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Geothermal Direct Application and its Development in Tunisia

Mouldi Ben Mohamed

Regional Commissariat for Agricultural Development, CRDA Manouba, 2010, Tunisia

mobmo@mailcity.com

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ABSTRACT

In Tunisia, the use of geothermal energy 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. 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 toward the development of the oasis sector, which is supplied with geothermal water for irrigation. Therefore, about 80 boreholes are operating mostly to complete the irrigation of 31,500 ha of oases after cooling the water in atmospheric cooling towers. Generally, when the water temperature is less than 40-45°C, it is used directly for irrigation.

In 1986, the government started using geothermal energy for greenhouse farming, which is considered a promising and economically feasible application, by planting one ha in the southern part of the country (Kebili area). The results of this experiment were encouraging, and thus the cultivated areas have today increased to 194 ha. The utilization of geothermal resources is increasing very fast showing a real boom in greenhouses areas. Nowadays, heating greenhouses in southern parts of Tunisia are considered as the only experience in the world in terms of development in this field in the difficult desert conditions. By the end of 2016, the objectives certainly will be crossed, reaching 315 ha.

1. INTRODUCTION

Geothermal utilization is divided into two categories, 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 194 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 the history of the geothermal resources in Tunisia. Following this, the utilization of groundwater in agriculture and the future outlook for bathing, tourism and spas, washing and animal husbandry is discussed.

2. HISTORY OF GEOTHERMAL RESOURCES IN TUNISIA

Tunisia is a North African country with a small total area of 164,000 km². The arable land is only about 5 million ha, with rare and sometimes 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 at depths reaching 2,800 m. The resources are located in a reservoir of 1,000,000 km² which extends to Algeria and Libya. In Tunisia, it covers the regions of Kebili, Tozeur, Gabes and the extreme south in a reservoir of 80,000 km². 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 flowrate varies from 70 to 200l/s, the salinity from 2 to 4 g/L and the water is utilized mainly for agriculture purposes.

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 was no reason use it for oases irrigation (Figure 1). This was in the beginning of 1950's and 1960's. After that, these resources were utilized for oasis's irrigation for the first time because of the abundance of water in some oases and the large expansion of areas. The important period of drilling boreholes was in the middle of 1980's and in the beginning of 1990's. Till now, over 80 wells were drilled in the country. The most number is in the regions of Kebili (35 boreholes), Tozeur (18 boreholes) and Gabes (14 boreholes) mostly to complete the irrigation of oases after cooling the water in atmospheric towers and heating greenhouses. Some wells were drilled in the extreme south of the country for other uses. Geothermal resources are estimated to be 4,850 L/s, 85% are localized in the south part of the country (see Table 1).

3. DIRECT GEOTHERMAL APPLICATION 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 third of this energy use is for space heating, swimming and bathing (Lund, 2007).

Figure 1: Geothermal borehole in Souk Lahad locality, Kebili area

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 (Center)	278	6
Others (North)	458	9
Total country	**4,850**	**100**

In Tunisia, according to Ministry of Agriculture and Water Resources, the General Direction of Water Resources report (DGRE, 2005), about 1143 millions m3 are exploited from geothermal resources, 76% of which are used for agricultural purposes, 19% for water drinking and 5% for industry and tourism. This exploitation differs from region to region. In the case of Kebili region, 98% of geothermal resources are utilized for agricultural purposes (71% for oases and 27% for greenhouses), the remaining part (2%) is used for bathing (hammams), tourism and pools, washing and animal husbandry. The use in greenhouses heating in this region increases by 10% compared to the year 2002 (17%) and by 3% compared to last year (24%) due to the increasing of greenhouses areas. Consequently, the use of geothermal energy in greenhouses increases from year to year. Figure 2 shows the different direct geothermal uses in the area in 2009.

3.1 The Oases Irrigation

Located in the southwestern part of the country, the Kebili and Tozeur regions are characterized by 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. These difficult conditions require a large amount of water needs to maintain the humidity inside the oases system, mainly during the summer period. Thus, the major part of the geothermal water is used to complete the irrigation of 24,600 ha of oases. The water temperature varies from 27°C 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 to reach 35°C.

