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Geothermal Resources of Saudi Arabia – Country Update Report

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ABSTRACT

In terms of energy, the Saudi Arabian land is gifted with huge resources of petroleum, natural gas, and solar energy. It also holds bright prospects of exploiting the other forms of energy such as the wind energy, nuclear energy, and the geothermal energy, because of its variety of geological features and environments. With respect to geothermal resources, there are 10 hot springs with varying deep temperatures of 50 to 120°C and different flow rates. In addition to this, there are three major harrats namely Khaybar, Kishb, and Rahat of geothermal interest. The crust thickness in these areas varies between 20 and 40 km and its lower part consists of mafic meta-igneous granulites. As of today, none of these are being used as source of electricity generation or heating purposes. It is believed that some of the thermal water springs can be utilized for electricity generation purposes in the time to come.

1. INTRODUCTION

Exponentially growing global population, increasing pollution, changing global climate, and fast depleting sources of fossil fuels have been the matters of concern to environmentalists, engineers, scientists, and in recent years to governments, too. In order to counter all of these concerns green sources of energy like solar, wind, geothermal, tidal, etc. are being encouraged globally. Of these sources of energy, wind power has been on the top relative to others sources of energy in terms of its global installed capacity.

Saudi Arabia, though has abundance reserves of fossil fuels, has been on the forefront of the development and usage of renewable sources of energy, in particular solar. The measurement of global solar radiation and sunshine duration was started in 1970. A total of 41 radiation measurement stations were established. These stations were maintained by The Ministry of Agriculture, Saudi Arabia. Recently, in the year 1995, around 14 new generation solar radiation measurements stations were established to collect data on various components of solar radiation. These new generation stations are being maintained by King Abdulaziz City for Science and Technology (KACST). Another 63 stations were established between 1970 and 1985 where meteorological parameters like air temperature, surface pressure, relative humidity, wind speed, wind direction, rain fall, visibility and cloud cover are being recorded. These stations are maintained by Presidency of Environment and Meteorology previously known as Meteorology and Environment Protection Agency (MEPA). The other organizations including Saudi Aramco, Saudi Basic Industries (SABIC), Saudi Electricity Company (SEC), Royal Commission of Yanbu and Jubail, King Fahd University of Petroleum and Minerals (KFUPM), King Abdulaziz University (KAAU), Ummulqura University, King Saud University (KSU), etc. also collect data on various meteorological parameters.

The government has also provided lot of funding for research and development work on various aspects of solar energy utilization. A good amount of research papers are found in the literature on topics including solar radiation data analysis, development of empirical model for the prediction of solar radiation, wind data analysis, electricity production and energy cost estimation, solar cookers for Mina and Arafat, etc. A comprehensive review of the work done on solar radiation was compiled by Rehman and Halawani 1998.

The objective of this paper is to prepare an update on the existing, on-going, and planned sources of geothermal energy in Saudi Arabia. Section two describes briefly the geology of Saudi Arabia while electricity present and future demands are discussed in section 3. Section four is devoted to existing sources of geothermal energy in Saudi Arabia. Section 5 sheds light on some of the existing and planned usage of solar and wind energy in Saudi Arabia.

2. GEOLOGY OF SAUDI ARABIA

A hallmark of the land of Saudi Arabia is its enriched variety of geological features. This part of the Earth's crust is made of consolidated rock outcrops as well as unconsolidated sand dunes. The rocks display a large lithological variety of igneous, sedimentary and metamorphic types. The time period of the formation of these rocks stretches from Proterozoic to Quaternary and Recent. The western one third of Saudi Arabia is known as the Arabian Shield. The remaining eastern part is covered by the "cover rocks" of the vast Arabian Platform. The Platform region hosts most of the oil reserves of the country.

Tectonically, Saudi Arabia is situated in the southern part of the Arabian plate, one of the youngest of the 10 or more plates that make up the present-day surface of the Earth. In this area, the plate comprises a crystalline basement of Precambrian continental crust about 40-45 km thick and mostly 870-550 million years old, an overlying sequence of younger Phanerozoic sedimentary rocks that range in age from Cambrian (540 Ma) to the Pleistocene and in thickness from zero to 10 km, surficial Cenozoic flood basalt, and Paleogene-Holocene intracontinental and, now, oceanic basins along the Red Sea and Gulf of Aden.

