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Geothermal Resources in Algeria

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ABSTRACT

The electrical energy from renewables in Algeria contributed about 3.4% (280 MWe) in 2008 of a total power of 8.1 GWe and will reach 5% by the year 2017 according to the Algerian Electricity and Gas Regulation Commission (CREG). The country's target is reaching 40% by 2030. The geothermal resources in Algeria are of low-enthalpy type. Most of these geothermal resources are located in the north of the country and generate a heat discharge of 240 MWt.

There are more than 240 thermal springs in Algeria. Three geothermal zones have been delineated according to some geological and thermal considerations: (1) The Tlemcenian dolomites in the northwestern part of Algeria, (2) carbonate formations in the northeastern part of Algeria and (3) the sandstone Albian reservoir in the Sahara (south of Algeria).

The thermal waters are currently used in balneology and in a few experimental direct uses (greenhouses) in Ouargla and Touggourt (NE Algerian Sahara). Recently some fish farms started in Ghardaia and Ouargla by using the hot waters of the Albian aquifer (South of Algeria) to produce Tilapia fish. NW Algeria benefits from a geothermal heat pump for space heating and cooling by using a thermal water of 46°C with a flow rate of 25 m^3/h.

The inventory of thermal springs has been updated with more than 240 springs identified. The highest temperatures recorded were 68°C for the western area, 80°C for the central area, and 98°C for the eastern area. In the south, the thermal springs have a mean temperature of 50°C. The northeastern zone of the country, covering an area of 15,000 km^2, remains potentially the most interesting geothermal area, with the Barda spring giving 100 L/s, and another spring in the area having the highest temperature in the country (98°C).

1. INTRODUCTION

Algeria is situated in northern Africa, bordering the Mediterranean Sea, between Morocco and Tunisia. Algeria has the 9th-largest reserves of natural gas in the world. It ranks 16th in proved oil reserves. Currently, more than 98 percent of Algeria's electricity generation comes from fossil-fuel resources. The Algerian government recently adopted a renewable energy program and new legislation (law on energy conservation and law on the promotion of renewable energy) that aims to produce 40 percent of its national consumed electricity from renewable energy sources by 2030.

In this paper we summarize the geological setting, hydrochemical, and geothermal data of Algeria and present two geothermal conceptual models for the northern and southern regions. An overview of the electricity production from renewable energies is also presented in the paper.

There are a few published journal papers in the last two decades about Algerian geothermal reservoirs and chemistry of the hot springs and we can cite for examples: Fekraoui (1988); Kedaid and Mesbah (1996); Lahlou Mimi et al. (1998), Saibi et al. (2006); Kedaid (2007); Saibi (2009); and Bahri et al. (2011).

The geothermal exploration program in Algeria started in 1967 and was undertaken by the national oil company SONATRACH. In 1982 the national electric power company SONALGAZ undertook the geothermal recognition studies of the northern and eastern parts of the country in association with the Italian company ENEL. In the first stage, the geothermal studies concerned mainly the north-eastern part of Algeria. From 1983 onwards the geothermal work has been continued by the Renewable Energies Center of Algeria (CDER) and the program was extended to the whole northern part of the country. The relatively low prices of the conventional energies (natural gas and fossil fuels) and the national policy on rural electrification have a negative influence on the development of geothermal energy in Algeria. Geothermal development has remained stagnant during the last decade. Presently renewed effort is put into developing large projects with the establishment of the geothermal atlas of Algeria. The recent adoption of the renewable energies law by the government will certainly enhance the geothermal activities in Algeria. It is worth to mention that the term Hammam is an Arabic term for hot spring.

2. GEOLOGICAL SETTING

West Africa is essentially composed of two major tectonic units (Figure 1): the West African Precambrian Craton (WAC), stable since 2000 Ma; and the surrounding mobile belts largely of Upper Proterozoic age. The basement of the WAC exposed in the Reguibat and Leo uplifts is dominated by the occurrence of Archean nuclei surrounded by low-grade metamorphism of volcanoclastic Birrimian formations. These formations were affected by the Eburnean orogeny (approximately 2000 Ma) and intruded by numerous lower Proterozoic granitoids. The Taoudeni basin occupies the central part of the WAC, and is filled with sediments of Upper Precambrian to Paleozoic age. Changes in the gravity pattern support the subdivision of the WAC into discrete rigid crustal blocks of Archean age surrounded by accreted highly deformed Proterozoic belts (Lesquer et al., 1984). The WAC is surrounded by Pan-African mobile belts (Anti-Atlas, Tuareg shield, Benin-Nigeria shield, Rockellides, Mauritanides) overlain by Paleo-Mesozoic sedimentary basins (Sahara, Niger, Tindouf). These belts resulted from collisional tectonic processes around 600

