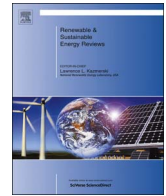




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# Renewable and Sustainable Energy Reviews

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## Pakistan geothermal renewable energy potential for electric power generation: A survey



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### ABSTRACT

Pakistan is among the naturally gifted countries that are rich in conventional and renewable energy resources. Despite the massive potential of energy resources, Pakistan is still an energy deficient country and have to import petroleum products to barely accomplish its energy demand. Geothermal energy is still one of the unexplored energy resources for electric power generation in Pakistan. Pakistan can overcome the energy shortage to a significant level by harnessing renewable energy resources, such as, geothermal energy. Majority of the geothermal hot springs and mud volcanoes exists within the seismic belt of Pakistan. Therefore, the country has viable geothermal energy manifestations. Several hot springs in Gilgit and Hunza region are originated due to the collision of Indian Plate with Eurasian Plate. Similarly, various geothermal reservoirs exist in Northeast to Southeast narrow belt along Indus basin margin. The survey discusses the current energy crisis in Pakistan and addresses the role of geothermal energy for the economic development of Pakistan. We served the manifestation and geographies of geologically active zones of Pakistan, like fault lines, plate tectonics, belt, and tectonic thrust, cleanest, base load, reliable, renewable, and sustainable geothermal energy resources. In our work, the hot springs and mud volcanoes of geologically active areas in maps are enlisted in Tables with potential features. The schemes used for extraction of geothermal energy for electric power generation are also investigated. The global electric power production from geothermal energy is visualized and discussed. Moreover, the suitable moderate temperature Binary Cycle Geothermal Power Plant for electric power generation in Pakistan is also described in detail. Furthermore, geothermal plants are experimentally summarized in different case studies. Finally the performance of geothermal and conventional thermal plants is critically analysed.

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**1. Introduction**

Fully stabilized energy supply is a need of Pakistan for the economic development. Due to increase in industrialization, urbanization, and growth rate, energy demand is increasing rapidly. Developing countries like Pakistan are facing problem to overcome the massive energy demand [1,2] and paying cost on energy import to fulfil the energy demand [3,4]. Due to aforementioned factor, Pakistan is bearing demand and supply mismanagement issues in power sector [5–7]. High cast of conventional fuel forced policy makers to renewable energy generation. In various categorizes of renewable generation, such as wind and solar energy, Geothermal energy is still an open challenge for Pakistan. This energy generation plant, feasibility study and reports, and data analysis is never touched in past decades.

The author in [8] described per capita energy consumption is directly related to economic development of Pakistan. The worldwide per capita energy consumption is listed in Table 1. The major contribution of global power generation capacity is illustrated in Fig. 1. The authors in [9] described that energy demand will potentially increase. While, conventional energy resources will deplete with time, cause increases in prices and largest source of environmental emissions [10].

The conventional energy resources emits harmful emissions in environment including CO<sub>2</sub>, SO<sub>x</sub>, and NO<sub>x</sub>. Due to depletion of coal, petroleum, and natural gas reserves, renewable energy resources is the best solution for future electric power generation. The renewable energy resources including solar, wind, biogas, and geothermal energy resources are environment friendly, produce less emission, viable, and alternative resource of power generation to meet the future energy demand. The energy demand is increasing at the rate of 2% annually, while renewable energy generation is capacity is increasing at rate of 5.2% annually which is even more than twice of demand. Thus, renewable resources are the best solution to balance energy demand and supply.

Renewable energy resources originates from natural resources, such as sunlight: water, wind, ocean tides, and biomass energy. In Pakistan resources are unlimited and replenished naturally [11,12]. Pakistan has a great potential of aforementioned renewable energy resources in various provinces such as in Punjab, North West KPK, and in 1000 km (km) coastline of Sindh, the average wind speed is almost in the range of 5–7 m/s [13]. Similarly,

Pakistan has high irradiance of solar energy and 1600 GW generation is possible annually from solar photovoltaic [14]. Solar power is an expensive option for high power generation. On the other hand, geothermal energy comprises around 2% of the renewable energy generation [15]. A surveyed, geothermal energy possesses the potential of producing 240 GW of electrical energy [16]. Geothermal energy, on the other hand, constitutes 5% of scientific studies in renewable energy, led by U.S. Geological Survey [17].

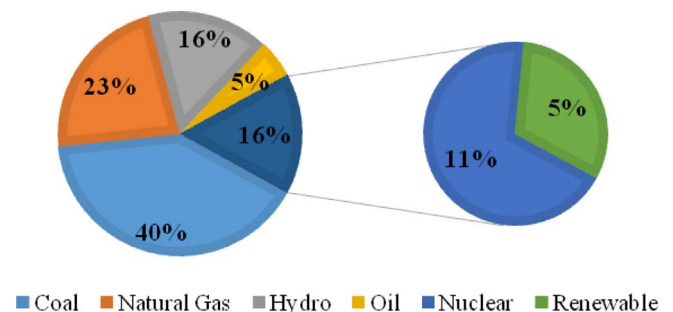
The authors in [18] stated that, solar and wind energy resources are intermittent in nature, expensive sources, and complex control schemes are required to achieve electric power for grid as compared to geothermal energy. According to Geologists, structural studies confirm that Pakistan lies on junction of tectonic plates. Therefore, country has abundant geothermal reservoirs including low, medium, and high temperature to support energy sector to a significant level [19]. Worldwide, more focus is given to geothermal energy. Global installed capacity of geothermal energy in the year 2015 is illustrated in Fig. 2 [20]. Unfortunately, Pakistan has no geothermal power plant yet installed [21]. So, among all the above-mentioned renewable energy resources, geothermal energy is the least exploited energy resource for electric power generation in Pakistan.

Geothermal energy is the heat energy present inside the earth surface in the form of hot springs, fumaroles, volcanoes, and geysers. This heat inside the earth is naturally created due to the continuous decay of fossil fuels (20%) and radioactive minerals (80%) [22,23]. Moreover, geothermal energy is one of the cleanest, abundant, reliable, renewable, and sustainable energy resources. Consequently, it produces less carbon emissions as compared to coal, oil, and gas [3]. In addition, the key benefit of geothermal energy is its 24 h availability, so called base load energy resource, while solar works only in daylight while wind turbines only work in the presence of favourable wind speed [4].

The occurrence of geothermal energy is analysed in four different types, namely hydrothermal, geo-pressured, hot rock, and dry rock. Due to versatility for various daily lie applications, the most explored form is hydrothermal resources [24]. Aforesaid geothermal energy resources provide temperature variations respective to the depth of reservoir well. However, the temperature is minor near to the surface and increase down towards core of earth. 1.5 km deep well of geothermal reservoir provide hot water to the surface [17]. The hot water is further utilized in various direct heating and indirect (electric power generation) applications [25]. The critical analysis of depth and

**Table 1**  
Global power generation capacity till end of 2012.

Country	Per capita energy consumption (KWh)
USA	13,361
France	7756
Germany	7217
China	2942
Turkey	2474
India	644
Sri Lanka	636.3
Pakistan	457
Nepal	454.1
Bangladesh	278.1
Afghanistan	119.8



**Fig. 1.** Shares of global energy resources.

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