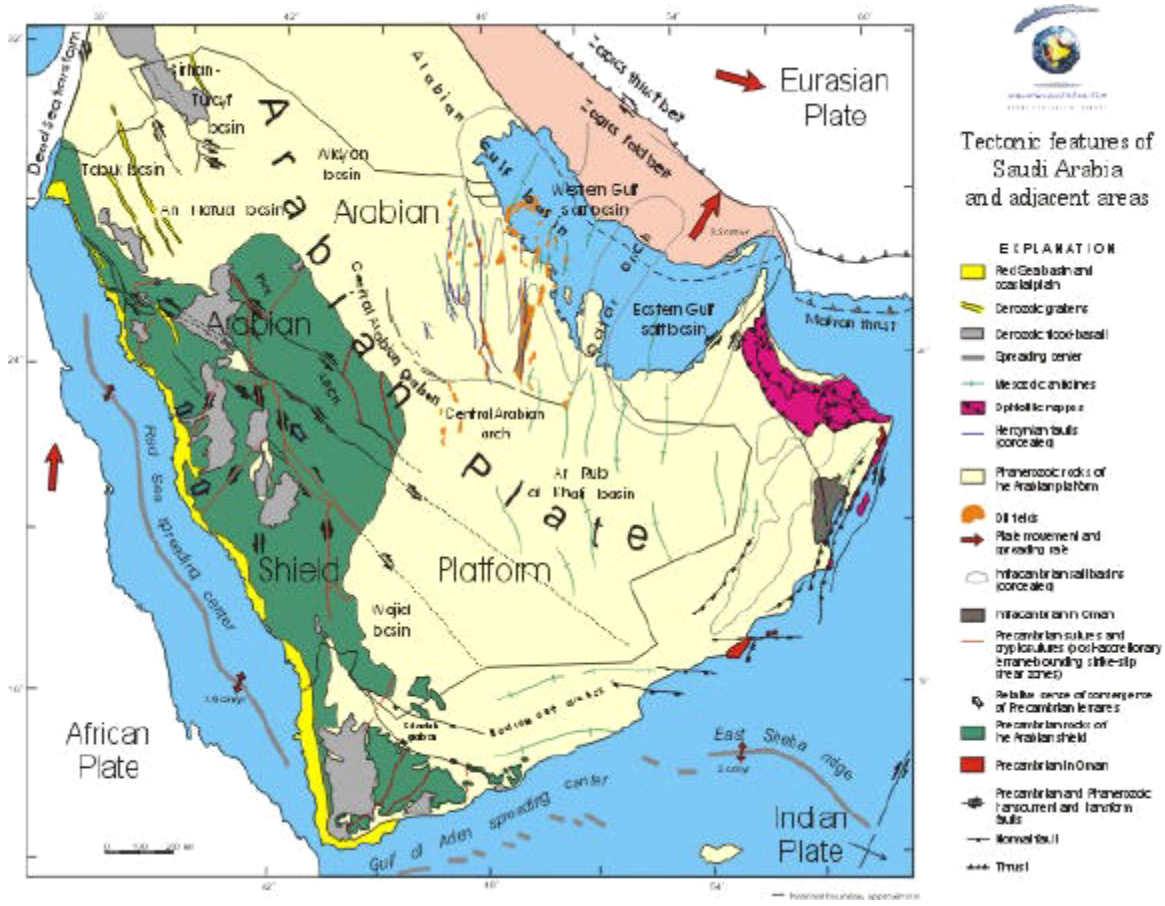

Figure 1: Map of Tectonic features of Saudi Arabia and adjacent areas, [SGS].

