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GEOTHERMAL ENERGY DEVELOPMENT IN TUNISIA: PRESENT STATUS AND FUTURE OUTLOOK

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ABSTRACT

The use of geothermal energy in Tunisia is limited to direct application because of the low enthalpy resources, which are localized mainly in the southern part of the country. For thousands of years, geothermal water has been used in bathing, and many of the geothermal manifestations in the country have the name of ‘‘*Hammam*’’ or bath, which reflects the main use of geothermal water over the centuries (Hammam Zriba, Hammam Benteljdidi, Hammam Bourguiba, Jebel Ouest, Hammam Korbous, Hammam Elhamma,…). Now, most of the resources are utilized for irrigation of oases and heating greenhouses. The government’s policy in the beginning of 1980’s was oriented towards the development of the oasis sector which is supplied with geothermal water for irrigation. Therefore, about 80 boreholes are operating mostly for the irrigation of oases after cooling the water in atmospheric cooling towers.

Years ago, the State started using geothermal energy for greenhouse farming, by planting an area of one ha. in the southern part of the country. The results of this experiment were encouraging, and thus the cultivated areas have today increased to 147 ha. The utilization of geothermal resources is increasing.

1. INTRODUCTION

Geothermal utilization is divided into two categories, the electricity production and direct application. Conventional electric power production is limited to fluid temperatures above 150°C, but considerably lower temperatures can be used with application of binary fluid technology (Fridleifsson, 1996). The primary forms of direct use include swimming, bathing, space heating, agriculture (greenhouses), fish farming and industrial processes. In Tunisia, because of the low enthalpy resources, the use of geothermal energy is limited to direct utilization, especially in agriculture. The resources are localized mainly in the southern part of the country (Kebili, Gabes and Tozeur regions) and utilized mostly for agricultural purposes. The government’s policy in the beginning of the 1980’s was oriented to the development of the oasis’ sector and the main aim was to supply oases with geothermal water for irrigation. Therefore, over 80 boreholes were drilled in the southern part of the country. In 1986 the State started using geothermal energy for greenhouse farming, by planting an area of 1 ha. The results of this experiment were very encouraging and thus, the areas today have increased to 147 ha.

This report presents the main direct uses of geothermal energy in Tunisia. The purpose is to describe the present status of geothermal utilization and to analyze the impediments to the agricultural operations. The study starts with an outline of the geothermal resources in Tunisia. Following this, the utilization of groundwater in agriculture, bathing, washing and swimming is discussed.

2. OUTLINE OF GEOTHERMAL RESOURCES IN TUNISIA

Tunisia is located in the North African region with a small total area which covers 164,000 km². The arable land is about 5 million ha. and only has rare and non-renewable resources. Geothermal resources are taken from the 'Continental Intercalaire' aquifer: the deep aquifer or CI, which is characterized by relatively hot water between 30 and 80°C) and at depths reaching 2,800 m. The resources are located in a reservoir of 1,000,000 km² which covers the regions of Kebili, Tozeur, Gabes and the extreme south, and extends to Algeria and Libya. The CI aquifer is one of the largest confined aquifers in the world, comparable in scale to the great artesian basin of Australia. The principal areas of recharge are in the South Atlas mountains of Algeria and Tunisia and the Dhahar mountains of Tunisia. Radiocarbon analysis has shown that the geothermal water is about 20-50 thousand years old and is of sulfate-chloride type (Agoun, 2000). The salinity varies from 2 to 4 g/L and the water is utilized mainly for agriculture purposes.

FIGURE 1: Geothermal borehole in the Souk Lahad locality, Kebili area

Because of the existence of cold artesian water in the past and because of the limited area of the oases, the geothermal resources were initially exploited for bathing. Since they are low-enthalpy resources, the use of geothermal energy is limited for washing and there were no reasons for it to be used for oases irrigation. This was in the beginning of the 1950's and 1960's. After that, and because of the abundance of water in some oases and the large expansion of areas, these resources were utilized for the oasis's irrigation for the first time.