Ma (Lesquer et al., 1984; Dallmeyer and Lecorche, 1989). The Tuareg shield is dominated by north-south elongated structural units, between which correlations are not always possible (Caby et al., 1981). Gravity data correlate with these structures and outline their north-south extension within the basement beneath the Sahara and Niger basins. The Pan-African belt has been locally reactivated by the Caledonian (Mauritanides) and the Hercynian (Mauritanides, Atlas and Ougarta) orogenies. Only the northern margin of the African plate has been affected by the Alpine orogeny (Maghrebide belts). Widespread Upper Mesozoic to Cenozoic volcanism affects the Pan- African mobile belt but is absent within the WAC. This volcanism is sometimes correlated with a system of swells (Hoggar; Tibesti, southern Libya; Cameroon; Darfur, western Sudan) and troughs (Benoue, northern Cameroon; Tenere). The Hoggar is a very large (800 km) Precambrian basement swell where the mean altitude ranges from 1,000 to 1,500 m. Evidence from lavas and xenolith petrography, as well as heat flow and gravimetric constraints, has suggested the interpretation that this uplift is due to a now-cooled altered upper mantle emplaced during the Late Mesozoic time (Lesquer et al., 1988; Dautria and Lesquer, 1989). The geology of Algeria (Figure 1) is divided into two main structural units: the folded Tellian Domain in the North, and the Saharian Platform in the South, separated by the South Atlasic Flexure (Fabre, 1976). The north of Algeria belongs to the Alpine structural domain (unstable) with significant seismic activity. It is characterized by complex geology of overthrusting allochthonous terrains; the geological formations are mainly carbonates and marls. The last phase of the Alpine folding of Astian age played an important role in the rejuvenation of the relief and the development of fractures as well as in the apparition of saliferous domes. Actually the Alpine phase affected only the Tellian Domain where magmatic activities appeared after the installation of the over thrusting nappes (Upper Miocene). The Saharian Platform has remained a stable zone characterized mainly by sedimentary basins, which constitute the hydrocarbon reservoirs and the Albian geothermal aquifer. To the South, in the Hoggar region, magmatic activities took place from the Miocene to the Quaternary.

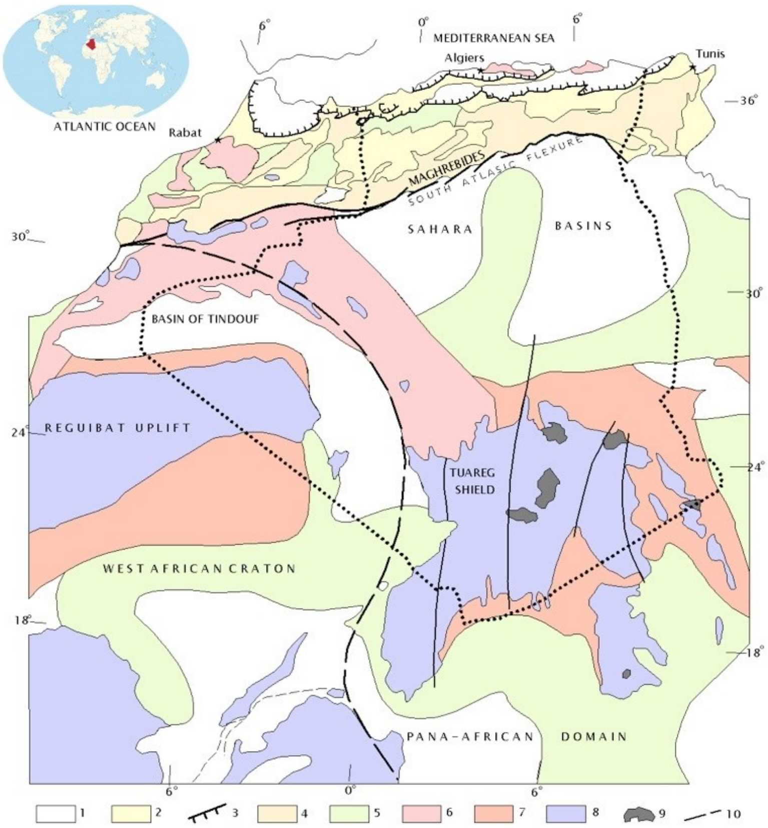

Figure 1: Major geotectonics units of West Africa modified from Fabre (1976). 1: Tertiary and Quaternary; 2: Alpine molasses; 3: Tertiary thrust sheet; 4: Secondary tabular; 5: Secondary plicative; 6: Primary plicative; 7: Primary tabular; 8: Precambrian and Precorce Cambrian of Sahara; 9: Cenozoic magma; 10: Megafault.

