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Geothermal Potentials of Pakistan -- a Country Update Report

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ABSTRACT

Pakistan has been facing an energy crisis for the last several years. The government has realized this situation now and has made efforts to boost power generation. Additional Power plants are being constructed to meet these energy requirements. As a result, there is a considerable reduction in power breakdown (load shedding), mostly in urban areas of the country. Simultaneously, the need for the development of alternate energy resources is intensely being felt. Unfortunately, due to various political/economic reasons, not enough work has been done in this sector. The country, however, is blessed with enormous geothermal potentials in different locations. It is, therefore, need to convince authorities in Pakistan about the importance of this cheaper and environmentally benign source of energy. Geothermal activity in Pakistan owes its Origin to the Collision of Indian Plate with the Eurasian Plate. Major structural elements such as Main Mantle Thrust (MMT) and Main Karakorum Thrust (MKT) produced. Geothermal manifestations concentrate along with these features. Hotsprings occur mostly in the northern areas and Azad Kashmir where the surface temperature is about 25oC, this is an indicator of higher subsurface environmental conditions. It has been observed that high enthalpy fields are generally confined to the zones of crustal weakness. These zones are such as plate margins and some in other areas of volcanic activity. During the rifting of the Indian Plate (L. Jurassic to E- Cretaceous), widespread volcanic eruption resulted in hotspot activity independent of tectonic plate boundaries in the area. In northern areas, rock units represent Indian mass, Karakoram Island Arc and Eurasian mass. The rock units exposed in the area are metamorphic to granitic and range from Pre-Cambrian to tertiary in age. There is a concentration of hot springs along with Main Mantle Thrust (MMT) in Chilas and Hunza areas respectively. In the province of Sindh thermal Springs are mostly concentrated in the vicinity of Karachi (Manghopir area). These are confined in the hilly terrain in Northwest and plain areas in the southeast. In Punjab the hot springs and seepages follow the alignment of syntaxial bend and are scattered in wide areas. In the province of Balochistan, Hamaun-e- Mashkhel, which is a large Graben structure, also indicates geothermal activity as observed by the aeromagnetic study.

1. INTRODUCTION

Overall Energy Setup in Pakistan

Pakistan is rich in all types of conventional and renewable energy resources, including geothermal. Yet, the nation is still facing growing shortages in the energy sector since the last two decades (Bukhari, 2015). The electricity production in Pakistan averaged 8122 Giga Watts hour from 2003 until 2019 reaching an all-time high of 15790 Giga Watt-hour in August 2018 and a record of lowest energy of 4195 in September 2010. The electricity breakdown was high up since 2008, and the government continued its endeavors to manage the crisis. Most of the industrial units were forced to produce electricity through power generators, hence increasing the use of fossil fuels. Though geothermal and all other types of conventional energy resources were rich, the country remained energy-deficient due to several economic/political reasons. The government is encouraging the use of LPG to combat the crisis as a result of which there is seen a constant increase in LPG filling stations in different parts of the country. Geothermal is still one unexplored source of energy for electric power generation in Pakistan. The country can overcome the electricity shortage by harnessing renewable energy sources such as geothermal energy because the country has its various geothermal manifestation in different parts. Presently, the government is trying hard to develop power plants to cope with the situation and to increase power output. This has unfolded a series of opportunities for investors to exploit the potential of these resources in the country for electricity production. The world electricity production from gas is 19%, while in Pakistan Natural gas contributes to producing 29%, and nuclear energy is only 2%. On the other hand, furnace oil contributes to 35% of the total electricity generation. As estimated, 180 billion tons of coal are present in Thar Coalfield in the province of Sindh, which is the third biggest coal reserve in the world. Unfortunately, according to some speculations, Thar's coal is unstable and cannot be treated to produce energy. Maybe this could be the reason that no serious effort is being made to exploit these reserves. The conventional energy resources emit harmful emissions into the Environment, including Carbon mono-oxide (CO), Sulphates (SO_3), nitrates(NO_3) and other poisonous gases. Meanwhile, renewable energy resources are environment-friendly and produce fewer emissions. According to recent research, present oil and gas reserves will exhaust in the second half of this century. Therefore, renewable alternative energy resources are being given due importance and are being extensively explored. Another important alternative source of energy is wind. A minimum of 13 km/hour speed is supposed to be sufficient to convert wind energy to electrical energy through wind turbines. Pakistan has potential places for wind energy in the coastal areas of Karachi, Thatta, Jiwani (Balochistan coastal belt) northern areas, and Azad Kashmir.