The important period of drilling boreholes was in the middle of the 1980's and in the beginning of the 1990's. Till now, over 80 wells were drilled in the country. The greatest number of them is in the Kebili area where 40 boreholes are operating mostly to complete the irrigation of oases after cooling the water in atmospheric towers. Geothermal resources are estimated to be 4850 L/s, 85% are localized in the south part of the country (see Table 1).

TABLE 1: The geothermal resources in Tunisia

Regions	Geothermal resources (L/s)	Contribution (%)
Kebili	1,100	23
Gabes	1,682	35
Tozeur	635	13
Gafsa/ Sidi Bouzid	697	14
Total south	**4,114**	**85**
Mahdia	278	6
Others	458	9
Total country	**4,850**	**100**

3. PRESENT STATUS OF GEOTHERMAL USE IN TUNISIA

Major direct utilization projects exploiting geothermal energy exists in at least 80 countries. The main utilization categories are swimming, bathing and balneology, space heating and cooling, agricultural applications such as greenhouse heating, aquaculture and industrial applications. Over two thirds of this energy use is for space heating, swimming and bathing (Lund, 2007). In Tunisia, 90% of the geothermal resources are used for agricultural purposes: ¾ for oases irrigation and ¼ for heating greenhouses and other uses. In the case of Kebili region, 97% of the geothermal resources is utilized for agricultural purposes: 73% for oases and 24% for greenhouses. The remaining part (3%) is used for bathing (hammams), tourism, washing and animal husbandry. The use in greenhouses in this region has increased by 7% compared to the year 2002 (17%) because of the increase of greenhouse area (plus 50% in terms of area). Consequently, the use of geothermal energy in greenhouse use has increased by 3% per year. Figure 2 shows the different direct geothermal uses in the area in 2008.

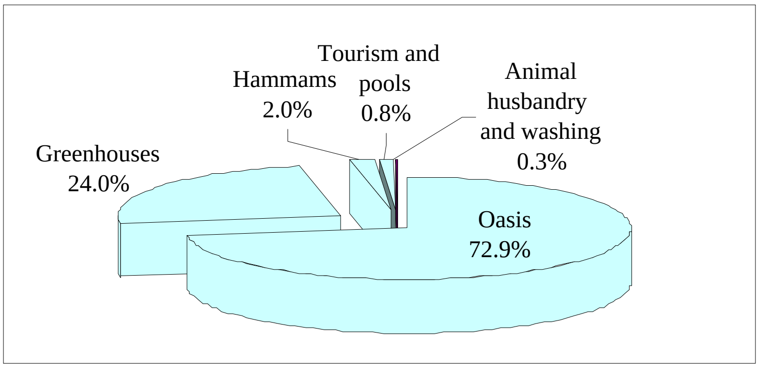

FIGURE 2: Geothermal uses in Kebili area in 2008

3.1 Irrigation of oases

The Kebili and Tozeur regions are located in the southwest part of the country and are characterized by a desert climate (arid). The annual precipitation is irregular and generally less than 100 mm. The maximum temperature is about 55°C (July) and minimum temperature is about –7°C (December). Then, the temperature range is very high. Theses difficult conditions require a large amount of water to maintain the humidity inside the oases systems, mainly during the summer period. Thus, the major part of the geothermal water is used to complete the irrigation of 24,700 ha. of oases (16,300 ha. in Kebili and 8,400 ha. in Tozeur). The water temperature varies from 27 to 80°C. Generally, water less than 45°C is used directly for irrigation or cooled by means of multiple ponds or cascaded as shown in Figure 3. By using this cooling system the temperatures can drop by 5-10°C. When the temperature exceeds 45°C, the water is cooled by means of atmospheric towers before being used for irrigation purposes (Figure 4). In normal conditions, the temperatures decrease to 30-35°C. However, these towers have the disadvantage of loosing water via evaporation, estimated at 5% of the total flowrates. This technology needs a big exploitation cost every year

FIGURE 3: The water cooling system (Cascade of Oum Elfareth, Kebili area)

FIGURE 4: The water cooling system (Cascade of Oum Somaa, Kebili area)

(10,000-15,000 dollars) which is divided between the electricity cost for ventilation, the maintenance and the gardening.