3. HEAT FLOW MAP OF ALGERIA

Evaluation of heat flow in 230 oil wells, using temperature measurements (bottom-hole temperature T_{BHT} and temperature of fluids in drill stem test T_{DST}) and various rock-porosity data reveal a high heat flow average (82±19 mW/m^2) associated with the Algerian Sahara basins. The high heat flow anomaly of the Algerian Sahara basins correlates well with a low S-wave velocity zone and locally with a low-amplitude negative gravity anomaly (Lesquer et al., 1990). The heat flow distribution map (Figure 2) exhibits significant regional variations overprinted by short-wavelength anomalies that, in general, are related to the local geological structure. On a regional scale, there is an essentially north-south zonation that is not directly related to the major structural units, except for the northern Alpine domain. The southern area, at the border of the Hoggar Precambrian basement, is characterized by very high heat flow values (90–130 mW/m^2) correlated with lithospheric and asthenospheric processes. The anomalies define a major axis, generally east-west, which seems to affect the northern part of the African plate, from the Canaries (volcanic islands located between latitudes 27°N and 30°N, with its eastern edge only 100 km from the NW African coast) to Libya. Locally, some relationships with extensional Miocene– Pliocene–Quaternary volcanism suggest an association with recent mantle thermal events.

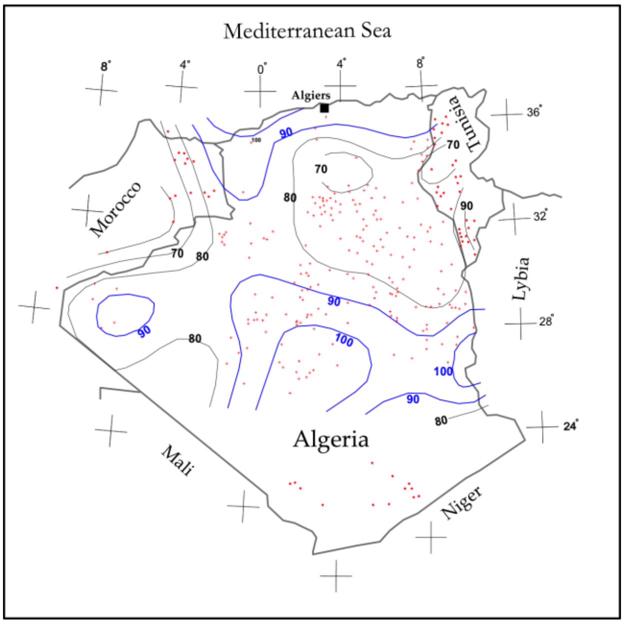

Figure 2: Heat flow map of Algeria (Takherist and Lesquer, 1989). Unit: mW/m^2. 230 oil wells are presented, with depths ranging from 500 to 5500 m. Number of temperature measurements vary between 3 and 15.

Figure 3 shows the distribution of temperature with depth. The Central Sahara, where most of measurements are located, shows a small dispersion around a mean gradient of 21°C/km. On the other hand, the two other regions show large dispersions around mean gradients of 32°C/km for the Western Sahara and 26°C/km for northern Algeria.

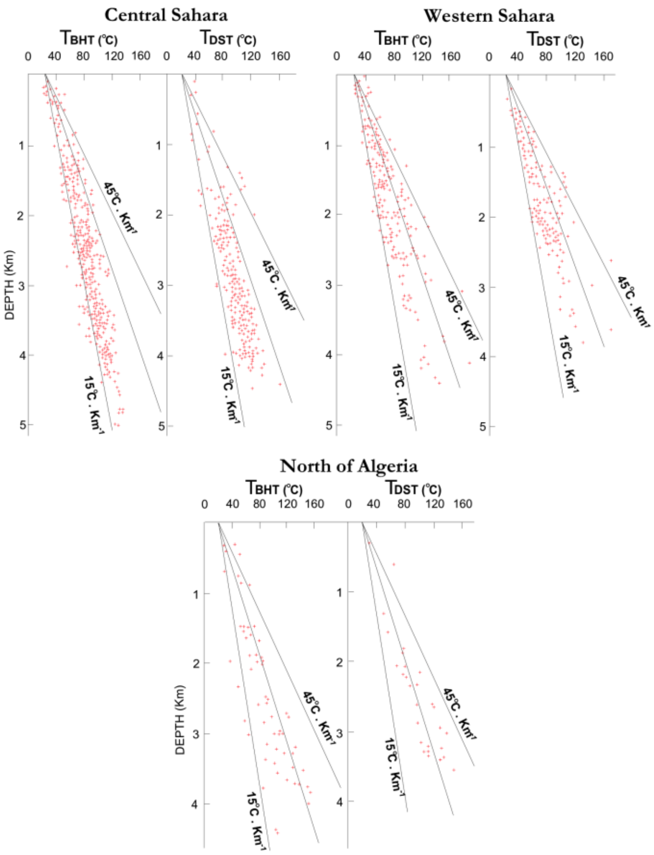

Figure 3: Plots of T$_{BHT}$ and T$_{DST}$ versus depth for different regions (Takherist and Lesquer, 1989).