2. GEOTHERMAL ENERGY IN PAKISTAN.

Geothermal areas have been identified in three areas of Pakistan. The Himalayan Collision zone, Chagai Volcanic arc, and the Indus basin margin Geothermal Resource potential are shown in Fig 1. A geological Survey of Pakistan has identified Mud volcanoes, hot geothermal fluids in the province of Balochistan, dormant volcanos, and hot magmatic water up to 150 °C in the Chagai Volcanic Arc. A GSP research concluded the presence of hydrocarbon basins and co-produced hot geothermal magmatic water (80-170) in the province of Sindh. In addition to that, there are 300 dry depleted and abandoned oil & Gas wells which can be used for Geothermal energy development. According to a Prominent Pakistani Scientist, Mr Javed Ahmad, 'the country has been blessed with large potential of Geothermal energy that could generate 100,000 MW of electricity at the cost of 5-10 cents /unit'. Research of Mr Javed was widely acknowledged by US experts during the US Pakistan clean energy Conference in Washington and. As a result of that, the Government of Pakistan included Geothermal energy in the Renewable policy framework. The Geothermal energy is a clean, sustainable/renewable form of energy that could be harnessed to meet the energy demand of the country. This energy could be used for electricity generation, space heating, and cooling of buildings Supply of hot water, Greenhouses, Fish farming, and setting up of small industrial units (Ahmed,2014). In the Northern Himalayan Region, there is extensive development of Mineral alteration zones and fumaroles, besides the presence of a large number of hot springs in different parts of the country and indications of Quaternary volcanism in the western part of Balochistan.