The Gabes area, located in the south-eastern part of the country, is characterized also by an arid climate but since this region is close to the Mediterranean Sea, it has a fresher climate. The temperature range is less high than the two other areas (Kebili and Tozeur) because of the air humidity. The water temperature in the CI aquifer varies from 40 to 69°C and the major part of the geothermal water is used to complete the irrigation of 7,000 ha. of oases.

FIGURE 5: The irrigation system

In Tunisia, more than the half of the oasis areas (57%) is irrigated by geothermal water (Figure 5). All the area is irrigated by submersion method (no localized irrigation). In this case, water is transported through a furrow to parcels causing high water wastage due to infiltration, evaporation and physical characteristics of the soil (light soil, sandy, salty soil). For conservation purposes, the government encourages farmers to install and utilize PVC pipelines for irrigation by subsidizing 40-60% of the total investment. The Tunisian policy in the agricultural field and especially in its hydraulic aspects was oriented in the beginning of the 1990's to give more importance, responsibilities and decision making to the non governmental organizations. In that way, many organizations related to management of water resources, called GIC and now nominated GDA: Agricultural Development Group, are operating and they contribute effectively to the management and the distribution of water.

FIGURE 6: The concrete canalization for oasis irrigation (Bazma project, Kebili area)

In the same policy of water saving, a project called APIOS (amelioration of irrigated areas in south oasis) started in 2001 by the installation of a concrete canalization for irrigation and a drainage system (see Figure 6). The project covers about 20,000 ha. of oases with a total cost of 30 million dinars co-financed by the Japanese authority. The objectives are to ameliorate the irrigation frequency, to ameliorate the oasis's efficiency and productivity and to valorize the water resources since they are rare.

3.2 Heating and irrigation of greenhouses

3.2.1 History of the greenhouses

Greenhouses are one of the largest low enthalpy energy consumers in agriculture. Geothermal heating of greenhouses started in Iceland in 1924. By the end of 1970 some glasshouses were heated in Yugoslavia. Other countries followed the experience and nowadays, there are around 1,000 ha. worldwide using geothermal energy for heating. In Tunisia, in addition to the irrigation of oasis, the geothermal water is used for heating plastic greenhouses. The utilization of geothermal energy started in the country as an experiment. The results were very encouraging and led to the idea of a Geothermal Utilization Project in Agriculture (PUGA-project, TUN/85/004) financed by the UNDP. In 1986 the government started to use geothermal energy in greenhouses in the southern part of the country. After one year, many projects were created in several places. Nowadays, the exploitation of geothermal resources for heating greenhouses in the southern part of Tunisia is considered as the only experience in the world in terms of development in this field in the difficult desert conditions.

3.2.2 Evolution of the greenhouse areas

Numerous crops have been raised in geo-thermally heated greenhouses in many countries. The use of geothermal energy for heating greenhouses can reduce operating costs and allow operation in colder climates where greenhouses would not normally be commercial. There are around 30 countries in the world using geothermal water for heating greenhouses and the total area is estimated to be 1,000 ha. The leading countries in 1998 (Popovski, 2002) were the USA (183 ha.), Hungary (130 ha.), China (115 ha) and republic of Macedonia (62 ha). At that time and according to these data, Tunisia occupied the fourth position with 80 ha. But, based on papers submitted for WGC2000 in Japan (Lund, 2002), Tunisia occupied the first place in the world in 2002 with 102 ha.

Starting with one ha. as an experiment in 1986, the total area of geo-thermally heated greenhouses in Tunisia has increased considerably. Indeed, the area reached 21 ha. in 1988 in which 51% were in the region of Kebili. In 1998, the total area covered was 80 ha. In 2005, the total area was 111 ha. Today, the total area is 147 ha, of which 47% are located in the Kebili area. Figure 7 shows the evolution of the greenhouse area in the country. The first projects established in the late 1980's showed a considerable growth of the areas as shown in Table 2.