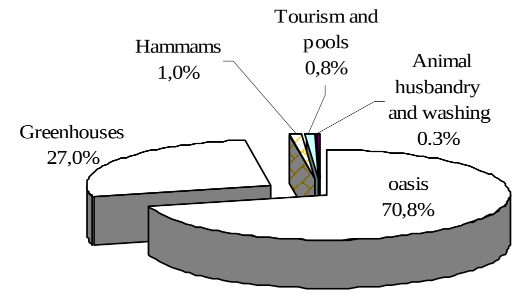


Figure 2: Geothermal uses in Kebili area (2009)

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

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 losing water via evaporation, estimated at 5-8% of the total flowrates. This technology needs a big exploitation cost by the years: the electricity cost for ventilation, the maintenance and the gardening.

Figure 4: The water cooling system (Cooling atmospheric tower, Kebili area)

The Gabes area, located in the south-eastern part of the country, is characterized also by arid climate but since this region is close to the Mediterranean Sea, it has fresher climate than the two regions mentioned before (Kebili and Tozeur). The temperature range is less high because of the air humidity. The water temperature in the CI aquifer varies from 40°C to

69°C and the major part of the geothermal water is used to complete the irrigation of the oases.

More than the half of the oasis areas in the southern part of the country receives complete geothermal water irrigation (Table 2). The soil is irrigated by submersion method (see Figure 5). In this case, water is transported through a sandy furrow to parcels causing high water wastage due to infiltration, evaporation and physical characteristics of the soil (light soil, sandy and salty soil).

Table 2. The Oases Irrigated Area.

Regions	Oases areas (ha)	Oases Irrigated areas (ha)	Contribution (%)
Kebili	16,200	4,900	30
Tozeur	8,400	6,500	77
Gabes	6,900	6,400	93
Total	**31,500**	**17,800**	**57**

Figure 5: The oases irrigation system

There is a drawdown of the water level due to the overexploitation of geothermal water because of the big oases demand for irrigation. Indeed, many of artesian wells are now pumped. For the period 1982-2000, the studies in the Kebili area, showed a drawdown between 9 to 40 m (Ben Baccar, 2007).

For saving purposes, the government encourages farmers to install and utilize PVC pipelines for irrigation by subsidizing 40 to 60% of the total investment. The Tunisian policy in the agricultural field and especially in its hydraulic aspects was oriented since the beginning of 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 GDA: Agricultural Development Group, are operating and they contribute effectively to the management and the distribution of water. 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 concrete canalization for irrigation and a drainage system (Figure 6). The project covers about 20,000 ha of oases with a total cost of 30 million dinars co-financed by Japan 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 The Greenhouses Heating and Irrigation

3.2.1 The Greenhouses History

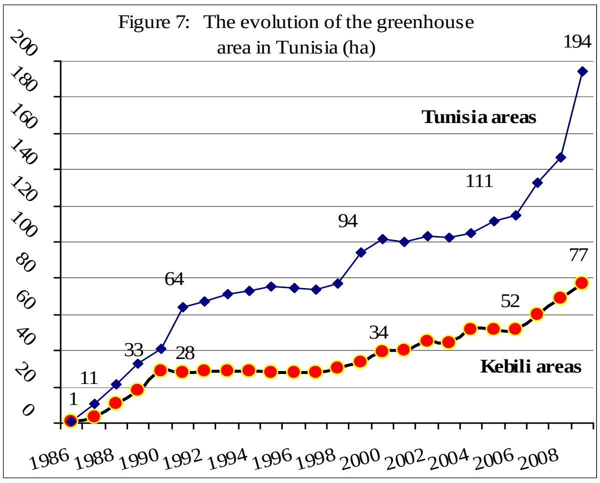
Geothermal heating of greenhouses started in Iceland in 1924. By the end of 1970 some glasshouses were heated in Yugoslavia. Other countries followed the experience and nowadays, there are around 1,000 ha worldwide using geothermal energy for heating (Ben Mohamed and Said, 2008).

Tunisia is one of the leading countries in using geothermal water 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 United Nations Development Program. In 1986 the government started to use geothermal energy in greenhouses in 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 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.

Figure 6: The concrete canalization for irrigation

3.2.2 The Evolution of the Greenhouse Areas in Tunisia

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. Nowadays, 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.



In 1998, Tunisia occupied the fourth position with 80 ha after the USA (183 ha), Hungary (130 ha), China (115 ha) and republic of Macedonia (62 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. The total area of geo-thermally heated greenhouses in Tunisia has increased considerably. Indeed, starting with 1 ha as an experiment in 1986, the area reached 21 ha in 1988 of which 51% were in the region of Kebili and 111 ha in 2005. Today, the total area is 194 ha, getting **an increase in terms of areas never realized before**. Figure 7 shows the evolution of the greenhouse area in the country and in Kebili area.