In its geotectonic framework, Saudi Arabia is the largest country of the Arabian Plate, occupying its 80 % area; the rest being shared by UAE, Yemen, Oman, Qatar and Bahrain. The Arabian Plate exhibits a variety in its plate margins as it includes all the three major types of plate margins, i.e., the diverging margin along the Red Sea spreading axis, the converging margin along the Zargos Mountains supra-subduction zone; and the transform fault margin along the Dead Sea transform fault, as shown in Figure 1. The Red Sea mid-ocean ridge itself varies in its character from just rifting in the northern part and active spreading in the southern part. Since these plate margins are controlled by the deeper Earth processes, it is obvious that a variety of processes are operating below this part of the world.

3. PRESENT AND FUTURE ELECTRICITY DEMANDS

In this era of modern and materialistic life pattern, human life is increasingly depending on the energy right from powering a personal computer to cooking food. The growth in population has a direct impact on the energy requirements. With respect to Saudi Arabia, there were 3,256,643 consumers in the year 1997 and reached to 3,792,210 in the year 2001. The increase in number of consumer in different years is shown in Figure 2. The consumer growth rate from year to year looks linear. In fact the number of consumers increased by 3.5%, 4.4%, 3.0%, and 4.6% from 1997 to 1998, 1998 to 1999, 1999 to 2000, and 2000 to 2001, respectively. The data presented in Figures 2 to 6 is taken from first annual report of Saudi Electricity Company (SEC) [2000-2001].

As seen from Figure 3, the energy growth reached to 122,944 GWh in the year 2001 from 97,050 GWh in 1997. The energy growth increased by 8.8% from 1997 to 1998 and growth decreased to 4.7% and 3.2% from 1998 to 1999 and 1999 to 2000, respectively. The growth increased sharply again from 2000 to 2001 by about 7.7%.

As shown in Figure 4, the total generation capacity of Saudi Electricity Company (SEC) was 22,817 MW in the year 1997 which increased to 24,329 MW in the year 1999 and finally it touched a figure of 26,326 MW in the year 2001. The generation capacity increased by 1.6% in 1998 compared to 1997 while it increased by 5% in 1999 compared to 1998. From 1999 to 2000 the generation increased by 2.4% and by 5.7 in 2001 compared to 2000. This trend shows that with time the generation requirements will be more and more.

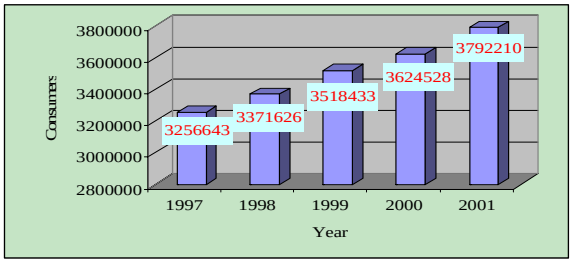

Figure 2. Year wise growth in number of consumers.