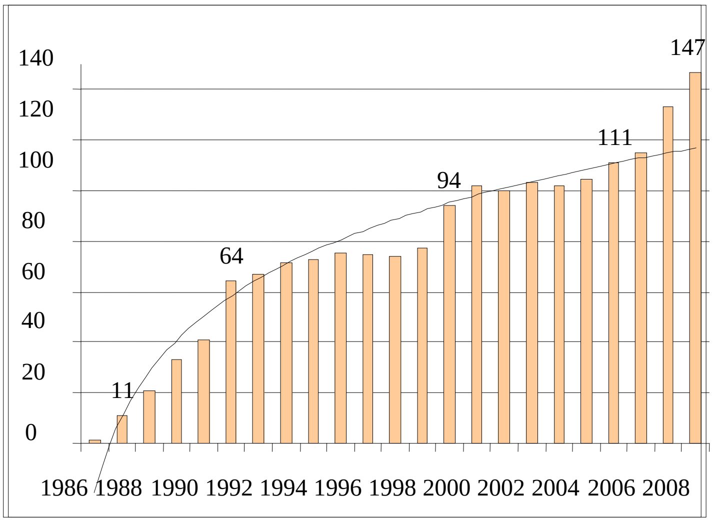

FIGURE 7: The evolution of the greenhouse area in Tunisia (ha.)

TABLE 2: The development of the greenhouses in some localities

Projects	**Number of greenhouses**		**Growth Rate (%)**
	At the year of implementation	**Now**	
Limagues 1	20	53	165
Limagues 2	60	147	145
Oum Elfareth	40	98	145
Behaier	46	74	61
Jemna	56	83	48
Charfedine	10	44	340
Ameur Ben Ameur	20	50	150

3.2.3 Occupation of the greenhouse areas

Utilization of the greenhouse area in Tunisia is based on three cultivations, the first is the autumn season "before season", from September to December which represents 21% of the total area; the second is the spring season "After season" from late December to June, with 31% and the third season is the "continuous" from September to June, with 48%. The exploitation is more than once per year and lasts nine months. About 167 ha. were cultivated in the country giving a rate of intensification of 114%. The cropping system in 2008 as shown in Figure 8 is composed of tomatoes and snake melons with, respectively, 50% and 26%. Melons represent 15%, watermelons 4% and others, generally

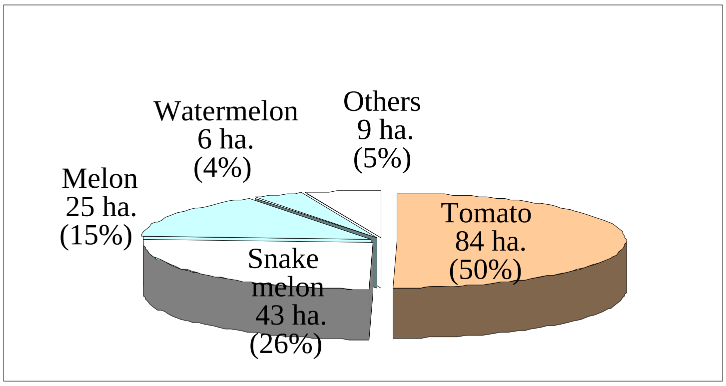

FIGURE 8: The greenhouse cropping system in Tunisia in 2008

peppers 5%. Also in 2001 and 2002, tomatoes and snake melons were the main vegetable crops due to their commercial value and their facility to be sold for export.

3.2.4 Evolution of the greenhouse productions

Despite some problems handicapping the greenhouse sector in the beginning of development, such as lack of qualification and bad techniques of some farmers, production increased from year to year caused by the expansion of areas. But, in comparison with unheated greenhouses, the geo-thermally heated greenhouses generate better quality and higher yields. In the season 2007/2008, the total production from heated greenhouses in the country reached 15,500 tons (see Table 3). The regions of Kebili and Gabes contributed 80% of the total production.

