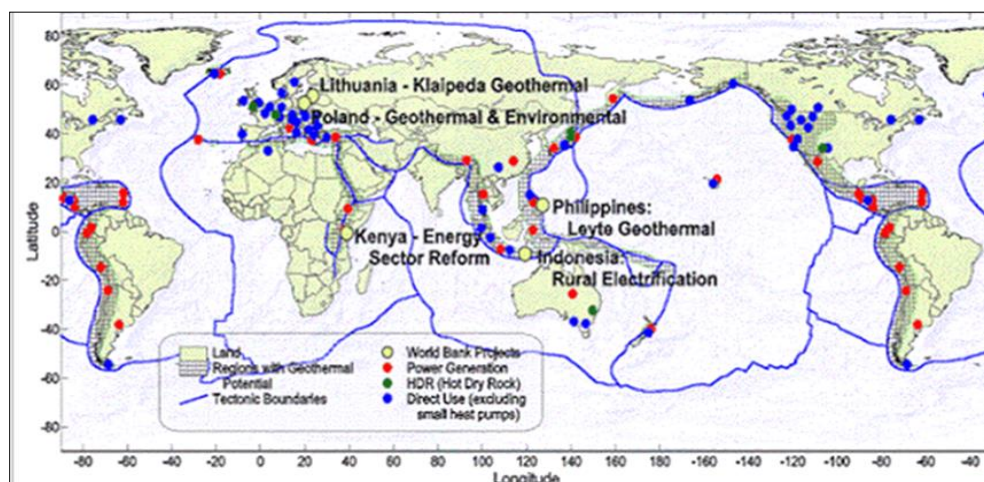
Keywords: applications, geothermal energy, scenario, greenhouse gases

Introduction

Geothermal energy is one of the renewable energy resources. It is cost effective, reliable, sustainable and environment friendly. However, geothermal wells release greenhouse gases but these emissions are much less per energy unit than those of fossil fuels. Resultantly, geothermal energy has the potential to mitigate global warming if fossil fuels are replaced by it. Geothermal energy is the heat that flows to the Earth's surface from its interior continuously. It is the natural heat of the earth originated from consolidation of dust and gas over 4 billion years ago that occur in rocks. The prime source of this heat is the gradual decay of long-lived radioactive isotopes (^{40}K , ^{232}Th , ^{235}U and ^{238}U). From the surface down through the crust, the normal temperature increase with the increase of depth ($17^\circ\text{C} - 30^\circ\text{C}$ per kilometer) Below the crust lies the

mantle that is made of highly viscous, partially molten rocks with temperatures between $650^\circ\text{C} - 1250^\circ\text{C}$. At the Earth's core, which consists of a liquid outer core and a solid inner core, temperatures vary from $4000^\circ\text{C} - 7000^\circ\text{C}$.

The outward transfer of heat occurs by means of conductive heat flow and convective flows of molten mantle beneath the Earth's crust. This results in a mean heat flux at the Earth's surface of $80\text{kW}/\text{km}^2$ approximately. This heat flux, however, is not distributed uniformly over the Earth's surface; rather, it is concentrated along active tectonic plate boundaries where volcanic activity transports high temperature molten material to the near surface. Major geothermal regions of the world are situated in circum-pacific margins, rift zones of East Africa, North Africa, Mediterranean basin of Europe, across Asia to Pacific (Figure 1).



Source: <https://www.google.co.in/imgres?imgurl=http%3A%2F%2Fwww.indiaenergyportal.org>

Fig 1: Major Global Geothermal Resources

Other renewable energy technologies, including solar photovoltaic (PV), solar thermal, small hydro power, geothermal, sea wave and biomass energy are also spreading. As greater reliance on renewable energy sources offers enormous economic, social, and environmental benefits, we need to explore more sources of renewable energy. Geothermal energy is one of the renewable sources of energy available in the form of vast natural reservoirs of heat energy in the earth's interior. A number of geothermal power plants, which generate more than 10,000 MW power are operational in at least 24 countries of the world. Besides, geothermal energy is being used directly for heating in at least 78 countries. The largest producer of this energy is USA.

Although volcanoes erupt small portions of this molten rock that feeds them, the vast majority of it remains at depths of 5 to 20 km, where it is in the form of liquid or solidifying magma bodies that release heat to surrounding rock. Under the right conditions, water can penetrate into these hot rock zones, resulting in the formation of high temperature geothermal systems containing hot water, water and steam, or steam, at depths of 500 m to >3,000 m.

