Geothermal Energy: Harnessing Earth's Natural Heat

M. Chakraborty [1, *] and S.Sen[2]
[1]Department of Physics, Asansol Girls' College, Asansol -713304, India
*Corresponding author. E-mail: bminakshi@yahoo.com
[2]Department of Physics, Triveni devi Bhalotia College, Raniganj- 713347, India
E-mail: sandip_sn@yahoo.com

Abstract: The heat emitted and stored in the Earth's crust is known as geothermal energy. The temperature in the center of the Earth stays about the same as that of the Sun because of continuous nuclear fusion. There are rocks that melt under high heat and pressure causing the mantle to rise; these rocks become lighter from the heat. Such molten rocks are forced from an underground source in the Earth's crust towards the surface, forcing them upwards and creating areas called "hot spots," where they become trapped [1]. Steam forms when sub-soil water comes into contact with the hot spot. This hot water formation occasionally reaches exit points on the surface. Hot springs are created when hot water dribbles out of one of these outlets. Geothermal heating , for instance, with water from hot springs, has been used for bathing since Paleolithic times and for space heating since Roman times. Geothermal power (the generation of electricity from geothermal energy) has been used since the 20th century. Geothermal power plants generate electricity at a steady rate regardless of weather conditions. Theoretically, geothermal resources are more than adequate to supply humanity's energy needs. The bulk of the extraction takes place in regions near tectonic plate boundaries.

1. Introduction: Geothermal energy (also called "thermal power") is the energy [2] created by natural heat from the earth and has many uses including cooking, heating, building, bathing, and generation of electricity. While the current energy demands in some way dwarf what geothermal power is currently used to generate on the planet in total, harnessing that energy to create power is tough. Despite its challenges, geothermal energy is emerging as an increasingly widely used renewable energy source because of its dramatic contrast to the burning of fossil fuels, such as coal and natural gas, which is not only a major contributor to greenhouse gas emissions but also a significant contributor to the climate disaster we observe today[3,4]. Geothermal energy draws from the internal heat of the Earth — a mixture of radioactive decay and planet-forming heat. In order to extract heat from this source, the hot water/steam is removed from wells drilled into Earth's crust. The steam or hot water extracted is then used to fuel turbines, which are paired with generators to generate power. Below the surface it rises 30 °C/kilometer for the first 10 km and 90 °F/mile for the first 6 miles [5]. Earth's internal heat is a colossal energy reservoir, visible above ground in mud pots and fumaroles and geysers and lava flows and volcanoes and hot springs. The main sources of generation of heat are the frictional heat between the crustal plates, as well as the radioactive decay of uranium, thorium and potassium from the crust and mantle of the Earth.

2. Geothermal Usage History: Hot springs have been utilized for bathing since the Paleolithic era. The earliest known spa is found at the Huaqing Chi palace [6]. In the first century CE, the Romans took control of Aquae Sulis, now recognized as Bath in Somerset, England, and made use of its hot

springs to create public baths and implement underfloor heating systems. These baths are considered among the earliest commercial applications of geothermal energy, as they charged admission fees. The Chaudes-Aigues district heating system in France has been operational since the 15th century and is regarded as the oldest such system in the world [7]. The first industrial application of geothermal technology occurred in 1827 when geyser steam was harnessed to extract boric acid from volcanic mud in Larderello, Italy. By 1892, geothermal energy powered the United States' inaugural district heating system located in Boise, Idaho, which was subsequently replicated in Klamath Falls, Oregon, in 1900. The Hot Lake Hotel in Union County, Oregon, built in 1907, was the first known structure to primarily rely on geothermal energy for heating [8]. In 1926, a geothermal well provided heat for greenhouses in Boise while similar methods were being used around the same time to heat greenhouses in Iceland and Tuscany[9]. In 1930, Charles Lieb invented the first down hole heat exchanger for home heating. By 1943, geyser steam and water were being utilized to warm homes across Iceland[4].The development of geothermal electric capacity gained significant momentum throughout the 20th century. On July 4, 1904, Prince Piero Ginori Conti successfully tested the first geothermal power generator at Larderello's steam field by lighting four light bulbs. This site later became home to the world's first commercial geothermal power plant established in 1911 and remained its sole manufacturer until New Zealand built a plant in 1958. By 2012, this facility had generated approximately 594 MW[12]. In California's The Geysers region, Pacific Gas and Electric inaugurated America's first geothermal power plant in 1960[13]; its initial turbine operated for over three decades producing a net output of 11 MW[14]. The USSR demonstrated an organic fluid-based binary cycle power station technology for the first time in 1967; this technology was implemented within the United States starting in 1981 and allows for harnessing temperature resources as low as 81 °C (178 °F). In an innovative breakthrough during 2006 at Chena Hot Springs, Alaska constructed an online binary cycle plant that generated electricity from a record low temperature of just 57 °C (135 °F)[15].