TABLE 3: The total production in the country

Regions	**Area (ha.)**	**Farmer number**	**Average of greenhouses by farm**	**Total production (tons)**	**Average yields (tons / ha.)**
Kebili	69	418	3	6,500	94
Gabes	51	39	26	6,500	127
Tozeur	27	71	8	2,500	93
Total	**147**	**528**	**6**	**15,500**	**105**

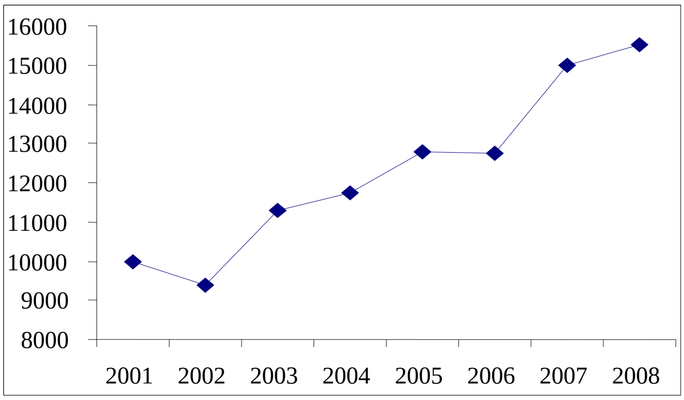

FIGURE 9: The evolution of greenhouse production (tons)

The production in Tunisia grew from 10,000 tons in 2001 to 11,750 tons in 2004 to reach 15,500 tons in 2008. From 2001 to 2008 it varied as shown in Figure 9 with an average of 12,300 tons per year. Since the size of the farms is higher in the Gabes region than the other two regions (26 greenhouses by farm), the yields are also higher.

3.2.5 The greenhouse vegetable export

The greenhouse sector represents the second place in the economy after the oasis sector. It contributes to the amelioration of the quality of life of the farmers by generating devises via export and it generates employment (about 7 permanent jobs and 400 seasonal day-work per one ha). The export quantity is also less than the objectives of the strategy, which projects a 50% export of the total production but only 21% of the production was exported in 2007, mainly from big farmers of Gabes region. The prices given for tomatoes are high in the European markets due to the high quality and taste. Small farmers, such as those in Kebili and Tozeur regions, need to be organized in groups or cooperatives to share the transport cost and consequently to minimize their total costs.

3.2.6 Heating of greenhouses

FIGURE 10: The heating system

Continuous low temperatures at 10-12°C during two successive days disturb the physiological behavior of plants. Paradoxically, temperatures higher than 30-38°C can provoke irreversible damage to crops. Normally, temperature variation should not exceed 5-7°C. In the south this is difficult to obtain, as the risk of temperature variation is frequent. In order to solve this problem, the use of geothermal water is a good solution, which can improve the climate inside greenhouses principally during the night. The heating is through pipes lying on the ground between the crops (Figure 10). Several types of pipes have been tried and polypropylene pipes were selected. Generally, an average of 8-10 loops is used per house and they are connected with the system by an easily operated valve. For heating greenhouses in the country, 45 wells are operating to supply 30 different sites where 528 farmers are operating. Table 4 shows the distribution of projects and farmers by area.

TABLE 4: The distribution of greenhouse projects, farmers and boreholes

Regions	Projects or sites number	Farmer number	Boreholes number
Kebili	12	418	14
Gabes	10	39	17
Tozeur	8	71	14
Total	**30**	**528**	**45**

The total area heated by geothermal water is 147 ha.; the temperatures vary from 45 to 80°C. The need for greenhouse heating is only six months, mostly during the night from November to April. The duration for heating is 14 hours per day. Farmers open the heating system in the afternoon when they finish working and stop it the next morning when they reach the farm (Ben Mohamed, 1995). The total amount of geothermal water needed for heating greenhouses is approximately 60,000 m^3/ha. for each six month period.

3.2.7 Irrigation of greenhouses

FIGURE 11: Concrete ponds for irrigation

After the thermal water has been used for heating greenhouses, a small part is collected in concrete ponds for subsequent use for irrigation (see Figure 11). These ponds need to be large to store all the cooled water until it is used for irrigation. In many projects, farmers utilize very small and simple ponds with plastic linings, which are cheaper and very practical. Their dimension varies from 40 to 80 m^3. Generally, these ponds are used for the irrigation of an open field area (oases) close to the greenhouses. The need for water irrigation during the growing period is very low compared to heating. In that way, farmers utilize a local system. Water circulates inside a perforate pipeline lying on the ground. The chemical composition of the geothermal water used in irrigation must be monitored carefully to avoid adverse effects on plants because of the high salinity in the region (from 2 to 4 g/L).