Geothermal energy in India and the world

In 2010, geothermal power plants have been installed at least in 24 countries. In 78 countries it was used directly for heat. Currently, these countries have a total capacity of 10.7 GW geothermal energy. But, only seven countries generated 88% of it: the United States, the Philippines, Indonesia, Mexico, Italy, New Zealand, and Iceland. The largest producer of this energy is USA that generates about 3,086 MW of electricity. Although geothermal power development slowed in 2010, with global capacity reaching just over 11 GW, a significant acceleration in the rate of deployment is expected as advanced technologies allow for development in new countries. Heat output from geothermal sources increased by an average rate of almost 9% annually over the past decade. It was mainly due to rapid growth in the use of ground-source heat pumps. Use of geothermal energy for combined heat and power is also on the rise.

India has reasonably good potential for geothermal. The potential geothermal provinces can produce 10,600 MW of

power. But yet geothermal power projects has not been exploited at all, owing to various reasons, mainly due to availability of ample coal at cheap costs. However, with increasing environmental problems with coal based projects, India would need to start depending on clean and eco-friendly energy sources in future; one of which could be geothermal.

Potential

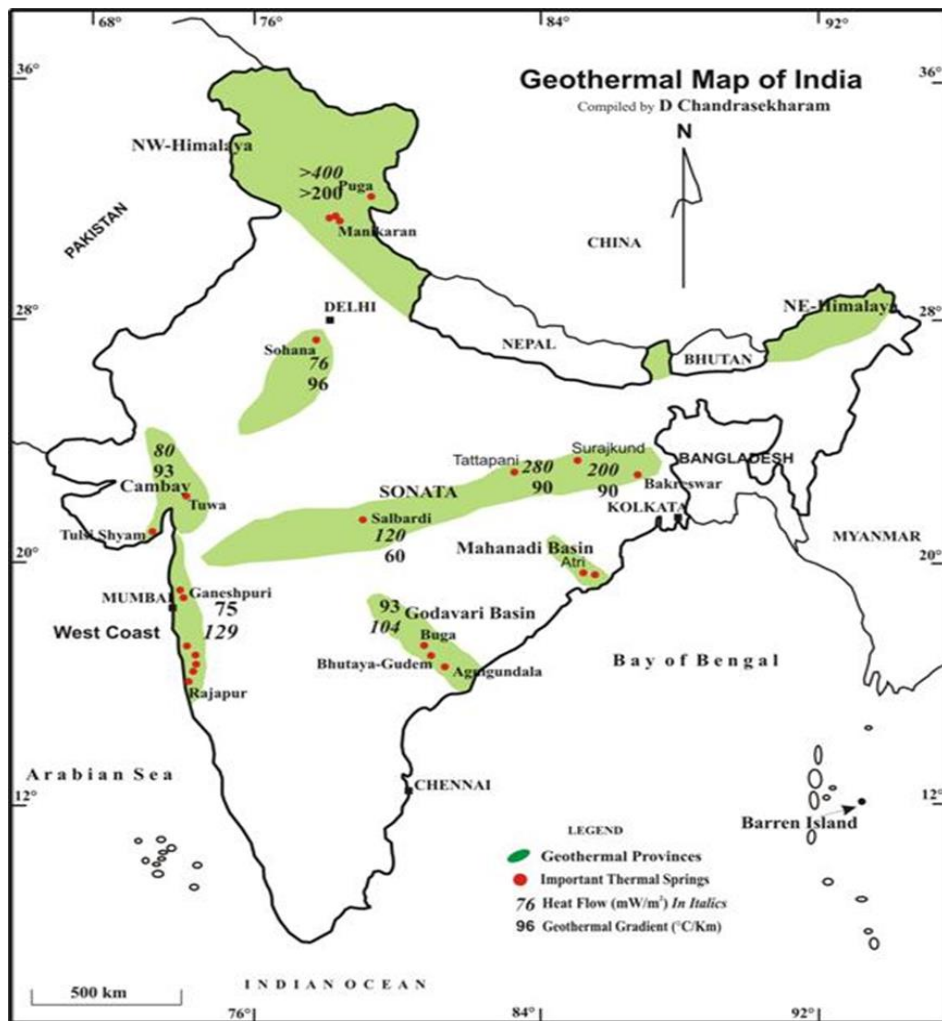
In India, exploration and study of geothermal fields started in 1970. From geological, geochemical, shallow geophysical and shallow drilling data it has been estimated that India has about 10,000 MW of geothermal power potential that can be harnessed for various purposes. Rocks formation in India range in age from more than 4500 million years to the present day and distributed in different geographical units. These rocks comprise of Archean, Proterozoic, the marine and continental Palaeozoic, Mesozoic, Tertiary, Quaternary etc. The GSI (Geological Survey of India) has identified 350 geothermal energy locations in the country. The most promising of these is in Puga valley of Ladakh. The surface temperature of the hot springs ranges from 35°C to 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. There are seven geothermal provinces in India: the Himalayas, Sohana, West coast, Cambay, Son-Narmada-Tapi (SONATA), Godavari, and Mahanadi. With the recent explosions, The Barren Island (a part of Andaman-Nicobar Islands chain) also has been added to these. The important sites being explored in India are shown in the map of India (Figure 2).

