UTES POTENTIAL FOR SPACE HEATING AND COOLING IN LIBYA

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1. BACKGROUND

Sweden is a leading country in using the ground for heating and cooling. In such Underground Thermal Energy Storage (UTES) systems the ground is used as heat or cold source or as medium for thermal energy storage. Heat pumps are usually part of these systems that today supplies about 15-20% (15 TWh) of all space heating in Sweden [EHPA, 2001]. During the last decade hundreds of cooling plants have also been built. This energy efficient technology is environmentally benign since extracted heat is renewable energy that is passively stored from ground surface.

The UTES system should be used in many more countries, to save energy and environment. One reason that this technology has not been promoted is probably that it is too simple. It can be constructed by local labor and companies, which means that this is not a product for export and thus no economic incentive [Nordell, 2000]. Ground heating/cooling systems are almost unknown in Libya and the neighboring countries though the local conditions in many areas are more favorable than in Sweden.

In Algeria, a fraction of the total geothermal capacity of 152.3 MW is used for space heating and cooling, while 98% is used for other applications (greenhouse heating, baths etc) [Fekraoi, 2005]. In Tunisia, the application is limited to 35 boreholes supply water mainly for irrigation and greenhouse heating in the southern part of the country [Ben Mohamed, 2002]. In 2005, Ben Mohamed (2005) reported that the total area of greenhouses applying UTES for heating purposes is 110ha (up from 95 ha in 2001).There was no reports on any kind of geothermal applications in Morocco and Libya [Lund, 2005].

After several visits in Libya, lecturing in this field at universities and research centers, there is an increasing interest in UTES for direct heating and cooling and also for seasonal storage of solar heat. For this reason Libya will be the starting point in implementing ground heating/cooling systems in North Africa.

The UTES technology will be more easily spread to other countries in North Africa by demonstration plants in Libya, which is an influential country in this region. Libya can afford the cost of UTES development for North African conditions and the population also shares the Arabic language with other countries in the region.

The Libyan interest in UTES is indicated by the fact that Luleå University of Technology (LTU) from Oct 2005 has a Libyan research student within the field financed. The project is financed by Libyan and Swedish research foundations. The studies will mainly be carried out at Sebha University (SU), supervised by LTU and SU. LTU is also collaborating with Al Fatah University, Tripoli, where three MSc students are working within the same field.

2. OBJECTIVES

The overall objective of current project is to transfer Swedish UTES know-how and to adapt UTES for North African conditions. Initially the UTES technology will be studied and demonstrated in Libya. The technology will be promoted in North Africa through conferences, seminars and articles in international and Arabic journals. This PhD project will be summarized in Mohamed Grein's PhD thesis.

3. OVERVIEW OF RESEARCH FIELD

Principle outline

The main idea is to extract or dissipate heat into the ground for space heating and cooling. In such systems boreholes in the ground are most commonly used as ground heat exchangers. In areas where the larger land areas are available, horizontal pipe systems are used for the extraction of heat and cold. In colder climates heat pumps are used to extract the heat during the winter while the ground is used for direct cooling (no cooling machines) during the summer. In a warmer climate the situation would be the opposite, the heat of the cooling machines is dumped into the ground and this heat is used for direct heating during the winter season. In the most favorable case the ground could be used for both direct cooling and direct heating. This means that the heat and cold is extracted by circulating water through a buried pipe system. Figure 1 outlines two systems for space heating and cooling of a building.

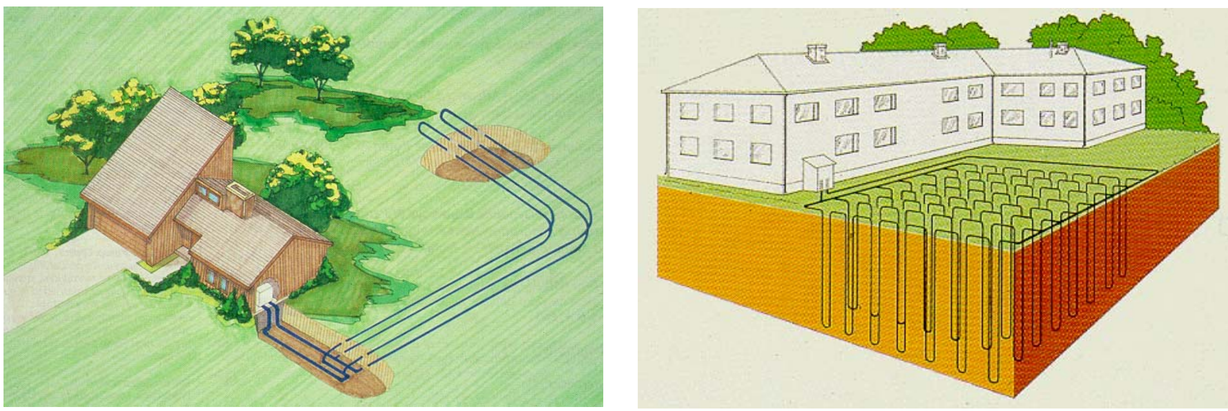


Figure 1. Examples of horizontal and vertical ground coupled pipe systems for space heating and cooling. Left shows a system with two pipes in each ditch.