3.2.8 Geothermal return water

Tunisia is the only country in the world using geothermal water both for heating and irrigation. From the borehole, water goes directly through pipes lying on the ground inside the greenhouse for heating. After that, it is collected during the night in ponds outside (Figure 12), and then used for irrigation of oases and greenhouses. Only 10% of the total water is sufficient for greenhouse irrigation and the rest is used for oasis irrigation. The average need for heating and irrigating a mono-tunnel greenhouse of 500 m² is respectively 0.3 and 0.03 L/s (Ben Mohamed, 2005). The rest or what is called 'the return water' which represents 90% (0.27 L/s) should supply the oases surrounding the area, but this is often difficult to achieve because of the conflict between users, especially when there is no relation between oasis's farmers and greenhouse's farmers.

FIGURE 12: type of ponds to store the return water

Greenhouse heating occurs during the night, while irrigation occurs during the day. Therefore, it is necessary to store the return water in ponds to be used later for irrigation purposes. This is why two types of ponds should be installed in a greenhouse project. The first pond is small and used for the irrigation of crops inside the greenhouses. The second is bigger, used to store the return water from all the greenhouses for oasis irrigation. The storage capacity should be at least equal to the total volume of return water for two or three nights (Saïd, 1997). In order to facilitate the water supply to the oasis, the storage pond should be located a relatively high level. Otherwise, water must be pumped and farmers will pay an additional cost. *It is important to note that the location of a greenhouse project near the oasis is preferred and a combination greenhouse-oasis must be considered in the future* for better use of the return water. The best idea is to give greenhouses to the same farmer exploiting oases. Figure 13 shows the proposed connections between a greenhouse project and an oasis one.