Details about the temperatures, heat flow values and geothermal gradients of the provinces discussed have been given in the table given below:

Table 1

Province	Surface temp. (°C)	Reservoir temp.(°C)	Heat Flow(mw/m ²)	Thermal Gradient °C)
Himalaya	>90	260	468	100
Cambay	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

(Source: Chandrashekhram, 2000)



(Source: <https://www.google.co.in/imgres?imgurl=http%3A%2F%2Fdchandra.geosyndicate.com>)

Fig 2: Major Geothermal Resources of India

Characteristics and applications of geothermal energy

Geothermal energy is a huge, power resource that is clean (emits little or no greenhouse gases), reliable (95% of average system availability), and home-produced (making our dependency less on imported oil). Geothermal resources range from shallow ground to hot water and rock several kilometers below the Earth's surface, and even farther down to the extremely hot molten rock called magma. Deep wells can be drilled into underground reservoirs to tap steam and very hot water that can be brought to the surface for use in a variety of applications.

The general characteristics of geothermal energy which make it important significantly for both electricity production and direct use are:

1. Extensive global distribution; it is accessible to both developed and developing countries.
2. Environmentally friendly nature; it has low emission of greenhouse gases.
3. Indigenous nature; it is independent of external supply and demand effects and fluctuations in exchange rates.
4. Independence of weather and season.
5. Contribution to the development of diversified power sources.

Potential applications of geothermal energy

1. Power generation
2. Cooking
3. Space heating
4. Use in greenhouse cultivation
5. Crop drying

Geothermal energy can be used effectively in both on- and off-grid developments, and is especially useful in rural electrification schemes. Its use spans a large range from power generation to direct heat uses, the latter possible using both low temperature resources and "cascade" methods. Cascade methods utilize the hot water remaining from higher temperature applications (e.g., electricity generation) in successively lower temperature processes, which may include binary systems to generate further power and direct heat uses (bathing and swimming; space heating, including district heating; greenhouse and open ground heating; industrial process heat; aquaculture pond and raceway heating; agricultural crop drying; etc.)

Technology for electricity generation

There are two types of geothermal plants: Flash steam and Binary.

1. Flash steam plant

When the geothermal energy is available at 150 °C and above temperature, the fluids can be used directly to generate electricity. In some cases, direct steam is available from the geothermal reservoir; otherwise the steam is separated and turbines are used for power generation.

2. Binary plant

These plants are used when geothermal temperature is between 100 °C and 150 °C. The fluid is extracted and circulated through a heat exchanger where the heat is transferred to the low boiling point organic liquid. This gets converted into high pressure vapour, which drives organic fluid turbines. There are several Indian organizations working in the field of geothermal energy, such as;

1. Central Electricity Authority
2. Geological Survey of India
3. Indian Institute of Technology, Mumbai
4. Regional Research Laboratory, Jammu
5. National Geophysical Research Institute, Hyderabad
6. Oil and Natural Gas Corporation, Dehradun

Moreover, there are several ongoing Projects in India working on geothermal energy, such as;

1. Magneto-telluric investigations in Tattapani geothermal area in Madhya Pradesh
2. Magneto-telluric investigations in Puga geothermal area in Ladakh region, Jammu & Kashmir

Achievements in the field of geothermal energy

Geothermal Atlas of India, prepared by the Geological Survey of India(GSI) gives information/data for more than 300 geothermal potential sites. This Atlas is being updated by GSI with the support from MNES. Applications of geothermal energy for small-scale power generation and thermal applications are being explored.

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