4. GEOTHERMAL RESERVOIRS AND HYDROCHEMISTRY OF HOT WATERS

Bahri et al. (2011) studied 41 hot waters sampled from different regions of Algeria, collected in Nov. 2008 and Jan. 2009. The temperature of the thermal waters varied from 26°C to 86°C. pH values varied from 6.5 to 8.5 and more than 90% of the samples exhibited high salinity (550-5,500 mg/L). Most of the samples belong to the sodium-chloride water type. Figure 4 shows the estimated reservoir temperatures of the 41 hot spring samples.

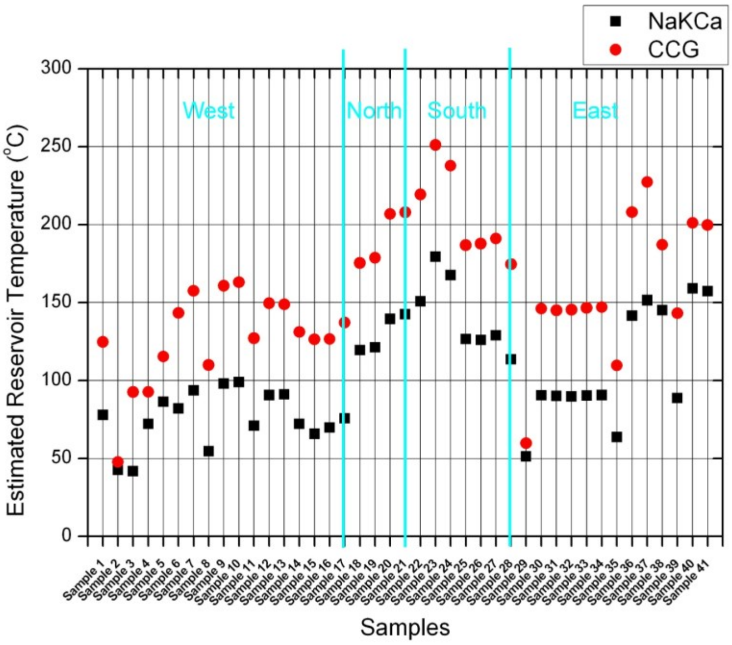

Figure 4: Calculated reservoir temperatures of the Algerian hot springs from CCG (Cationic Composition Geothermometer) and Na-K-Ca geothermometers (Bahri et al., 2011)

Three geothermal regions have been delineated according to the distribution of thermal springs and geological and geophysical considerations (such as permeability and geothermal gradient) presented in Figure 5. The inventory of the thermal springs has been updated to show more than 240 sites. The temperatures of Algerian hot waters vary from 22 to 98°C. The highest spring temperatures recorded are: 68°C for the western area (Hammam Bouhnifia), 80°C for the central area (Hammam El Biban) and 98°C for the eastern area (Hammam Meskhoutine) in northern Algeria (Figure 6). In the southern area, there are some thermal springs with a mean temperature of 50°C. The total dissolved solids (TDS) of the hot springs in northern Algeria are greater than 1 g/L (Figure 7). Carbonate formations constitute the main geothermal reservoirs in northern Algeria, while in southern Algeria the reservoirs are dominantly composed of sandstone.

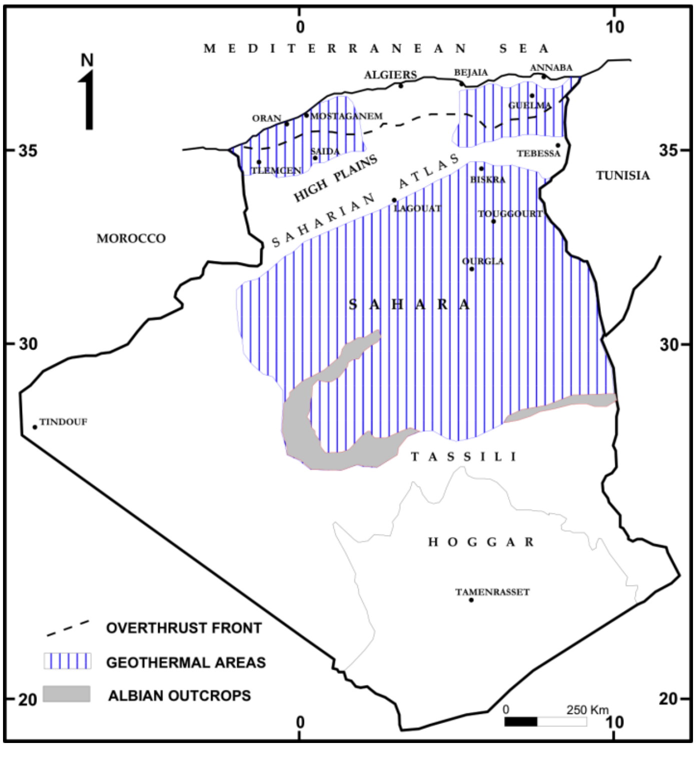

Figure 5: Main Algerian geothermal areas (Fekraoui and Abouriche, 1995).