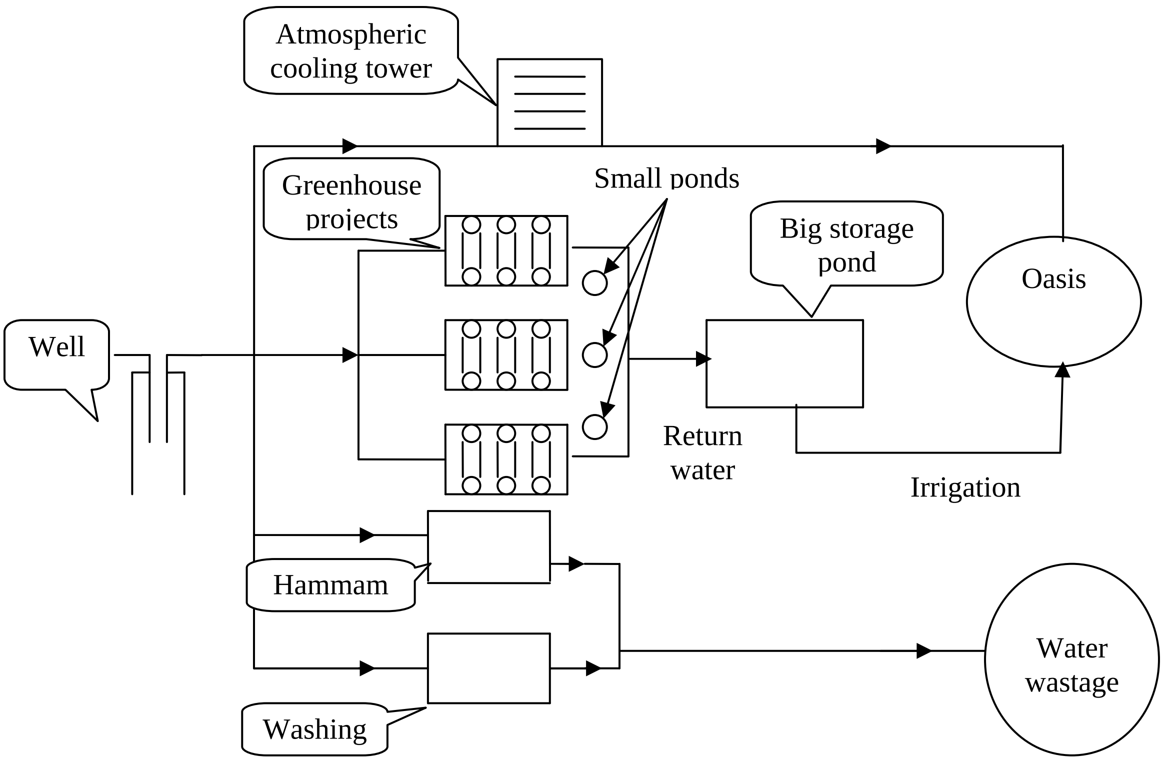

FIGURE 13: Proposed configuration for using the return water

Due to disinterest of some farmers and to the bad design of some greenhouse projects, water couldn't reach the ponds. Farmers dispose of the water close to the fields and often in the drainage system producing a waste of water resources. Normally the return water should supply the old oases or the new ones close to the greenhouses project, but, sometimes, there are conflicts between users. As an example, the total amount of water returned from the greenhouses to the oases in Kebili region is estimated at 215 L/s, which represent only 50 % of the available water (see Table 5). The same figure exists for Gabes and Tozeur regions.

TABLE 5: The return water: case of Kebili region

Sites	Heating flowrate (L/s) (1)	Irrigation flowrate (L/s) (2)	Effective return water (L/s) (1-2)	Actual return water (L/s)	Return water (%) of effective
Limagues (CI8)	98	10	88	45	51
Saïdane	14	2	12	10	83
Oum Elfareth (CI9)	34	3	31	15	16
Steftimi (CI7)	30	3	27	0	0
Behaier (CI23)	26	3	23	10	43
Ras-elaïn (CI10)	46	5	41	15	24
Jemna (CI11)	47	5	42	10	24
Hniche (CI12)	9	2	7	0	0
Lazala (CI18)	12	2	10	9	90
Faouar (CI19)	45	4	41	35	85
Debabcha1 (CI14)	29	3	26	20	77
Debabcha2 (CI17)	13	2	11	5	45
Mansoura (CI13)	21	2	19	11	58
Bazma (CI16)	60	6	54	20	37
Total	**484**	**52**	**432**	**215**	**50**

3.2.9 Future outlooks: the geothermal strategy in greenhouses

Geothermal resources in Tunisia are estimated to be 4850 L/s, 85% are localized in the southern part of the country. These resources are able to create 378 ha. of greenhouses heated by geothermal energy of which, almost 40% of the projected area is implemented (see Table 6).

TABLE 6: The geothermal greenhouse strategy

Regions	Strategy or objectives (ha.)	Actual area (ha.)	Remaining area (ha.)
Kebili	100	69	31
Gabes	100	51	49
Tozeur	100	27	73
Gafsa/ Sidi Bouzid	38	-	38
Total south	**338**	**147**	**191**
Mahdia	22	-	22
Others	13	-	13
Total country	**378**	**147**	**231**

Plastic houses were attributed in the beginning to small farmers with two units of houses. The first experiment was in the Limagues locality at Kebili region, where 1 ha. was planned in 1986, then many small projects in the southern part of the country where established. The area now has 69 ha. Development of the greenhouse sector has been very fast, at least for some small farmers starting with two houses, who now have five-six or even 10 greenhouses. Concerning the big farmers, some of them started with only 10 greenhouses, now they have 40 greenhouses (as seen in Table 2). The establishment of projects in the other two regions follows the same rhythm. Utilization of the geothermal resources will, without a doubt, increase in the future after implementing the final phase of the geothermal greenhouse project (strategy). By the end of 2011, 50 ha. will be added in the country reaching 197 ha (Table 7).

TABLE 7: The geothermal greenhouse area projection to 2011

Regions	Actual area (ha.)	Contribution (%)	Added area in 2011 (ha.)	Total projected area (ha.)
Kebili	69	47	1	70
Gabes	51	34	9	60
Tozeur	27	19	40	67
Total	147	100	50	197

3.3 Bathing (hammams)

People have used geothermal water for bathing for many thousands of years. Balneology, the practice of using natural mineral water for the treatment and cure of disease, also has a long history (Lund, 2000). For thousands of years, geothermal water has been used for bathing in Tunisia and many of the geothermal manifestations in the country have the name of ‘‘Hammam’’ or bath, which reflects the main use of geothermal resources in the centuries.

