Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Low Enthalpy Geothermal Resources Application in the Kebili Region, Southern Tunisia

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Keywords: geothermal resources, direct utilization, oases, greenhouses, hammams

ABSTRACT

In Tunisia, only low enthalpy resources, which are localized mainly in the southern part of the country, are available. Then, the use of geothermal energy is limited to direct application. For thousands of years, geothermal water has been used for bathing, and many of geothermal manifestations in the country have the name of ''Hammam'' or bath, which reflects the main use of geothermal water over the centuries. Now, the resources are utilized mostly for agricultural purposes (irrigation of oases, greenhouses). The government's policy in the beginning of 1980's was oriented towards the development of the oasis sector and the main aim was to supply oases with geothermal water for irrigation. Therefore, in the Kebili area, over 35 boreholes are operating mostly for the irrigation of 16,000 ha of oases after cooling the water in atmospheric cooling towers. Eighteen years ago, the State started using geothermal energy for greenhouse farming, by planting an area of one ha in the region. The results of this experiment were very encouraging, and thus the cultivated areas have today increased to 51 ha (47% of the total cultivated area in the country). Utilization of geothermal resources will without a doubt, increase in the future once we have implemented the last phase of the greenhouse project.

1. INTRODUCTION

Commonly, 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, 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 in the regions of Kebili, Gabes and Tozeur 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, in the Kebili area, about 35 boreholes are operating mostly for irrigation of 16,000 ha of oases after cooling the water in atmospheric towers. 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 51 ha.

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

2. GEOTHERMAL RESOURCES

The region of Kebili is located in the southwestern part of the country. Geothermal resources are taken from the CI aquifer, the largest in Tunisia (the deep aquifer or CI: Continental Intercalaire). This aquifer is characterized by relatively hot water (30-75°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 Dahar mountains of Tunisia. In the Kebili area, 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 reaches 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 and washing. This was in the beginning of 1950 and 1960. After that, and because of the abundance of water in some oases and the large expansion of areas as shown in Figure 1, these resources were utilized for oases's irrigation.

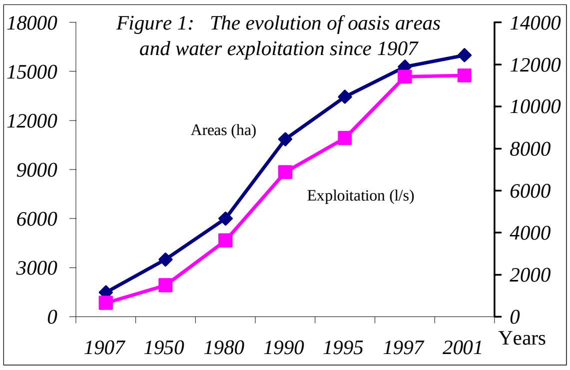


Figure 1: The evolution of oasis areas and water exploitation since 1907

The important period of drilling boreholes was in 1985 and 1986 (twelve wells) and in the beginning of 1990 (eight wells). Then drilling activity was stopped until 1994 to start again in 1999 and 2000 (five wells). From 1952 to 2004, 35 wells were drilled in the region.

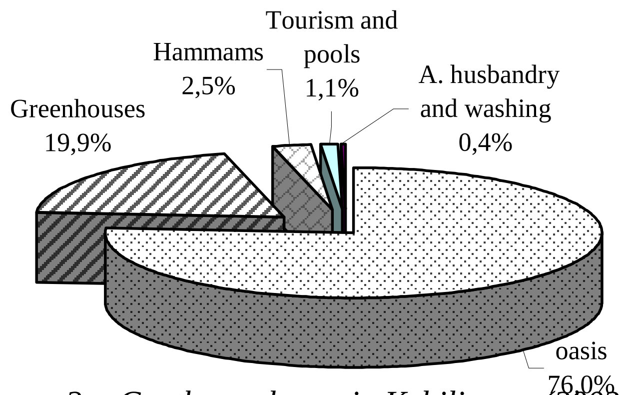


Figure 2: Geothermal uses in Kebili area (2003-2004)

3. GEOTHERMAL USES
(RESULTS AND DISCUSSION)

Major direct utilization projects exploiting geothermal energy exist in about 60 countries. About two third of this energy use is for space heating, swimming and bathing. In the Kebili region 96% from geothermal resources is utilized for agricultural purposes: 76% for oases and 20% for greenhouses. The remaining part (4%) is used for bathing (hammams), tourism (hotels and pools), washing and animal husbandry. The use in greenhouses increases by about 3% compared to the year 2002 (17%) because of the increasing of greenhouses areas. Figure 2 shows the different direct geothermal uses in the area in 2003 and the beginning of 2004.