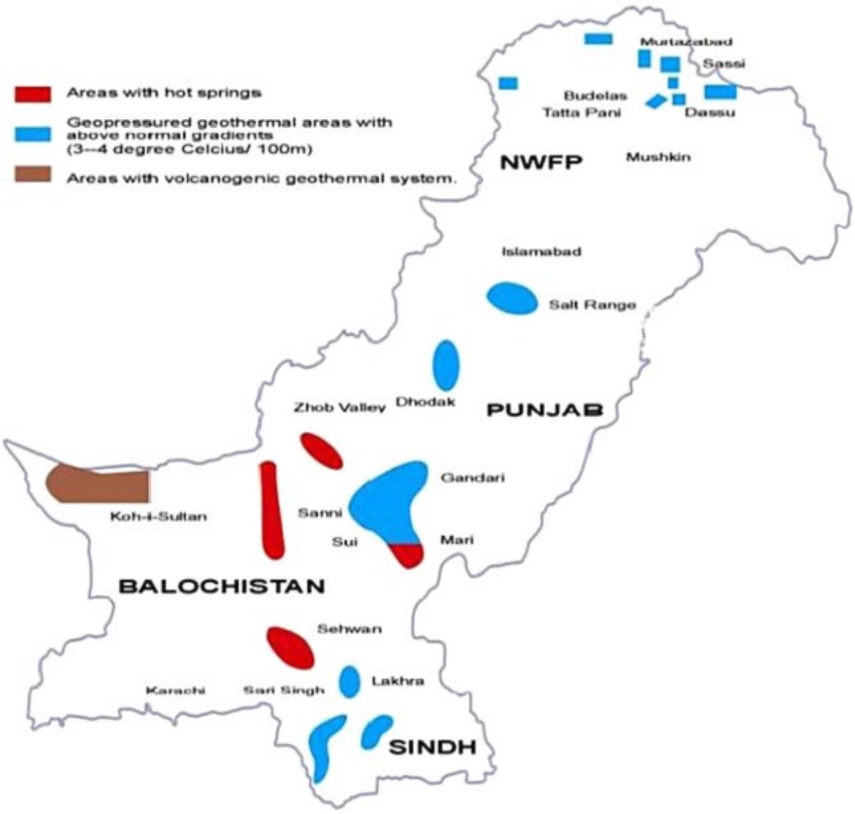

Fig 1. Map showing the Geothermal areas of Pakistan

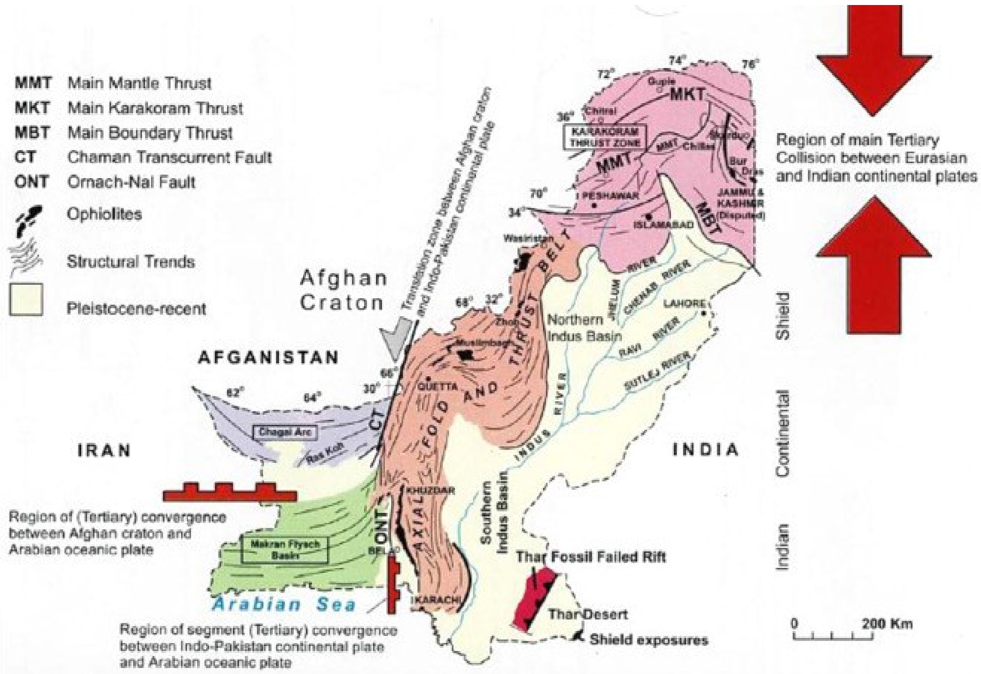

Fig 2. Map showing the Structural elements of Pakistan.

In the northern areas of Main Karakoram, thrust extends towards the east up to Myanmar. This plate boundary extends into the northern areas of Pakistan, including Kashmir. In shallow regions, active fault systems are the main heat source (Kazmi, 1979.) The shallow part of the crust is highly effected by secondary faults like the Main Boundary Thrust (MBT) (Fig2). Actually, it is the Plate marginal zone located along the Striking junctions (suture zone) of Eurasia extended in the Northern areas of Pakistan including parts of Kashmir. Further, volcanic regions are considered highly favorite spots to explore Geothermal energy (Bukhari,2015). As shown in the map, Pakistan's volcanic regions are entirely located in Balochistan.

3. METHODS OF GEOTHERMAL STUDIES

3.1 Preliminary Investigations:

Initially, large geothermal fields are investigated with relatively inexpensive methods. This methodology is to mature stages when advanced and expensive methods are adopted in most promising fields (Mughal, M.N.1998). Geological and Geophysical methods of exploration are generally used to explore the geothermal resource. The main purpose is to obtain the maximum amount of information about the properties of any geothermal system. At the beginning of a research program, water samples are collected applying different thermometers such as Na/K, Na-K-Ca, and SiO2. Following methods that are thought to be most suitable for the expected type of Geothermal System. Chemical data is also interpreted with the help of qualitative geothermometers. The methodology adopted to warm buildings is shown as in Fig (3), other measurements like pH, eH water conductivity. Flow rates are determined by using calibrated containers. The nature of low temperature and high-temperature fields are usually quite different. The former is based upon heat transfer through general heat flow while the latter has heat sources of intrusive origin. Temperature gradients are sometimes measured to detect heat flow anomalies. However, most exploration for Geothermal resources (superheated water and steam) is done with indirect methods. Resistivity or Seismic methods may be used to map the magma chamber, which is the source of heat or to detect faults, or other subsurface features that control the heat flow.

3.2 Geological Mapping:

The location of hot springs is often at faults or dykes that break up the rock series such as volcanic lava series of sedimentary formations. Knowledge of these structures is of utmost importance for complete apprehension of the geothermal system. To prepare a geological map of the area is necessary to map geothermal manifestations in any geothermal field. Then, other parameters such as temperature, the flow rate of the springs, regional stratigraphy. Structural features such as dykes, folds, faults, joint patterns, and others are recorded. Hydrological properties such as porosity & permeability of the strata are given due importance.