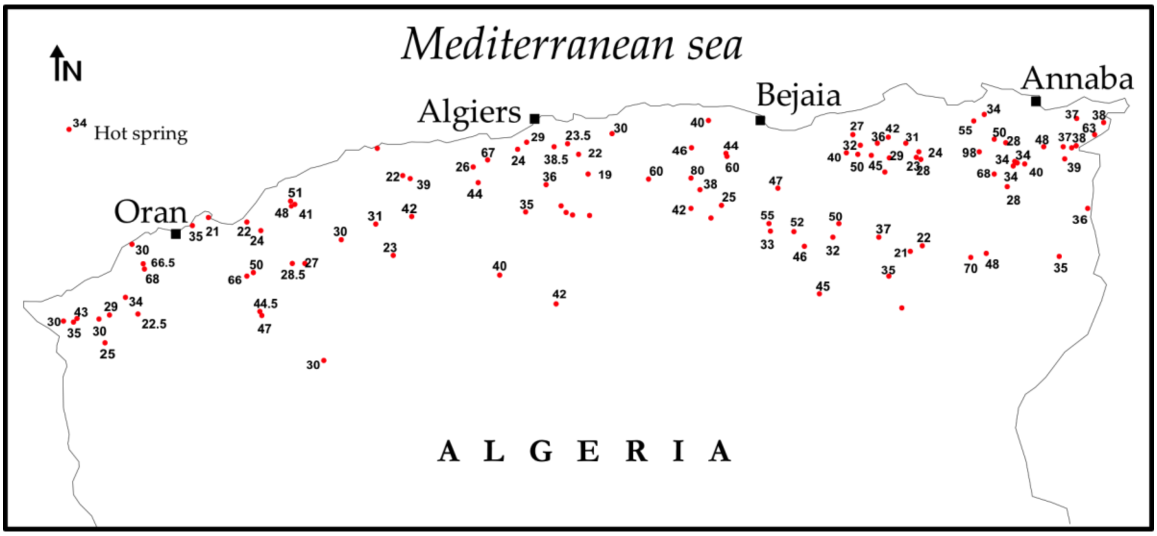

Figure 6: Temperatures of the main hot springs of the northern part of Algeria (Kedaid, 2002).

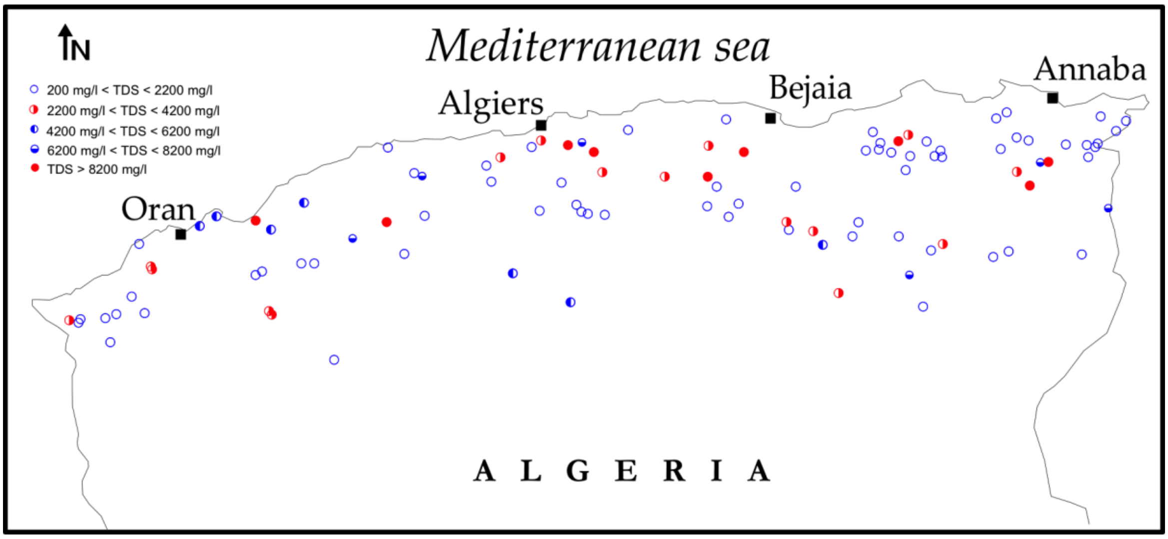

Figure 7: Total Dissolved Solid (TDS) of the main hot springs of the northern part of Algeria (Kedaid, 2002).