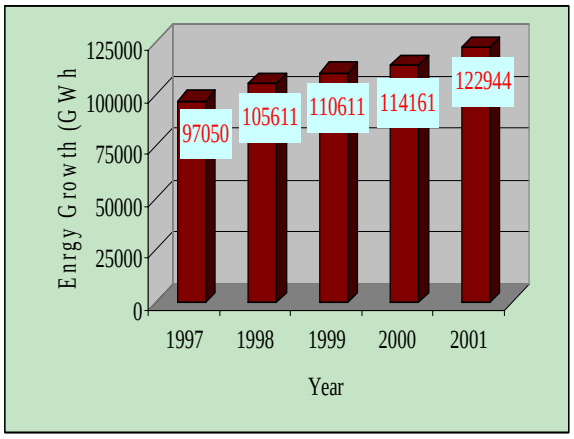

Figure 3. Year wise energy growth

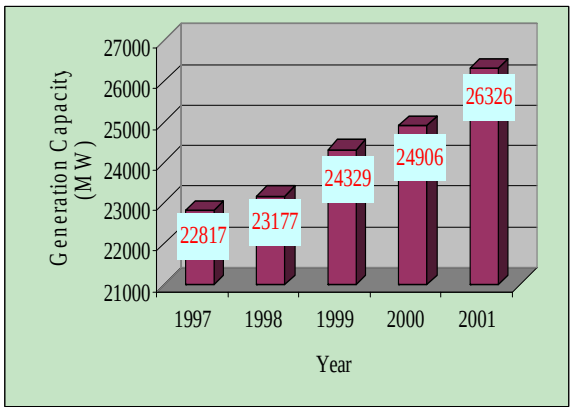

Figure 4. Year wise generation capacity

Figure 5 shows the total forecast demand in MW for the Kingdom of Saudi Arabia as per the details given in report SEC [1996]. As per the demand forecast, it is expected that the demand will increase to 34,704 MW in the year 2005 compared to 27,933 MW in 2000 i.e. an increase of approximately 24.2%. The demand forecast is expected to increase by 22.9%, 20.2%, and 15.6% by 2010, 2015, and 2020, respectively.

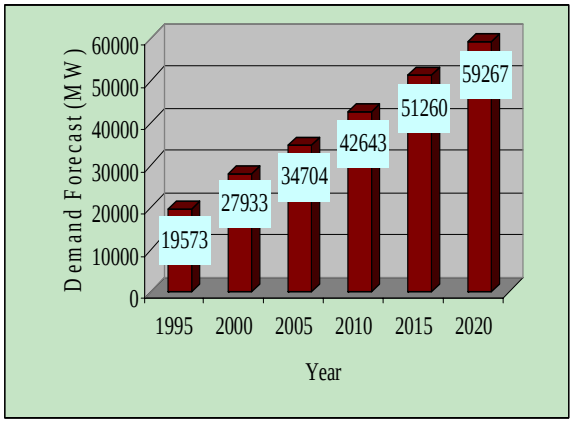

Figure 5. Future forecast demand load.

The net generation increased by 75.7% i.e. from 19,662 MW to 34,538 MW corresponding to years 1993 and 2000. From 2000 to 2005 it is expected that net generation will increase by 22.7% and 21.3% by the year 2010. As per future projection, the net generation will reach 69,520 MW in the year 2020 i.e. an increase of 14.3% compared to year 2015, as shown in Figure 6.

The investment requirements for generation and bulk transmission system additions in millions of Saudi Riyals (SR million) are shown in Figure 7. As seen from this figure a huge sum of 138,551 million SR (US $ 36,950 millions) was spent on the electricity generation and facilitation in the Kingdom of Saudi Arabia during the years 1995 and 2000. During next five year plan i.e. from 2001 to 2005 a sum of 79,797 million SR (US $ 21,378 millions) was planned to be invested into electricity sector. As per forecast figures, an amount of 77,698 million SR (US $ 20,720 millions) will have to be invested during the period 2006 to 2010. The investment requirements for the period 2011 to 2015 and 2016 to 2020 are also given in Figure 7.

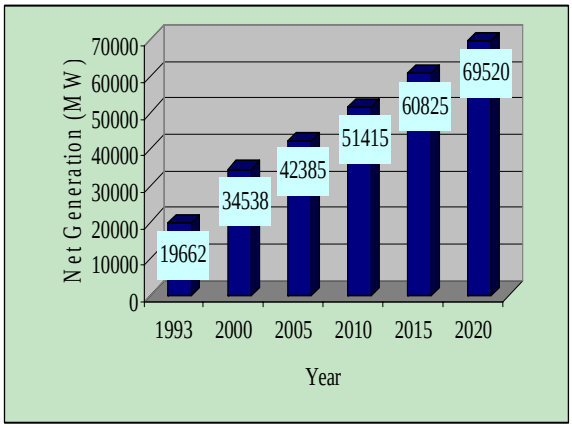

Figure 6. Future net generation requirements.