3.3 Geothermometry:

The estimation of pressure-temperature conditions at which a geological material is formed is geothermometry. These are commonly based on mineral assemblage and mineral composition information. The most commonly used geothermometer is silica geothermometer. The quartz geothermometer is used for prediction of high temperature(>180°C), while the Chalcedony geothermometer is used for low reservoir temperature. The solubility of the amorphous silica has an effect by pH values when it is greater than 9.5. In order to deal with high pH and hard waters that do not yield reliable temperatures, when using the silica geothermometer, Na-K and Na-K-Ca geothermometers were proposed and have been used successfully in such systems.

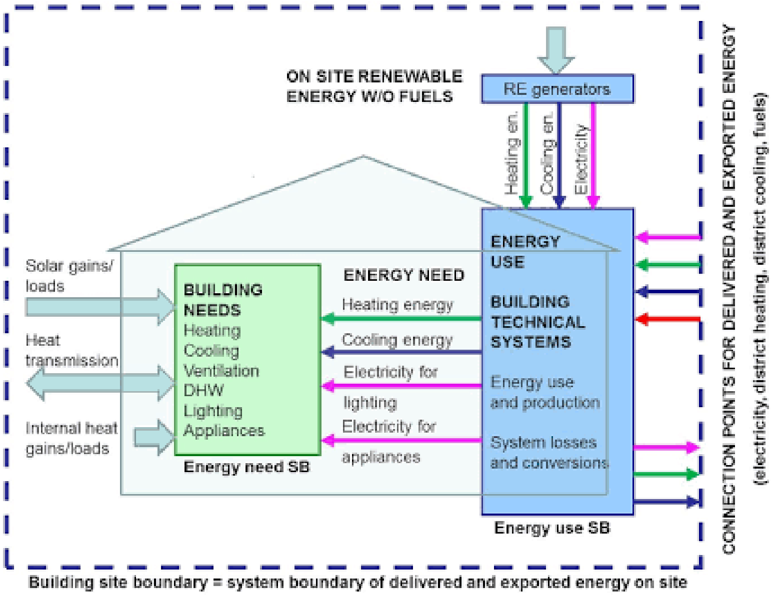

Fig 3. The methodology generally adopted to warm and improve the energy performance of a building.

3.4 Geochemistry:

Geochemistry has important applications in the exploration of geothermal resources. In the early exploration stage, it is mainly used to provide estimates of the reservoir temperature and the general chemical characteristics of the geothermal water. Geochemistry aids in the selection of the geothermal area for more detailed surface exploration and exploratory drilling. In production, it is an important monitoring method for controlling changes in the geothermal Reservoir (Moghul, N.A., 1998).

4. GEOTHERMAL ENERGY ZONES OF PAKISTAN

Geothermal energy resources of Pakistan are classified on their distribution in specific tectonic zones. Also, on the basis of thermometry and mode of occurrence, such as sedimentary basins distribution. The geothermal energy resource zones of Pakistan are as follows:

(i). The Northern Himalayan Region

(ii) The Sedimentary Basins of Pakistan

(iii). The Chagai Volcanic Arc of Baluchistan

(i) The Northern Himalayan region

The Northern Himalayan Region is associated with the global geothermal belt. The Main Karakoram Thrust (MKT) extends in the east up to Myanmar and in the west up to the Alps. It is a high-temperature geothermal area in Pakistan, consisting of hot springs, geysers, and fumaroles. It is the Plate Marginal Zone located along the striking junction (suture zone) of Eurasia extended in the Northern Areas of Pakistan including some parts of Kashmir. The heat sources are mainly active secondary faults and volcanic influence in the shallow part of the Earth's crust. The earth's crust near subduction zone is the deepest part of the earth crust whereas the crust of sub-Himalaya and lesser Himalaya is the shallow part of the crust. This one is highly affected by secondary faults like Main Boundary Thrust MBT, Main Central Thrust MCT, Salt Range Frontal Thrust, and others. The heat source is mainly due to the movement of actively associated faults. According to Mughal, there is a possibility that young intrusions of granite & granodiorite, which do not reach the surface, are still in the process of cooling. However, there is no evidence of Volcanic activity, except for Kamila Amphibolites in the Swat area (Loucks etc.) of Panjal Volcanism of Permo Carboniferous Ages.