The heat discharge from the main Algerian hot springs and from the exploited wells of the Albian aquifer (South of Algeria) was evaluated to 642 MWt by Ferkaoui and Abouriche (1995) with 240 MWt for northern regions of the country. The authors used a mean annual atmospheric temperature of 18°C for the northern areas and 30°C for the Southern regions in the calculations. The flow rates are taken from Blavoux and Collignon (1986) for the northwestern area; from Dib (1985) and SONALGAZ (1982) for the eastern area and from Conrad (1983) for the South.

4.1. The Tlemcenian dolomites in the northwestern area

According to the chemical types of the waters, this north-western area can be divided into two zones: the southern zone is characterized by homogenous geological formations (dolomites and carbonates) and dominantly Ca–HCO_3-rich waters. The northern zone is set on allochthonous terrains. The thermal springs have a variety of chemical types. The studies of the former zone gave little information about the reservoir and the thermal water origin. Verdeil (1982) and Blavoux and Collignon (1986) have established a close relationship between the thermal springs and the seismicity of the area. The isotopic data, particularly ^{13}C and ^{18}O, show that the waters are of a deep origin (Blavoux and Collignon, 1986). Fenet (1975) indicated that the main thermal springs originated from deep transverse faults. The Plio-Quaternary volcanic rocks in the coastal zone could be related to the thermal waters such as at Hammam Bouhadjar and Hammam Bouhnifia (Fekraoui and Abouriche, 1995). To the south of this zone, the Jurassic dolomites of Tlemcen on the Tlemcen-Saida axis constitute a shallow reservoir. About fifteen thermal springs whose temperatures range from 25 to 47°C have been recorded as bicarbonate water type (Blavoux and Collignon, 1986).

4.2. Carbonate formations in the northeastern area

This area covers approximately 15,000 km^2 and consists of mainly carbonate formations. In the northeastern part of Algeria, the Neritique Constantinois formations and the carbonate part of the Tellian sheet form the reservoirs of Guelma and Bouhadjar, respectively (SONALGAZ, 1982). This area is characterized by springs of high flow rates, i.e. more than 100 L/s for Hammam Barda and by the highest temperature in the country (98°C for Hammam Maskhoutine). The thermal waters in this area are chemically dominated by chloride and sulphate, and have TDS ranging between 1.6 and 2.2 g/L. Two prospects have been chosen for more detailed investigations where geothermal reservoirs could exist at different depths (SONALGAZ, 1982). On the basis of ^{18}O and ^{2}H analyses performed on waters from the northeastern areas, the thermal waters are of meteoric origin (Kedaid and Mesbah, 1996).

4.3. Albian sandstone reservoir in the Sahara area (south of Algeria)

Thermal springs are scarce in this area. The Albian aquifer is exploited by the wells mainly for domestic and agricultural purposes. The sandstone Continental Intercalary formation constitutes the reservoir for the Albian aquifer, covering an area of 600,000 km^2 (Conrad, 1983). This reservoir outcrops in its southern part and dips towards the north to reach a depth of 2,600 m in the Biskra region. This reservoir is covered by calcareous formations, which yield the chemical characteristics of the water type (CaNa–SO_4Cl) with a mean TDS of 1.5 g/L.

4.4. Geothermal Conceptual Models

For northern Algeria, we proposed the following conceptual model (Figure 8a). The meteoric water goes downward through deep fractures, and is heated from below by a slightly high conductive heat flow; then the heated water rises to the surface and produces the hot springs. The temperature of the hot springs depends on the velocity of water flow, time of circulation and fracture characteristics. Saibi (2009) estimated the penetration depth of waters up to 7 km, which explains deep circulation of the waters. Bahri et al. (2011) mentioned that the origins of Algerian thermal waters range in depth from 780 to 2,580 m.

For the southern Algerian case, a sedimentary basin type geothermal system is assumed (Figure 8b). The water in the pore of the sedimentary rocks is heated by conductive heat flow from below. Almost no circulation of water occurs, and the reservoir exhibits very high pressure creating a geopressured system.

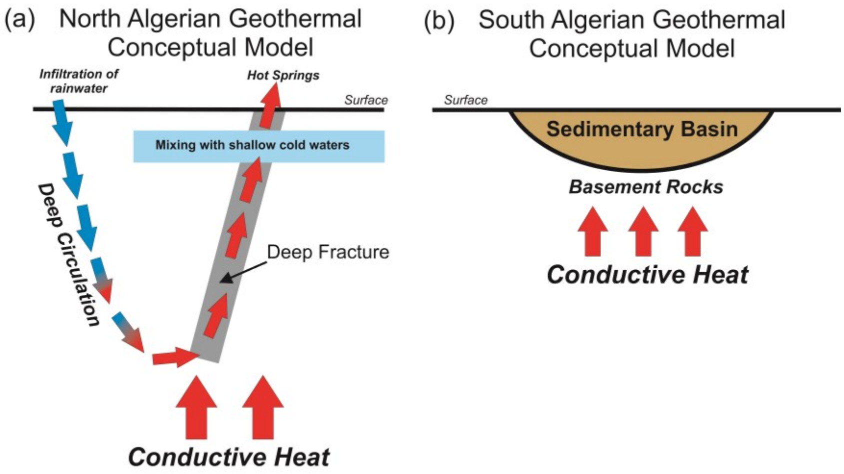

Figure 8: (a) Idealized northern Algerian geothermal system characterized by heating of the filtered meteoric water. (b) Idealized southern Algerian geothermal system, characterized by basement heating of the sedimentary basin (Saibi, 2011).