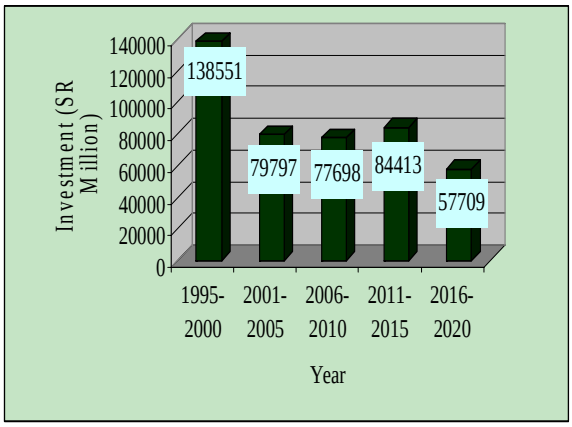

Figure 7. Total investment requirement.

4. GEOTHERMAL RESOURCES AND POTENTIAL

In Saudi Arabia, the studies on geothermal resources exploration were started in 1980. These efforts consisted of hydrogeological reconnaissance of the hot springs in the south part of the country and a geological reconnaissance of the large volcanic areas known as harrats in the western part. The Harrats region of Saudi Arabia holds bright prospects as a source for the geothermal energy. Its geothermal potential is reviewed by Berthier et al. 1981. The hot sprins and the harrats are discussed in details in sub-sections 4.1 and 4.2.

4.1 Description of Existing Thermal Springs

As per the available information, there are ten thermal springs in Saudi Arabia, (Al-Dayel 1988). Of these, six are in Gizan (viz. Ain Khulab, Ain Khulab Quwa, Ain Mijara Quwa, Ain ad Damad, Ain al Wagrah and Ain al Wagrah Dam, Figure 8) and four in Al-Lith area (viz. Ain al Harra, Ain Jumah, Ain Markub, and Ain ad Darakah, Figure 9). Table 1 summarizes the geographical locations of all the thermal springs, known to date in Saudi Arabia. In Gizan area, the Ain Khulab and Ain Mijara Quwa thermal springs have very low flow-rates and flow over wadi Alluvia. According to Al-Dayel 1988, the deep temperatures are low at these location i.e. 80 - 100°C at Ain Khulab and 70°C at Ain Mijara Quwa. At Ain ad Damad the temperature is found to be 80 – 90°C. The Ain al Wagrah and Ain al Wagrah dam springs represent two fractions of a mixture of thermal water and a shallow water aquifer. At these locations, the deep temperatures calculated using chalcedony was found to be around 120°C (Al-Dayel 1988). The thermal springs at Al Wagrah and Al Wagrah Dam are located on a major N100° striking fault which brings two very different units of the metamorphic basement inro contact (Al-Dayel 1988). The other springs at Al Khulab and Quwa are located on the edge of the same granite unit and are controlled by faults that bring the granite into contact.

In Al-Lith area, all the springs are located in the vicinity of granite boundary along a cataclastic zone. Three springs, viz. Ain Darakah, Ain Markub, and Ain al Harra, represent different fractions of a mixture of thermal water with a confined aquifer. Ain al Harra, the least mixed spring contains 48% of surface water, (Al-Dayel 1988). At these thermal springs, the estimated deep temperatures were reported to be about 100°C using Na – K geothermometer. The deep temperature at Ain Jumah spring was found to be approximately 100°C. The chemical composition of this spring was reported to be almost the same as that of the Ain al Harra.

4.2 Description of Existing Harrats

The Harrats are formed by the Tertiary to Recent volcanic activity that has continued till the historical times. The volcanic eruptions of “harrat" near Madina area are recorded for the year 1256 A.D. (Camp et al., 1987). The association of "harrats" with the Red Sea rifting makes them a feature that is presently active. As the Red Sea is continuing its opening; and rifting is giving way to seafloor spreading; the volcanism of "harrats" is also in operation. This would mean the transport of hot fluids closer to the surface of Earth in this region; which can be a geothermal resource. The evidence for the occurrence of a plume under the Red Sea may provide another source for the higher geothermal gradient in the crust.

In a recent study of the Red Sea region, based on Neon isotopes, large-scale plume-lithosphere interaction has been revealed (Hopp et al., 2004). As per available resources, there are only three major areas of geothermal interest, viz. harrat Khaybar, harrat Kishb, and harrat Rahat. The physical locations of these harrats are shown in Figure 10 which is taken from [Saudicaves]. According to Al-Dayel [1988], harrat Khaybar and harrat Rahat have potentially high heat flow. As seen from Figure 12 there are other volcanic regions like harrat ash Shamah in the north, harrat ar Raha and harrat Uwayrid near Tabuk, harrat ithnayn in the north west region, and so on.