(ii) The Sedimentary basins of Pakistan

Pakistan's large Sedimentary Basins are the product of intricate plate interactions involving Indian, Arabian, and Eurasian Plates. A large (more than 800km long) transform zone (Bela-Chaman) separates two major sedimentary Basins, the Indus in the east, and Balochistan to the west. A third Basin, the Pishin, resides in the Plate margin region and extends northward into Afghanistan where it is known as the Katawaz Basin. Pakistan is characterized by the presence of about 300,000 sq.km of a sedimentary area with a sedimentary volume of 1,000,000 cu, m. These features speak of the potential for large hydrocarbon yields, a variety of petroleum plays including Cambrian, Permian, Jurassic, Cretaceous, Paleocene, Eocene, and Miocene. Indus Basin is the major sedimentary basin of Pakistan. The hot sedimentary aquifers are associated with hydrocarbons, and also developed as a result of the development of secondary faults in the Indus Basin, where dozens of geothermal springs have been identified. The Indus Basin has been further subdivided into Upper, Middle, & Lower Indus Basin.

The Upper Indus Basin, also known as Northern Indus Basin, is the sedimentary basin which covers the entire Northern area of the province of Punjab, and Kohat & Bannu areas of the province of Khyber Pakhtun Khaw (KPK). The sub-basin is filled with thick (up to 7000 m) of marine and continental fluviatile sediments which range in age from Pre-Cambrian to Pleistocene. Upper Indus Basin has been the leading oil-producing area since the first commercial oil discovery in 1915 at the Khaur locality. The Potwar-Kohat Basin is a part of the Upper Indus Basin, which is famous for hot sedimentary aquifers in Pakistan. The Potwar Basin is the largest geothermal Basin of Pakistan, which has many producing oil and gas fields. There are dozens of wells which are coproducing geothermal hot waters from 80 to 140° C temperatures. Many dry wells with no hydrocarbon discovery have been capped because of hot water and high pressure in the Basin. These are sources of geothermal energy for power generation. The temperatures in the dry, abandoned and producing wells are given in Table 1.

The Middle Indus Basin, also known as Central Indus Basin, has a Fold and Thrust Belt in the west, a Depression in the middle, and a Platform area in the east. In this Basin, Jurassic, Cretaceous Paleocene and Eocene hydrocarbons plays have been found productive. Trusted anticlines characterize the Fold Belt, the depression has a thick sedimentary fill and is a major hydrocarbon kitchen. The Platform is a westward dipping monocline where stratigraphic traps, fault traps, paleo topographic features, salt produced traps, and occasional compressive folds are present. Many geothermal springs and hot water sedimentary aquifers have been located at different sites in the Middle Indus Basin. The Middle Indus Basin covers the southern part of the Punjab Province and small parts of Baluchistan & Sindh Provinces. It contains sedimentary rocks of Pre-Cambrian to Quaternary Ages. The thickness of the sedimentary section is maximum in the central depression. Many oil, gas and condensate discoveries have been made in this Sub-Basin and are producing since 1954.

The coproduced and geo pressured geothermal hot waters have been reported at different places. The temperature of geothermal waters in dry and producing wells in Middle Indus Basin is given in Table 2.

The Lower Indus Basin or Southern Indus Basin is a sedimentary basin that is famous for the discovery of several oil & gas fields in Pakistan. This zone is north elongated to south. The Basin covers most of the Sind Province and some parts of the Baluchistan Province. The Lower Indus Basin is filled with 5000 to 10000 m thick sedimentary rocks of Mesozoic to Recent Ages. Like Middle Indus sub-basin, it also has a platform area in the east, some troughs and highs, a major depression, and a Fold Belt in the west. A number

The Baluchistan Basin is located in the subduction zone, where an oceanic slab of the Arabian plate was subducted beneath the Eurasian plate. It is mainly a basin formed of thick Tertiary and Quaternary clastic sediments with some carbonate rocks of Cretaceous, Palaeocene, and Eocene Ages in the northern part of the Basin. Very little exploration has been carried out for hydrocarbons evaluation in this basin. The large offshore area along with the Coastal Belt is particularly prospective for hydrocarbon discoveries. There are a number of mud volcanoes in the Makran Coastal area where geothermal springs and fumaroles are present, flowing with hydrothermal fluids at some localities. No effect has ever been made to survey the Mud volcanoes or geothermal sites of Baluchistan Basin including Makran Coastal Areas.