5. RENEWABLE ENERGIES AND GEOTHERMAL

The renewable energies in Algeria are mainly represented by wind and solar. The Algerian Ministry of Energy and Mining (AMEM) planned to generate 22,000 MWe of power from renewable energy sources between 2011 and 2030, of which 12,000 MWe will be meant for domestic electricity consumption and the remaining 10,000 MWe for export. Also AMEM planned to produce 37% of the total national electricity production from solar and 3% from wind by 2030. Algeria is determined for its engagement in increasing electricity production from environmentally friendly renewable energies like solar, wind, biomass, geothermal and hydropower, in order to diversify energy sources, save its fossil energy reserves and promote sustainable development of the country. The Algerian government adopted many recent renewable energy laws to support these programs.

5.1. Solar energy

Algeria's geographic situation gives its location a top source of solar energy potential in the Mediteranean basin. The solar energy potential of Algeria was estimated to 169,440 TWh/year. The Algerian government is focusing to increase and support this source of energy by planting some projects such as: solar-diesel power plant in Hassi R'Mel in Algerian Sahara producing 150 MWe, including 25 MWe in solar and two thermal-solar power plants with storage of a total capacity of 150 MWe each. The Hassi R'Mel integrated solar combined cycle power station is one of the world's first hybrid power stations and started in 2011. Also the government will install future solar energy electricity power plants in south of Algeria: 1,200 MWe from four thermal solar power plants between 2016 and 2020, 500 MWe between 2021 and 2023, and 600 MWe between 2024 and 2030.

5.2. Wind energy

This renewable energy source is ranked second after solar in terms of utilization and electricity production in Algeria. Algeria has a wind potential of about 35 TWh per year. Currently there is one wind-diesel power plant in Adrar (South of Algeria) with installed capacity of 10 MWe. Two more plants are planned for the period 2014-2015 to produce 40 MWe for both. Current studies are searching for suitable sites to produce 1,700 MWe of power during the period 2016-2030.

5.3. Geothermal energy

The main utilizations of the hot water in Algeria are balneology and space and greenhouse heating. Recently, some new projects are established for fish farming and agriculture, where the Algerian government gives financial support of 80% for such projects. A heat-pump project was installed in a primary school (Sidi Ben Saleh primary school) in Saida (NW Algeria) for heating and cooling purposes. A thermal water of 46°C with a flow rate of 25 m^3/h was used for this project. A similar project is planned in Khenchla (NE Algeria) and a binary-cycle geothermal power plant is also planned in Guelma (NE Algeria). Recently some Tilapia fish farming projects started in Algeria (Ghardaia and Ouargla prefectures). These projects utilize the hot waters of the Albian aquifer of south of Algeria.

For practical reasons, the Ouargla and Touggourt sites (north-eastern of the Algerian Sahara, Figure 8) have been chosen for the experimental greenhouses/geothermal heating systems (Bellache et al., 1984). These greenhouses are used for melon and tomato cultivation. Even though the Sahara area is characterized by hot weather, important temperature variations are recorded during the winter, and the summer seasons where the night temperatures could reach a value below 0°C. Eighteen greenhouses covering a total surface of 7,200 m^2 are heated by the 57°C Albian geothermal water. The source temperature combined to a flow rate of 1 L/s is used to assure a minimum temperature of 12°C inside every greenhouse. The heating system, which is a reserve flow type, has been operating since 1992. The polypropylene tubes are put directly on the ground close to the plants. The main results are precocity of 20 days and an increase of 50% in production, compared to that of the unheated greenhouses. Bellache et al. (1995) states that the geothermal potential in these regions is sufficient to heat 9,000 greenhouses, with a flow of 3,421 L/s. The total energy use for geothermal is about 1,778.65 TJ/yr.