The first projects established in late 1980's showed a considerable growth of areas as shown in Table 3.

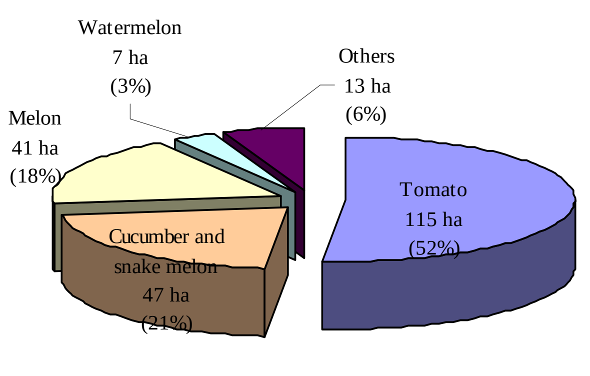
Table 3. The Development of the Greenhouses in Some Localities of Kebili Area.

Projects	Number of greenhouses		Growth Rate (%)
	At the year of implementation	Now	
Limagues 1	20	58	190
Limagues 2	60	159	165
Oum Elfareth	40	126	215
Beha.ier	46	78	70
Jemna	56	83	48
Cha.rfedine	10	44	340
Ameur B Ameur	20	50	150

3.2.3 The Greenhouse Cropping System

The utilization of the greenhouse area in Tunisia is based on three cultivations periods, the first is the autumn season "before season", from September to December; the second is the spring season "after season" from late December to June, and the third season is the "continuous" from September to June. The exploitation is more than one time per year and lasts nine months. About 223 ha were raised in the country in 2009 giving a rate of intensification of 115%. The cropping system in 2009 as shown in Figure 8 is composed principally of tomatoes and snake melons with, respectively, 52% and 21%. Melons represent 18%, watermelons 3% and others, generally peppers 6%. Also in the past years, tomatoes and snake melons were the main vegetables crops due to their commercial value and their facility of selling for export.

Figure 8: The greenhouse cropping system in Tunisia (2009)



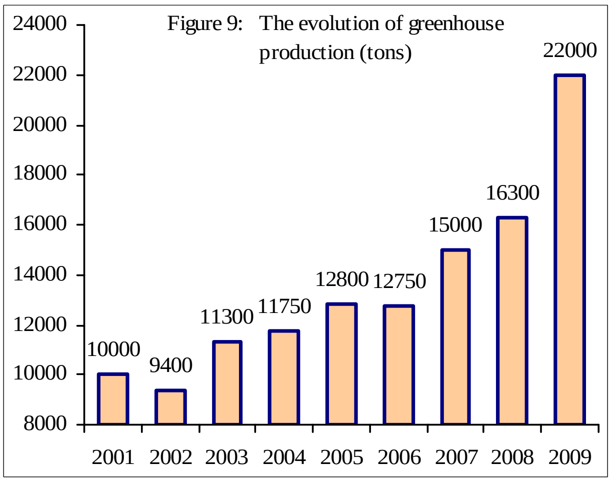
3.2.4 The Greenhouse Productions

Compared with unheated greenhouses, the geo-thermally heated greenhouses generate better quality and higher yields. Production increased from year to year due to the increase growing areas and good yields of some farms. The total production from heated greenhouses in the country is estimated to 22,000 tons in 2009. It grew from 10,000 tons in 2001 to 11,750 tons in 2004 to reach 16,300 tons in 2008 (see Table 4). From 2001 to 2009 it varied as shown in Figure 9 with an average of 13,500 tons per year. Since the size of the farm is higher in Gabes region than the other two regions (43 greenhouses by farm), the yields are also higher.

Table 4. The Total Estimated Production in the Country (2009).

Regions	Area (ha)	Average of greenhouses by farm	The total estimated production (tons)	Average Yields (tons/ ha)
Kebili	77	3	6,500	84
Gabes	84	43	13,000	155
Tozeur	33	9	2,500	76
Total	**194**	**7**	**22,000**	**113**

Figure 9: The evolution of greenhouse production (tons)



3.2.5 The Greenhouse Vegetable Export, Economics and Social Development

The greenhouse sector represents a good place in the development of the southern regions of the country. It is considered economically feasible since it contributes for the amelioration of the level life of farmers by generating good incomes and devises via export. Indeed one unit of greenhouse generates an income from 2,000 to 2,500 TND (Tunisian dinars). This means an income from 40,000 to 50,000 TND per ha. Growers are well attached to their greenhouses which allow a flux in the treasury (money entrance during all the period of the year). The work is one of the most principal factors defining the process of the production system inside the farm. Greenhouse farms, especially medium and big farms are generator of employments (about 7 permanent employments and 400 seasonal days-work by one ha).