The Pishin sedimentary Basin is located in the northeastern part of the Baluchistan Province and extends into Afghanistan where it is known as the Katawaz Basin. Two major faults bound the Pishin Basin: Chaman Transform Fault in the northwest and Zhob Valley Thrust in the east. There are other thrust faults and high angle reverse faults in the Basin. The occurrence of thermally mature hydrocarbons has been confirmed in the Pishin Basin. There are many oil & gas seeps in the Basin. A series of Mud volcanoes are located in the north of the Killa Saifullah Town. Geothermal springs have been located in the Killa Saifullah and Zhob Districts within the Pishin Basin, where hot geothermal fluids are flowing at some locations (Javed).

5. THE CHAGAI VOLCANIC ARC, BALUCHISTAN PROVINCE

The Chagai Volcanic Arc located in the Chagai District of Baluchistan is associated with the nearest active magmatic activity and several dormant volcanoes. Volcanic regions are considered highly favorite spots to explore Geothermal energy (Bukhari, 2015). Koh-i-Sultan, which is a dormant volcano, is a major source of geothermal water in the Chagai District. There are many hot springs, for example, in the Cheken Dik area north of the Nokhundi town, and fumaroles observed in this Arc in the northwest of Baluchistan Basin (Abu Bakr,1965). The heat sources are mainly from volcanic influence in the shallow part of the Earth's crust. The temperatures of geothermal waters from the Koh-i-Sultan dormant volcano have been recorded from 120 to 150°C.

Preliminary resource estimates that the geothermal energy resource potential of Pakistan has been preliminarily estimated as under Table 1.

Initial investigations show that Punjab and Sindh Provinces have the maximum potential of co-produced and geo-pressured geothermal energy resources. These are available in Potwar Geothermal Basin, Badin Sanghar Rift-Basin & Upper Indus Geothermal Basin. Since 1866 total number of 841exploratory wells have been drilled in Pakistan. More than 500 well was dry or with no commercial discovery. The author has evaluated the temperature data and found that 300 wells could produce geothermal energy having more than 105°C for power generation in Pakistan (Ahmed, 2014). Moreover, 1164 wells have been drilled for appraisal and development. Many of these oil & gas appraisal wells were dry and or now depleted and are a good source of geothermal energy for power generation. However, detailed investigations are required to evaluate the potential of each well for power generation.

5.1 Hydrothermal Energy Resources

Hot water or steam springs, geysers or fumaroles are some types of hydrothermal energy resources which are continuously flowing in many areas of Pakistan. The Northern Areas of Pakistan, including Chitral, Giglit, Baltistan, and Kashmir are famous for such type of geothermal energy resources with temperatures ranging from 80°C to more than 180 ºC (Table 2). The geothermal energy resources may exceed 30,000 MW of electricity and heat in the Northern Areas of Gilgit Baltistan, Chitral, and Azad Kashmir. There are many hot water springs in Punjab, KPK, Baluchistan and Sind Provinces which are a source of geothermal energy. Photo Graph A shows hot steam and water at 140°C flowing all the year in Astor valley in Giglit Baltistan. iii. Deep Geothermal Resources/ Enhanced Geothermal Systems (EGS).

5.2 Deep Geothermal Resources

Geological and Tectonic features such as active seismic zones and abandoned oil and gas wells with high temperature show the deep geothermal energy resources that are available in different parts of the country. These could be developed through enhanced Geothermal Technology. As estimated, these resources can produce 30,000 MW of electricity.

5.3 Shallow Geothermal Resources

Shallow Geothermal energy resources, such as solar energy, are available from 10 feet to 500 feet depth and are used for cooling and heating of buildings and supply of hot water. Pakistan has sunshine all over the country; therefore shallow energy resources may be estimated at more than 60000 MW equivalent of electricity.