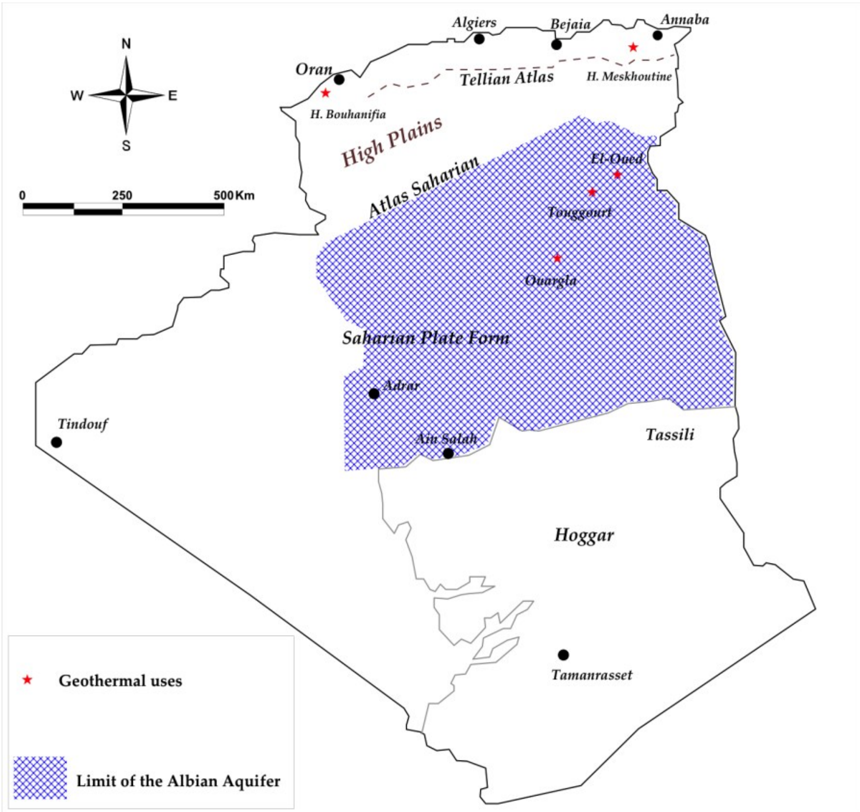

Figure 8: Location of Algerian geothermal uses sites (Fekraoui and Kedaid, 2005).

6. CONCLUSIONS

Despite being a petroleum- and gas-rich country, Algeria is making efforts to exploit its renewable energies. The Algerian government has adopted new renewable energy laws and financial support for the investors to facilitate the exploitation of the renewable energies for electricity production and direct utilizations. Algeria has relatively abundant geothermal resources especially in the northeastern parts but not totally used.

We recommend further use of the country's geothermal resources to improve food production, especially the use of greenhouses outside the conventional periods when the climate requires heated greenhouses to enhance growth. Despite the determination of the three main geothermal areas, more detailed geophysical, hydrochemical and geothermal reservoir engineering studies are needed to delineate the reservoirs and to evaluate their energy potentials.

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STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (Solar, Biomass)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2014				56776		3837.2				4302.32		64916
Under construction in December 2014												
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020												

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

1) I = Industrial process heat; H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling); D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables); B = Bathing and swimming (including balneology)
F = Fish farming; G = Greenhouse and soil heating
K = Animal farming; O = Other (please specify by footnote)
S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate (kg/s)	Temperature (°C)		Enthalpy[2] (kJ/kg)		(MWt)	Ave. Flow (kg/s)	Energy[4] (TJ/yr)	Capacity Factor[5]
			Inlet	Outlet	Inlet	Outlet				
H*. Meskhoutine	B	80	90	30			20.08	80	633.12	0.25
H. Ouled Ali	B	83	50	20			10.42	83	328.43	0.13
Ain Berda	B	100	28	20			3.35	80	84.42	0.03
Mouhammadia well	B	12	47	30			0.85	12	26.91	0.07
Teleghma well	B	10	48	25			0.96	10	30.34	0.09
H. Boughrara	B	7	37	20			0.50	7	15.70	0.07
H. Bouhnifia	B, H	9	68	35	6		1.24	9	39.17	0.16
H. Chiguer	B	5	35	20			0.31	5	9.89	0.06
H. Rabbi	B	6	47	25			0.55	6	17.41	0.09
H. S. Aissa	B, C	6	46	39	3		0.18	6	5.54	0.99
Ain Skhouna	B, F	60	31	20	20		2.76	60	87.05	0.04
Ghardaia well	F	150	28	18			6.28	150	197.85	0.04
Ouargla well	F	44	21	17			0.74	44	23.21	0.016
H. Salihine	B	65	43	20			6.26	65	197.19	0.09
TOTAL		637					54.47	617	1723.65	2.126

H*: Hammam

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2014

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	1	13.05	0.41
District Heating [4]			
Air Conditioning (Cooling)	0.08	2.76	1
Greenhouse Heating			
Fish Farming	9.02	279.1	0.98
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	44.37	1428.74	1
Other Uses (specify)			
Subtotal	54.47	1723.65	
Geothermal Heat Pumps	0.17	55	
TOTAL	54.56	1778.65	2.39

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)					
Production	>150° C					
	150-100° C					
	<100° C	4				>2
Injection	(all)					
Total		4				>2

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

Period	Research & Development Incl. Million US$	Field Development Including Production Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1995-1999						
2000-2004	0.07					100
2005-2009	0.6		1.25		20	80
2010-2014						