The export quantity remains under the objectives of the strategy, which projects a 50% export of the total production. Only 21% of the productions were exported in 2007, mainly from big farmers of Gabes region. In 2009, the export reaches a record of 28% of the total production mostly are tomatoes, which increases by over 50% compared to last year (6150 tons).

The prices given for Tunisian tomatoes product are high in the European market 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 The Greenhouse 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).

Figure 10: The greenhouse heating system

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, 34 wells are operating to supply 32 different sites where 566 farmers are operating. Table 5 shows the distribution of projects and farmers by area.

Table 5. The Distribution of Greenhouse Projects, Farmers and Boreholes.

Regions	Projects number	Farmer number	Boreholes number for greenhouses
Kebili	14	456	14
Gabes	11	39	13
Tozeur	7	71	7
Total	**32**	**566**	**34**

The total area heated by geothermal water is 194 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 heat lasts 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). Normally, the total amount of geothermal water needed for heating greenhouses is approximately 60,000 m3/ha for six months period but the real amount can go over this volume.

3.2.7 The Greenhouse Irrigation System

After the thermal water has been used for heating greenhouses, a small part is collected in concrete ponds for subsequent use for irrigation after being cooled. 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 also used for the irrigation of an open field area (oases) close to greenhouses. The need for water irrigation during the growing period is very low compared to heating. In that way, farmers utilize a localized system (dropping 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 relatively high salinity in the region (from 2 to 4 g/L).

3.2.8 What is the 'Geothermal Return Water'?

Worldwide, using geothermal water both for heating and irrigation is practiced only in Tunisia. From the borehole, water goes directly through pipes lying on the ground inside the greenhouses for heating. For new projects, only 10% of the total heating water is sufficient for greenhouse irrigation and the rest is collected during the night in a big pond outside (Figure 11). Then it is used for oases irrigation. But for old projects, the need for irrigating a greenhouse reaches 15% of the total heating volume.

In normal conditions, the needs average 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 and due to some old irrigation system projects.

Figure 11: Type of big 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 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 in 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 for better using return water. The best idea is to attribute greenhouses to the same farmers exploiting oases. Figure 12 shows the best connections between a greenhouse project and an oasis one.

Due to disinterest of some farmers and to the bad design of some greenhouse projects, water couldn't reach easily the ponds. Farmers dispose of the water close to the fields and often in the drainage system producing a waste of water resources (Ben Mohamed and Said, 2008). 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. For instance, the total amount of water returned from the greenhouses to the oases in Kebili region is estimated at 250 L/s, which represent only 50% of the available water. The same figure exists for Gabes and Tozeur regions.

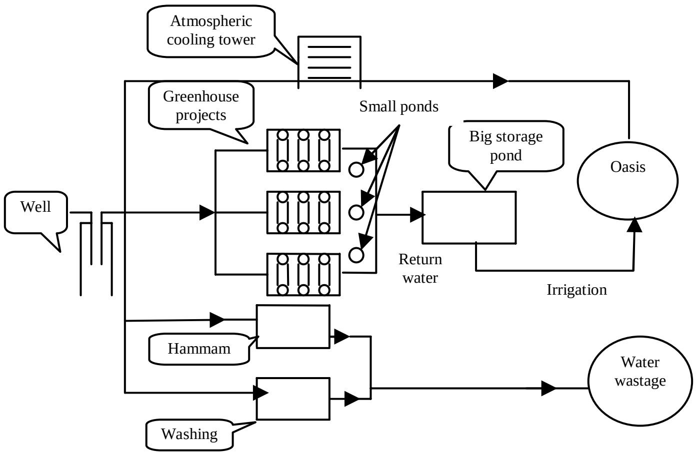


Figure 12: Best configuration for using the return water

<u>3.2.9 Future Outlook: the Geothermal Strategy in Greenhouses</u>

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, over 50% of the projected area is implemented (see Table 6).