6. GEOTHERMAL ENERGY POTENTIAL FOR POWER GENERATION.

Pakistan is producing more than 80% of electricity using fossil fuels like furnace oil, diesel oil, natural gas, and gasoline. About 15% of electricity is produced from hydropower, nuclear, and wind resources. Pakistan's economy is highly dependent on imported fossil fuels, and the average import bill is more than 15 Billion USD per annum. The geothermal energy resource available in all the province of Pakistan could be used for power generation, heating & cooling of buildings, a supply of hot water, and direct use applications. This will reduce its dependence on imported fossil fuels. Presently, the co-produced hot waters from the oil & gas wells are being drained out in dry streams, or re-injected into the wells, or evaporated after heating using natural gas. Keeping in view the coproduced, geo pressured, hydrothermal, and deep geothermal energy resources available in all over Pakistan the preliminary potential for power generation has been estimated at about 100,000. MW (Photo Graph- B). Geothermal water flowing at 5000 barrels per day at 105°C being drained tributary.

Note: i) Present geothermal energy consumption for power generation is Nil.

ii) Three Geothermal Heat Pumps have been installed for demonstration of the purpose at different locations in Pakistan by Energy Foundation, Pakistan.

The developable geothermal resources have been estimated, keeping in view the different sectoral requirements.

TABLE 1: Temperature and Geothermometer estimates based on samples from the hot springs in the Northern areas of Pakistan (*Shuja 1986*)

No	Location	SiO_2 (°C)		Na-K	Na-K-Ca (°C)		Na-K-Ca (Mg- Corr)	Temp
		Adiabatic	Conductive	(°C)	β=1/3	β=3/4		°C
1.	Chilas	83.0	79.4	215.5	171.7	75.2	66.6	30
2.	Jaglot	85.4	82.1	56.9	56.9	127.7	84.8	65
3	Jaglot	88.7	85.9	85	148	160.1	43.2	50
4.	Murtzabad.	93.8	91.7	212.7	220.4	235.3	133.0	75
5.	Murtazabad	110	110.5	240.6	226.8	221.3	8.9	80
6.	Murtzabad	110	110.5	240.6	226.8	221.3	8.9	80
7.	Murtazabad	119.6	121.7	312.7	235.2	175.4	72	26
8.	Murtazabad	122.1	125.1	209.3	219.3	236.9	76	91
9.	Hakuchar	115.4	116.7	252.3	191.3	97.9	53.4	50
10	Hakuchar	116.6	118.2	251.2	0.0	0.0	95.3	49
11.	Buladas	113.4	114.2	159.1	116.6	116.6	23.7	39
12.	Buladas	119.0	121.0	153.8	104.5	104.5	75.6	40

Table 2. Locations of Geothermal Springs in Pakistan (*Moghul,1998).*

Location		Temperature.
Himalayan Collision Zone.	*Tarboto Das (Gilgit Area)*	Ranges Up to 910° C
	Darkot Pass(Gilgit Area)	Ranges Up to 910°C
	Garam Chashma	850-2520°C
	Mashkin	860° C
	Sassi	400°C
Chagai Volcanic Arc.	*Chicken dik Springs*	25-320°C
	Koh-e-Sultan Springs.	
Indus Basin Margin	*Mango Pir Area*	480° C
	Salt Range Area	25-32°C

Table 3. Table showing different Parameters recorded on Murtazabad(M), Budelas (B), and Tatta Pani (TP) Hotsprings Northern Areas of Pakistan ***(Shuja,1986).***

Hot spring.	Temp (°C)	Flowrate	pH	Electric Conductivity µ S/cm	Hot water Properties	Geologic Assemblages
M 1	42 (Amb 35)	33 l/min	7.50	1720	Colorless	Granitic Staurolite.
M 2	37 Amb 33.5	67 l/min.	7.8	1856	Colorless H_2S Smell	Baltit Group Rocks
M 3	30 Amb 28	500 l/min Visual Est.	9.21	2470	Colorless H_2S Smell	Terrace deposit
B 1	46 Amb 32	100 l/m Visual Est.	7.85	1540	Colorless H_2S Smell	Talus Garnet Mica Schist
B 2	36 Amb 17	100 kl/hr Visual Est.	7.49	776	Colorless H_2S Smell.	Talus-Garnet Staurolite.
TP 1	83 Amb 17	>62 l/min	8.83	1060	Colorless H_2S Smell.	Terrace deposit Fractured Amphibolite.
TP 2	65.5 Amb 36.5	800 l/min.	8.57	1540	ColorlessH_2S Smell., salty Hot.	Talus Fractured Amphibolites.