The volcanoes by the side of the expressway from Jeddah/Makkah to Madinah, belong to a much younger set of basaltic lava-fields with age dates from 10 million years right up to the historic eruptions. This chain is 600km long and is called the Makkah-Madinah-Nafud volcanic line [Saudicaves]. Between Makkah and Madinah the Harrat Rahat lava-field is spread over an area of 20,000km^2 with 644 scoria cones, 36 shield volcanoes and 24 domes. Between Madinah and the Great Nafud are the coalesced harrats Khaybar, Ithnayn and Kura with an area of 20,560km^2 and 327 scoria cones, 46 basaltic shield volcanoes, 20 domes, 5 tuff cones, one basaltic stratovolcano, and 39 massive and very long lava flows [Saudicaves]. According to personal communication [2004], there are live surface fumeroles in and around harrat Ithnayn which can be utilized for electricity generation.

According to Al-Mishwat and Nasir [2004], the calculated xenolith temperatures derived from two-pyroxene geothermometer of Wells [1977] vary between 800 and 900 °C for group I xenoliths and between 730 and 815 °C for group II xenoliths. In simpek, engineering terms, it can be said that there exists high temperatures molten materials below the earth crusts and its high energy contents can be utilized for electricity generation.

Table 1. Physical properties of thermal springs.

Name	Latitude	Longitude	Temperature (°C)	Flow Rate (L/min)	Aquifer type
Ain Khulab (Gizan)	16°45N	43°07E	75.5	1 - 2	TS*
Wadi Khulas (Gizan)	-	-	31.4	10.0	Wadi
Ain Khulab Quwa (Gizan)	16°48N	43°12E	59.0	2.0	TS*
Ain al Wagrah (Gizan)	17°03N	42°59E	55.0	1.5	TS*
Ain al Wagrah Dam (Gizan)	17°03N	42°59E	59.0	20.0	TS*
Ain al Harra (Al Lith)	20°29N	40°28E	79.0	4 - 5	TS*
Ain al Jumah (Al Lith)	20°18N	40°42E	46.0	0.3	TS*
Ain Markus (Al Lith)	20°33N	40°09E	46.0	0.3	TS*
Ain al Darakah (Al Lith)	20°39N	40°01E	39.5	0.1	TS*