3.1 IRRIGATION OF OASES

3.1.1 Water Cooling System

Located in the southwest of the country, the region of Kebili, is 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). The temperature range is very high. These difficult conditions require a large amount of water to maintain the humidity inside the oases system. The major part of the geothermal water is used for irrigating 16,000 ha of oases (76%) but all the resources taken from the Complexe Terminal aquifer (CT) are used for irrigation. The water temperature varies from 27°C to 73°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 this cooling system we can lower the temperature by 5-10°C.

When the temperature exceeds 45°C, the water is cooled by means of atmospheric towers before being used for irrigation. In normal conditions, we can drop the temperature to 30-32°C. However, these towers have the disadvantage of losing water via evaporation, estimated at 2-5% of the total flowrates and need a big exploitation cost by the years (10,000-15,000 dinars) which is divided to the electricity cost, the maintenance and the gardening.

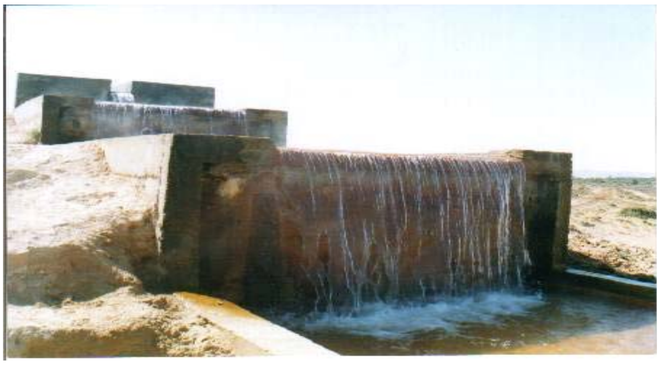


Figure 3: The Water Cooling System (Cascade of Oum Elfareth)

3.1.2 IrrigationSystem: the Water Saving Project

The irrigation in the region is by the submersion method and all the area is irrigated (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 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 in the beginning of 1990's to give more importance, responsibilities and decision making to the non governmental organizations. In that way, 99 organizations related to management of water resources, called GIC, are operating in the region 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 (see Figure 4). The project covers about 7,500 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.

Figure 4: The concrete canalization for oasis irrigation (Douz project)

3.2 HEATING AND IRRIGATION OF 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 950 ha worldwide using geothermal energy for heating. In Tunisia, in addition to irrigation of oasis, the geothermal water is used for heating plastic greenhouses. The utilization of geothermal energy recently 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 southern part of the country. After one year, many demonstration projects in several places had been established. Nowadays, the exploitation of geothermal resources for heating greenhouses on the edge of the desert represents a promising alternative for the development.

3.2.1 Evolution of Areas

Numerous commercially marketable crops have been raised in geo-thermally heated greenhouses in many countries. The use of geothermal energy for heating 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 950 ha. The leading countries in 1998 (Popovski, 2002) are USA (183 ha), Hungary (130 ha), China (115 ha) and republic of Macedonia (62 ha). At this time and according to these data, Tunisia occupied the fourth position with 80 ha, after the USA, Hungary and the republic of Macedonia. But, based on papers submitted for WGC2000 in Japan (Lund, 2002), Tunisia occupied the first place in the world 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 (40% in the region). Today, the total area is about 110 ha, of which 47% are located in the Kebili area. Figure 5 shows the evolution of the greenhouse area in the country and in the region.