Table 6. The Geothermal Greenhouse Strategy.

Regions	Strategy (ha)	Actual area (ha)	Remaining area (ha)
Kebili	105	77	28
Gabes	100	84	16
Tozeur	100	33	67
Gafsa/S. Bouzid	38	0	38
Total south	**343**	**194**	**149**
Mahdia	22	-	22
Others	13	-	13
Total country	**378**	**194**	**184**

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 has now 77 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. Some big farmers, started with only 10 greenhouses, now they have 40 greenhouses (as seen in Table 3). 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 2016 (final year of the 12th Plan of development), 121 ha will be added in the country reaching 315 ha, which represents more than 80% of the strategy (see Table 7).

Table 7. The Geothermal Greenhouse Projected Area in 2016.

Regions	Actual area (ha)	Contribution (%)	Added area in 2016 (ha)	Total projected area (ha)
Kebili	77	40	59	136
Gabes	84	43	30	114
Tozeur	33	17	32	65
Total	**194**	**100**	**121**	**315**

3.3 From Traditional Thermal Baths to the Spas!

People have used geothermal water for bathing for many thousand of years. Balneology, the practice of using natural mineral water for the treatment and cure disease, also has a long history (Lund, 2000).

In Tunisia, the history of thermal waters dates for thousands of years. It witnessed a significant development during the Roman period when resorting to hot waters was a cult, an art to cure people and an art of life. Geothermal water has been used for a long time for bathing and many of geothermal manifestations in the country have the name of ''Hammam'' or bath, which reflects the main use of geothermal resources in the centuries. There are more than 70 hot springs in Tunisia, 28 are located in the northwest region (Ben Dhia and Bouri, 1995) 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.

Whereas, according to the 'Thermalism office' Tunisia has more than 80 thermal manifestations including 50 inventoried hot springs with the required physical and chemical composition for thermal treatment in various therapies. The number of thermal bath visitors has been increasing year after year, an indication of the importance which Tunisians give to those beliefs. For instance, in 2001, about 2.5 million people seeking treatment visited these thermal baths.

The hammam's activity is very known and 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. In Kebili area, for example, there are around 10 traditional baths using 1% of the total volume of geothermal water. Generally, they are small baths with a similar design with two small covered pools (two for ladies and two for gentlemen), two sitting rooms, two dressing rooms, and one pray-room. Surrounding the hammam, there are often a parking, a cafeteria and small stores for shopping. The hammam, to be successful, must have better service 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.

The most famous thermal stations or spas in the country are Korbous, Djebel-Ouest, Hammam Bourguiba and the Djerba spas. Thousands of citizens visit the stations every year, not only for bathing and having curative treatments, but also for fun and recreation.

Figure 13: The previous Ras-Elain swimming pool, Kebili region

Some pools in different hotels of the country are supplied by hot water for touristy purposes. A small amount of water is used for hotels and swimming pools.The small pool of Ras-Elain located inside the oasis in Kebili area, for example, was a real place for people recreation. It has been renovated by the municipality in 1998, now it is closed because its location inside a private park for recreation. People visited the pool every season by the year at early morning and late afternoon (see Figure 13)

3.4 Animal Husbandry and Washing

The quantity of water used for animal husbandry (dromedary, sheep and goats) is also small. It is important to indicate that animals, especially dromedary like warm water than cold water. In addition, warm water is so demanded in wintertime because of the salty taste and gives more appetite for animals, which are crossing many kilometers to reach hot sources.

Figure 14: The washing activity, close to Steftimi bath, Kebili region

As mentioned before, the geothermal resources have been exploited for the first time for bathing and washing. This was in the beginning of 1950 and 1960. Generally, ladies are washing clothes, wool and heavy things such as winter covers. Thermal water is transported through 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 (see figure 14) and developed for many reasons: washing easy, warm water in winter time, with no cost (water saving), large space and washing 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.

CONCLUSION

In Tunisia, geothermal water is mainly used for oasis irrigation after being cooled in atmospheric cooling towers and heating of greenhouses. The energy consumption in greenhouses is increasing by every year due to the new greenhouses projects in the southern part of the country. Sometimes there are some unresolved conflicts between users. Thus, for water saving purposes, cascaded use should continue in the country. For some projects, especially the new ones, the outlet water from greenhouses is used directly for oasis irrigation. The need for irrigating a greenhouse is only 0.1 times the heating. 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 has been practiced all over the country since long ago. 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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