*TS - Thermal Spring

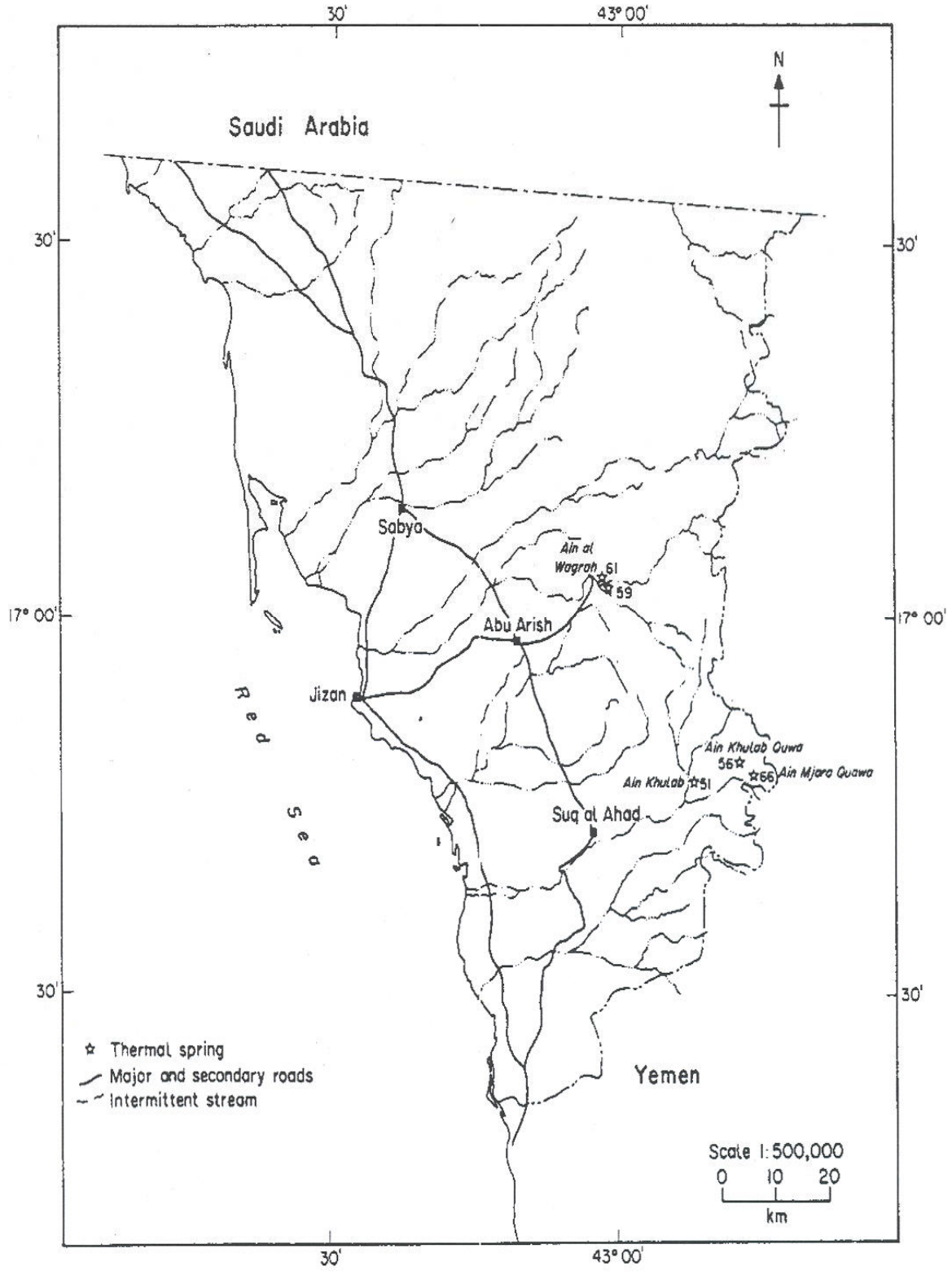

Figure 8. Map of Gizan area, showing the locations of hot water springs [Al-Dayel 1988].