Plastic houses were attributed in the beginning to small farmers with two units of houses. The first experiment was in the Limagues locality where 1 ha was planned in 1986. The area involved later rose to 18 ha in 1989. Since 1990 this sector has stagnated, for a revision period, in the range of 28 ha, but started increasing again in 2000 and has now reached 51 ha. Development of the greenhouse sector has been very fast, at least for some small farmers starting with two houses, who now five-six or even 10 greenhouses. Concerning the big farmers, some of them started with only 20 greenhouses, now they have 50 greenhouses (see Table 1). Utilization of the geothermal resources will, without a doubt, increase in the near future after implementing the final phase of the geothermal greenhouse project (strategy). By the end of 2006, 15 ha will be added in the region reaching 65 ha.

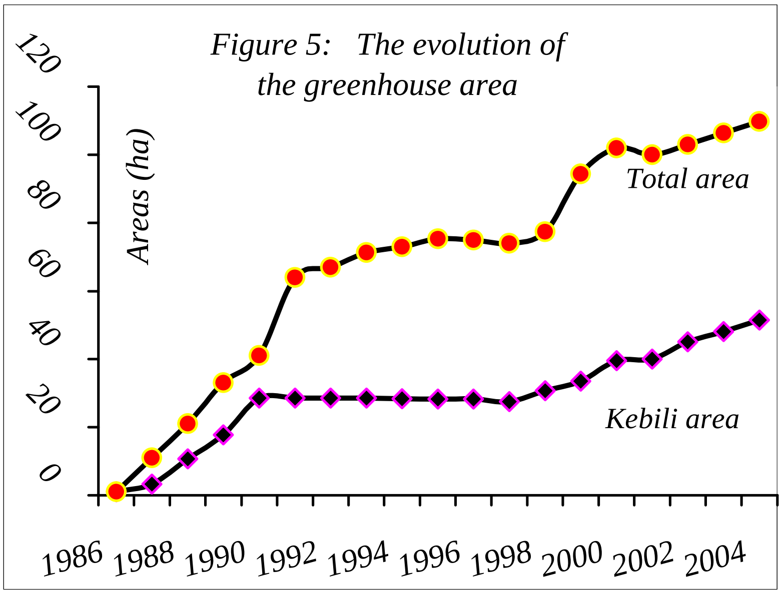


Figure 5: The evolution of the greenhouse area

TABLE 1: The Development of the Greenhouse Area in some Localities

Projects	Number of greenhouses		Growth Rate (%)
	At the year of implementation	Now	
Limagues 1	20	51	61
Limagues 2	60	145	59
Oum Elfareth	40	95	58
Steftimi	60	85	29
Behaier	46	68	32
Jemna	56	70	20
Charfedine	10	24	58
Ameur Ben Ameur	20	50	60

TABLE 2: The Geothermal Greenhouse Strategy

Region	Geothermal resources	Strategy (ha)	Actual area (ha)	Remaining area (ha)
Kebili	1,100	100	51.45	48.55
Gabes	1,682	100	36.6	63.40
Tozeur	635	100	21.75	78.25
Total area	3417	300	109.80	190.20

3.2.2 Regional Geothermal Strategy

Geothermal resources in Tunisia are estimated to be 4850 l/s, 70% are localized in the south part of the country. These resources are able to create 300 ha in the country; one third of the era is implemented (see Table 2).

3.2.3 Occupation of Areas

Utilization of the greenhouse area in Kebili region is based on three cultivations, the first, from late August to December, the second from late December to June and the third from late August to June (continuous). The exploitation is more than one time per year and lasts nine months. The cropping system in 2000 for example was composed of cucumbers and tomatoes representing, respectively, 40 and 29%, melons (21%), watermelons (8%) and peppers only 2%. In 2001 and 2002, cucumbers and tomatoes were also the main vegetables composing the cropping system with respectively 66 and 70% due to their commercial value and their facility of selling. Figure 6 shows the composition in 2002. Inside a greenhouse, several species of crops can be raised simultaneously. Growers, in this way, try to diversify their production in order to bypass agricultural risk.