Table 4: Some measured Physical Characteristics of hot springs in the Chagai area of Balochistan. ***(Todaka, N. et al., 1988).***

S.No	Locality	Temp (°C)	Flow Rate.	pH	Properties.	Conductivity µ s/cm	Geological Characteristics
C 1.	Chiken dik	29 Amb 40.9	<2l/m	6.58	Colorless Odorless.	>10000 µs/cm	Recent Deposits.
KS 1.	Kon-e- Sultan.	29.5 Amb 34.7	> 1 l/min	7.44	Colorless Odorless.	1060µ s/cm	Basal Conglomerate
KS 2	Koh-e-Sultan	23.2 Amb 36.9	<1 l/min	6.7	Colorless Odorless	> 10000µs/cm	Koh-e-Sultan Volcanics.
KS-3	Koh-e-Sultan	32.0 Amb 36.9	<1 l/min	6.7	Colorless Odorless	2021 µ s/cm	Koh-e-Sultan Volcanics
KS-4	Koh-e-Sultan.	26.9 Amb 31.1	<1 l/min	2.77	Colorless H_2S smell	>10000µs/cm	Altered Andesitic lava.
KS-5	Koh-e-Sultan	25.6 Amb 31.9	<1 l/min	2	Colorless H_2S smell	>10000µ s/cm	Altered Andesitic lava

Table 5: Preliminary Estimates of Geothermal Energy Resources of Pakistan ***(after Javed Ahmed, 2014).***

Geothermal Energy Resources.	Proposed Developable Resources				
	Preliminary Estimated Resources.	2020	2030	2040	2050
	MWe	MWe	MWe	MWe	MWe
Coproduced & Geo pressurized	40,000	10000	15000	10000	10000
Hydrothermal	30,000	2000	5000	5000	5000
Deep geothermal.	30,000	2000	3000	5000	10000
Thermal Use:	MWt	MWt	MWt	MWt	MWt
Shallow Geotherm for Air Conditioning hot water.	6000	5000	5000	10000	1000
Direct Used	30000	3000	5000	5000	5000

Photograph A: Hot spring at Gurgur on Karakoram Highway, Pakistan (*Source GSP/Flicker Scott Christian Creative Common).*

Photograph B: Tattapani hot springs used for bathing and for Skincare by local people because the water is rich in Sulphur *(Source GSP/touristindia.com).*

7. CONCLUSION & RECOMMENDATIONS:

High-temperature Geothermal Reservoirs generally confined to Neovolcanic zones such as in Iceland and other parts of the world utilize geothermal energy, and >200oC Temperature is required for this purpose. In Turkey, geothermal fields are not related to young volcanic activity (Kizildere Geopower Station).

The Koh-e-Sultan volcanic eruption, which is very large, is of Pleistocene age. This eruption shows high heat conductivity owing to a large magma chamber, while in the Chagai area, groundwater is mixed with Hydrogen sulphide gas-forming alteration zones.

In Northern areas, there is a concentration of geothermal springs. However, no younger volcanism is known in the area. Apparently, geothermal activity is the result of the collision of the Indian Plate with the Eurasian Plate (Todaka et al. 1999).

Hotsprings are found along the Main Mantle Thrust (MMT) and the Main Karakoram Thrust (MKT). Such as Tatta pani sassi bumodin related to MMT, and Murtazaba, Buledas and Chutran to MKT. Further study is required to ascertain it. Similarly, hot springs of the Karachi area have reservoir temperature < 100oC; it needs further study.

Following Recommendations are suggested in order to a complete framework of geothermal manifestations and to utilize these resources mainly for power generation (Aftab, S.M. 1998).

- A fundamental geological investigation, including detailed geological mapping of areas bearing Geothermal potentials.
- Study of the Tectonic Mechanism, Geodynamic set up the variation in altitude and horizontal position of potential sites with the help of Remote sensing and satellite imageries.
  Study of the volcanic activity, radioactivity, and emplacement mechanism of igneous intrusions.
- Hydrological studies including groundwater circulation impact on tectonic stress, recharge study, and hydrothermal evolution of the geothermal system.
- Seismic electric aeromagnetic surveys in order to make a subsurface of a three-dimensional model.
- Geothermal gradient and determination of depth drilling of production wells.
- Study of Physical properties and behavior of rock fluid samples at elevated temperature and pressure.

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