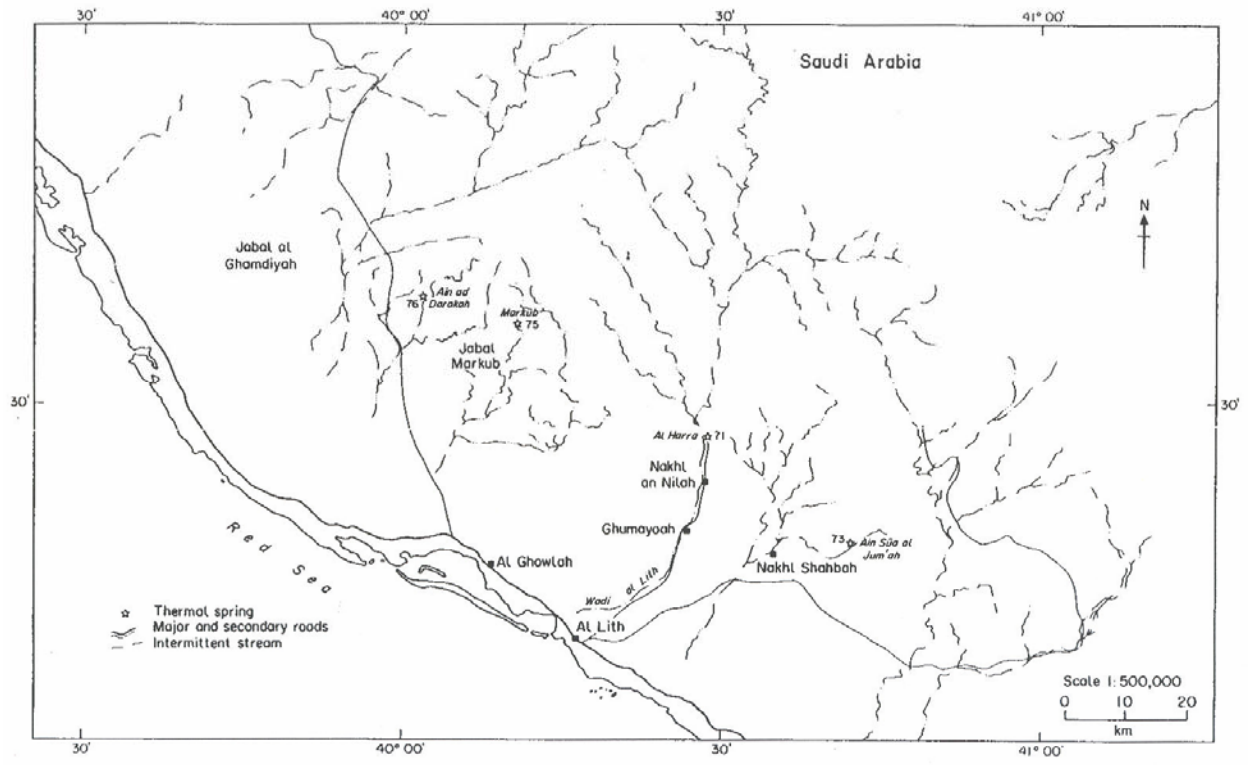

Figure 9. Map of Al-Lith area, showing the locations of hot water springs [Al-Dayel 1988].

Figure 10: Map of the Arabian plate showing locations of the Harrat Al Kishb and the Harrat Ash Sham and other basalt lava fields (harrats)., after [Saudicaves].

5. OTHER RENEWABLE SOURCES OF ENERGY

In Saudi Arabia, photovoltaic panels are being used for various applications since 1981. Some of these applications include a 350 kW installed capacity electricity generation plant for a remote village in Riyadh (Solar Village), a 350 kW PV system for hydrogen production (Solar Village), another 6 kW PV system for grid connected supply (Solar Village), 4 kWp PV system for agriculture usage (Muzahmia), 10.63 kWp PV system for sea water desalination (Sadus village, approximately 70 km from Riyadh), 57.60 kWp PV lighting system for tunnels in southern region of Saudi Arabia, etc. According to Alawaji [2001], the cumulative PV installed capacity in Saudi Arabia sums up to 4 MWp upto year 2000. At present, none of these applications are in use. The other major applications of PV systems in Saudi Arabia include the cathodic protection in oil and water pipe lines and the communication towers.

As of today, the power of the wind has not been utilized to generate electricity in Saudi Arabia but the Saudi Electricity Company has recently awarded two projects to King Fahd University, (i) to identify three potential locations for grid connected wind farms development and (ii) to conduct feasibility study for wind diesel hybrid system for a remote village powered by diesel only system. So in near future, Saudi Arabia may have some MW of wind power installed capacity for the generation of electricity.

6. CONCLUSIONS

The literature survey presented in this paper can be summarized as follows:

1. At present, the existing geothermal resources like hot water springs and harrats are not being used for electricity generation or heating purposes. As per author's knowledge and available information, there is no existing plan to use

geothermal sources for electricity generation in the near future.

2. The total PV installed capacity in Saudi Arabia used to be 4 MWp till year 2000 but is no more in service due to various reasons. At present, PV modules are being used to energize the cathodic protection systems in oil and water pipeline and microwave towers. The actual numbers of such systems and ratings are not available in the literature.

3. The usage of PV modules for grid connected and as well as hybrid systems is also being studied by the researchers at universities and the institutes in the Kingdom.

4. The Kingdom of Saudi Arabia is looking forward towards the utilization of power of wind to generate electricity for grid connected systems and as well as wind diesel hybrid applications for remote villages.

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