Figure 6: The cropping system (2002)

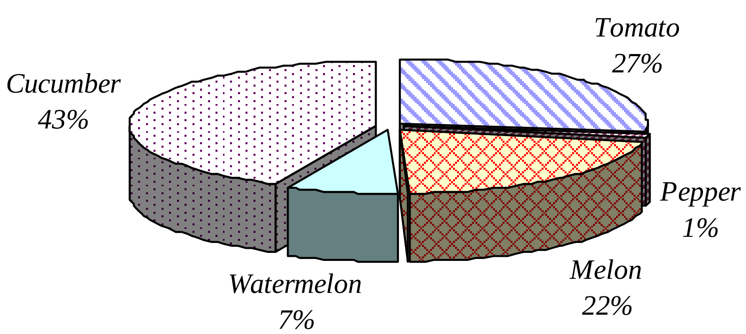
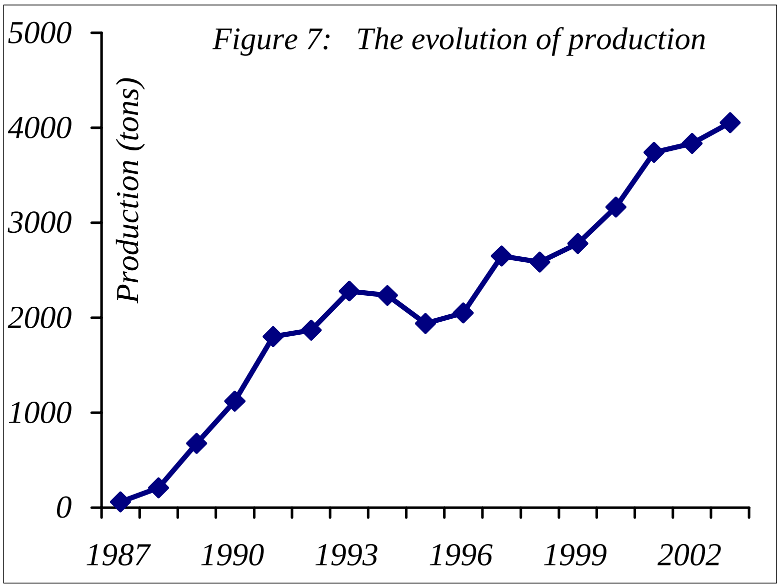


TABLE 3: The Total Production in the Country

Regions	Area (ha)	Production (tons)	Production contribution (%)
KEBILI	49	4,000	40
TOZEUR	21	2,000	20
GABES	36	4,000	40
TOTAL	106	10,000	100

The production in Kebili region grows from 210 tons in 1988 to 1,120 tons in 1990 to reach 1,939 tons in 1995. From 1996 to 2003 it varied as shown in Figure 7 with an average of 3,100 tons per year.



3.2.4 Evolution of Productions

Despite some problems handicapping the greenhouse sector in the beginning, such as lack of qualification and bad techniques of some farmers, production increased from year to year. This is not always a result of good productivity but sometimes generated by the expansion of areas as mentioned above. But, in comparison with unheated greenhouses, the geo-thermally heated greenhouses generate better quality and higher yields. In the season 2002/2003, the total production from heated greenhouses in the country reached 10,000 tons (see Table 3). The regions of Kebili and Gabes contributed with 40% each of the total production.

3.2.5 Heating of Greenhouses

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. 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 Kebili region, 12 wells are operating to supply 21 different sites. An area of 51 ha is heated with a water temperature varying from 45 to 73°C. The need for greenhouse heating is only six months, mostly during the night. Farmers start heating in November-December and stop it in April. The duration lasts 14 hours per day. This means that they 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).

3.2.6 Irrigation of Greenhouses

After the thermal water has been used for heating it is collected in concrete ponds for subsequent use for irrigation (see Figure 8). 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 m3. Generally, these ponds are used for the irrigation of an open field area close to 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).

Figure 8: Concrete Ponds for Irrigation

3.3 BATHING (HAMMAMS)

People have used geothermal water and mineral waters for bathing and their health 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). For thousand of years, geothermal water has been used for bathing in Tunisia 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.