According to Ben Dhia and Bouri (1995), there are more than 70 hot springs in Tunisia, 28 are located in the northwest region where hot springs are preferably associated with tectonic activity (faults and fissures) and the natural flowrate is usually small (less than 10 l/s). They are used mainly for curative treatment and bathing. Temperatures of waters in these springs exceed 40°C and some springs are above 50°C. The most important and famous thermal stations in the country are: Korbous, Jebel Ouest, Hammam Bourguiba Hammam Zriba and Hammam Elhamma. Thousands of citizens visit the stations every year, not only for bathing and having curative treatments, but also for fun and recreation. The hammam’s activity is very well known and is spread all over the country, especially in the south where two areas are called hamma (Gabes and Tozeur regions) because of the hot water in these places.

FIGURE 14: The Steftimi bath, Kebili region

In the Kebili area, for example, there are 10 traditional baths using 2% of the total volume of geothermal water, the same number applies to the Tozeur region. Generally, they are small baths with a similar design with two small covered pools. The Steftimi bath at Kebili locality, for example, has a different design, with four covered pools 3 x 6 m and 5 x 6 m (two for ladies and two for gentlemen), two sitting rooms, two dressing rooms, and one prayer-room (see Figure 14). Surrounding the Steftimi hammam, there is parking, a cafeteria and small stores for shopping. For the hammam, to be successful, it must have better services such as living rooms for visitors coming from outside the region and spending more than one week. People visit the hammam to cure or prevent diseases, to relax and reduce stress, to clean and to spend time (mostly in Ramadan) but, never to be in solitude, to reduce weight, to quit smoking or to meet people.

3.4 Hotel swimming pools, animal husbandry and washing

Some pools in different hotels of the country are supplied by hot water for tourist purposes. A small amount of water is used for hotels and swimming pools. The quantity of water used for animal husbandry (dromedary, sheep and goats) is also small. It is important to indicate that animals, especially dromedary, prefer warm water to cold water. In addition, warm water is in so much demand in wintertime because of the salty taste and it increases the appetite for animals, which cross many kilometres to reach the hot sources (Figure 15).

FIGURE 15: Animal husbandry

As mentioned before, the geothermal resources were exploited for the first time for bathing and washing. This was in the beginning of the 1950's and 1960's. Generally, ladies wash clothes, wool and heavy things such as winter covers. Thermal water is transported through a furrow to parcels for irrigation; an amount of water is taken off for washing. In the Kebili region, 55 places for washing were counted in 17 localities (Ben Mohamed, 2002). The use of hot water in washing is very practical and developed for many reasons: washing is easier, there is warm water in winter time with no cost (water saving), it is in a large space and the women wash together (spending time). The same activity is spread in the Gabes and Tozeur regions near most of the boreholes or close to the canalization of oases irrigation.

4. CONCLUSIONS

In Tunisia, geothermal water is mainly used for oasis's irrigation after being cooled in atmospheric cooling towers and heating of greenhouses. The energy consumption in greenhouses is increasing by the years due to the new greenhouse projects being implemented in the southern part of the country. Sometimes there are some conflicts between users that have not been resolved. Thus, and for water saving purposes, the use of the cascade way should continue in the country. For some projects, especially the new ones, where there is a good relation between the users and water from greenhouses goes directly to the oasis's for irrigation. The need for irrigating a greenhouse is only 0.1 times the heating. The rest or the return water should supply the oases surrounding the area, but this is often difficult to achieve. The location of a greenhouse project near the oasis is preferred and a combination greenhouse-oasis must be considered in the future. In that way, the attribution of an open field oasis project to the greenhouse's farmers could be a good idea and a very practical thing to consume, valorize and save all the geothermal return water.

Bathing activity in Tunisia is very ancient and it is practiced all over the country by native citizens since a long time ago (men, women, and children). We can develop the use of thermal water in the country by looking for a better conception to thermal stations and hammams, which should play the role of attractive points, especially on the edge of the Sahara.

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