3. **How Geothermal Energy is Generated:** The Earth's internal heat, which is a mix of radioactive decay and the planet's formation heat, is the source of geothermal energy. Hot water or steam is extracted from wells drilled into the Earth's crust in order to exploit this heat. The steam or hot water that has been extracted is then used to power turbines, which are connected to generators to generate electricity. Below the surface of the Earth, temperatures rise at a pace of around 30 °C per kilometer for the first 10 km and 90 °F per mile for the first 6 miles. Earth's internal heat is a vast reservoir of energy that can be seen above ground in the form of mud pots, fumaroles, geysers, lava flows, volcanoes, and hot springs. The primary sources of heat are friction created at the edges of continental plates and the radioactive decay of uranium, thorium, and potassium in the Earth's crust and mantle.

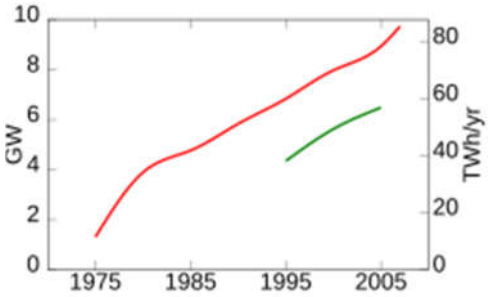
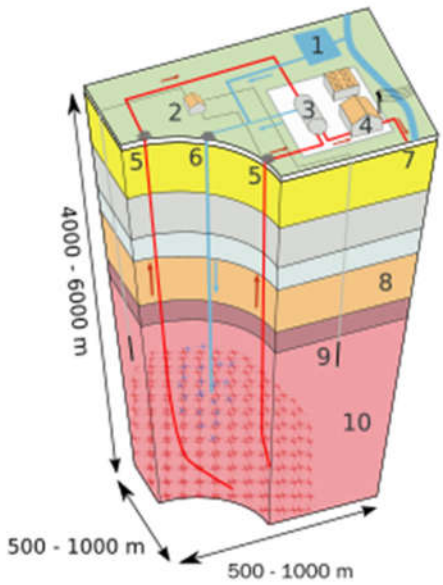


Fig 1 :Global geothermal electric capacity. Upper red line is installed capacity;[10] lower green line is realized production.[4]

4. Geothermal Energy applications: : Geothermal energy can be used for a variety of purposes, including as producing electricity, heating buildings directly, and powering different industrial and agricultural operations. In addition to powering district heating systems, this renewable energy source can be utilized to heat and cool homes and businesses.



Eig2; :Enhanced geothermal system 1:Reservoir 2:Pump house 3:Heat exchanger 4:Turbine hall 5:Production well 6:Injection well 7:Hot water to district heating 8:Porous sediments 9:Observation well 10:Crystalline bedrock [9]

Here's a more detailed look at the uses of geothermal energy:

(i) ***Electricity Generation***:

- Geothermal power plants use the Earth's heat to produce steam, which drives turbines connected to generators to produce electricity.
- This process is particularly effective in areas with high-temperature geothermal resources.

(ii) ***Direct Heating and Cooling***:

- *Heating Buildings*:

  Geothermal heat pumps can be used to heat and cool individual buildings or entire communities through district heating systems.

- *Industrial Processes:*

  Geothermal energy is used for heating and cooling in various industries, including food processing, manufacturing, and even mining.

- *Agricultural Applications*:

Geothermal energy can be used to heat greenhouses, aquaculture facilities, and even for drying crops and fruits [16 -19].

(iii) ***Other Applications***:

- *Heating water for bathing and domestic use:*

  Hot springs and geothermal wells have been used for these purposes for centuries.

- *Providing energy for spas and thermal resorts:*

  Geothermal energy is a key component of the tourism industry in many areas.

- *Melt snow and ice on roads and sidewalks***:**

Geothermal systems can be used to keep roads and sidewalks clear during winter.

(iv) ***Enhanced Geothermal Systems (EGS):***

- EGS technology involves injecting cold water into deep geothermal reservoirs to create or enhance fractures, allowing for the extraction of heat for electricity generation.
  - This can be particularly useful in areas with limited natural geothermal resources.

5. Conclusion: Geothermal energy offers a reliable and sustainable source of power that can be used for a wide range of applications, contributing to both energy independence and environmental protection While it faces challenges such as high initial costs and geographical limitations, advancements in technology and increased investment are paving the way for its growth. As the world transitions to a low-carbon future, geothermal energy can play a crucial role in providing clean, 24/7 electricity and heating. By addressing its challenges and leveraging its strengths, geothermal energy can significantly contribute to the global energy mix.

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