In the north, people go to hammams not only for bathing and having curative treatments, but also for fun, recreation, exercise, mud baths and other many reasons. These hammams have also the name of thermal stations (Spas in other countries). The hammam’s activity is very known and spread over the country, especially in the south. In Arabic speaking, the world Hami means hot. In the south, two areas are called hamma (Gabes and Tozeur regions) because of the hot water in these areas. In Kebili area, there are 10 traditional baths using about 3% of the total volume of geothermal water. Generally, they are small baths with a similar design with two small covered pools. The Steftimi bath, 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 pray-room (see Figure 9).

Thermal waters have a similar chemical composition from place to place. Table 4 shows some analyses of the major constituents of water from wells in several locations. There are high concentrations of chloride and sulphate.

A survey done with visitors shows that there are mainly six reasons to go to the hammam: to cure diseases, to prevent diseases, to relax, to reduce stress, to clean, to spend time (mostly in Ramadan). But, never: to be in solitude, to reduce weight, to quit smoking, to meet people.

Figure 9: Traditional bath of Steftimi with Two Small Covered Pools

3.4 SWIMMING POOLS AND TOURISM

Three pools in three different hotels are supplied by hot water for tourist purposes. There is another pool at Kebili-Ras-Elaïn which is a small public pool with a temperature of 42°C. It is located inside the oasis and 200m from the water cascade. It has been renovated by the municipality in 1998, now it is closed because its location inside a private park for recreation. People visit the pool every season of the year at early morning and late afternoon, the main reason is for cure. A questionnaire with visitors showed that one visit lasts from thirty minutes to two hours but most of the visitors stayed for one hour in average. More than 40,000 citizens visited the pool per year (Ben Mohamed, 2002). Four other hotels and a cafeteria are also supplied in the edge of the Sahara at Ksar Ghilane area. About 1% of the total amount of water is used for hotels and swimming pools.

TABLE 4: Composition of Water (mg/l) (Source: CRDA, 2001)

Wells	Ca	Mg	Na	K	SO4	Cl	HCO3	pH
Steftimi 2	336.6	107	558.6	31.2	869.3	673.6	122	8.1
Menchia	340	112	690	22	1200	1242	90	7.03
Menchia CI.6	232	164	310	36	816	781	102	8.1
Z.Chorfa CI.4	148	135	230	10	672	497	112	7.72
Bechri CI.2	220	112	265	24	912	639	115	7.74
Mansoura CI.3	384	82	519	35	1143	886	219	8
Kebili CI.10	328	26	358	23	744	687	158	8
Jemna CI.11	250	72	597	41	792	875	256	8.2
Douz CI.12	288	80	1064	60	898	1524	122	8.1
Faouar CI.19	180	77	413	37	730	602	134	8.1

Figure 10: The Washing Activity

3.5 WASHING

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 at Menchia and Steftimi areas. Generally, ladies are washing clothes, wool and heavy things such as winter covers (see Figure 10). About 0.5% of the total amount of water is estimated to be used directly for washing but it is difficult to estimate it. Thermal water is transported through furrow to parcels for irrigation; an amount of water is taken off for washing. In the 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: easy washing, warm water in winter time, with no cost (water saving), large space and washing together (spending time).

3.6 ANIMAL HUSBANDRY

A small amount of water is used for animal husbandry especially for camels, sheep and goats. Two wells are used in this purpose giving a total flow rate of 6 l/s. It is important to indicate that animals, especially camels 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. Camels are crossing many kilometers to reach hot sources.

4. CONCLUSION

In southern Tunisia, geothermal water is used for bathing, tourism, washing, animal husbandry and for agricultural purposes. The main use is for irrigation of oases and heating of greenhouses (95%). For water saving purposes, the use in a cascade way starts recently in the region. For some projects, especially the new ones, there is a good relation between the users and water from greenhouses goes directly to oases for irrigation. The need for heating and irrigating a greenhouse is respectively estimated at 0.3 and 0.03 l/s. The rest or the return water which represents 90% (0.27 l/s) should supply the oases surrounding the area, but this is often difficult to achieve. 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. 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 return water.

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