The horizontal pipe system in the ground is placed in many different ways. If large land areas are available the pipes are normally placed in lines with a few m spacing over the area. If smaller areas are available the pipe is placed in a more compact manner, see Figure 2.

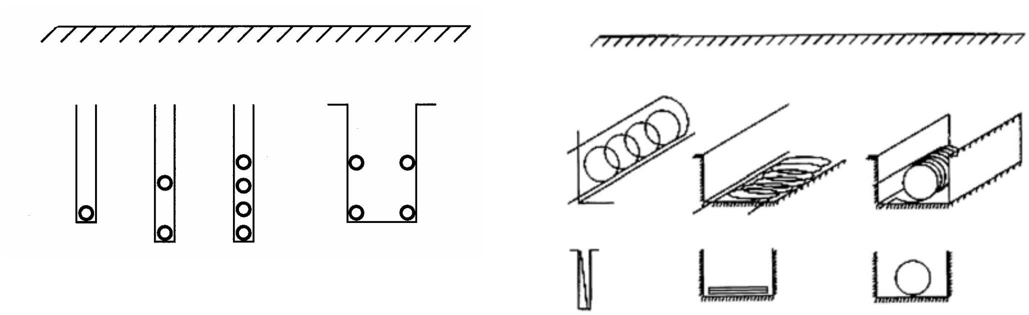


Figure 2. Different horizontal pipe systems for extraction of heat and cold form the ground.

The increasing market for ground heating and cooling means that there are several companies manufacturing different types of collectors. One example is the Fence Collector manufactured by the Swedish company IVT,. Another example is the coils of pipes (“Slinky”) mainly used in the USA.

4. PROJECT DESCRIPTION

Initially the potential of UTES systems in North Africa and in particular in Libya will be evaluated. Relevant data for the potential study concern e.g. climate, heating and cooling demand, geology, and groundwater. After that a suitable test building will be selected and more site specific data will be determined before the UTES is designed, modeled and constructed. The operation of the pilot plant will be monitored and evaluated. The research will mainly be carried out at Sebha University in Sebha (SU), about 800 km South of Tripoli. The research student will have two supervisors, one at LTU and one at SU. More specific tasks in this project are:

Climate (Energy) Data

- Climatic data
- Heating and cooling demand in the region (per m^2, over time, kW, kWh)

Ground related data

- Geology – soil and rock
- Groundwater conditions
- Thermal properties of the ground (thermal conductivity, ground temperature etc)

Building related data

- Appropriate distribution system for heating/cooling
- Investigate most suitable floor and wall material

Pilot plant

- Selection of suitable test building
- Design of pilot plant for ground cooling/heating (seasonal and diurnal storage)
- Construction of ground cooling/heating system
- Operation and monitoring of pilot plant
- Evaluation

Dissemination of results

- The technology will be promoted in North Africa by articles in international and Arabic journals.

Time Schedule and Financing

This PhD project which started in Oct 2005 is planned for 4 years of full time studies though current plan only stretches over the two first years until the Licentiate Degree. The full cost of the Libyan PhD student, supervision at SU, and the construction of the pilot plant are financed by National Research Board of Libya. LTU's cost of supervision and traveling during the first two years for both Libyans and Swedes engaged in the project is covered by the Swedish research foundation SIDA.

Research Environment and Research Group

The Department of Civil and Environmental Engineering at LTU has presently more than 100 PhD students. Even though the Libyan student most of the time will work at Sebha University he will be part of our academic atmosphere. LTU and Lund Institute of Technology (LTH), also in Sweden, have together an extensive experience of issues concerning commercial ground heating/cooling systems including thermal energy storage, and system for free cooling [Nordell, 1994; Hellström, 1991; Claeson et.al. 1985]. This collaboration started when the world’s first large-scale borehole heat storage system was built at LTU 1982. The LTU/LTH group has since worked on the development of design tools, construction, components, especially heat exchangers, thermal response test, and system studies. Furthermore the group has participated in pre-studies, design and evaluation of a large number of ground heating/cooling plants in Sweden and abroad. This LTU/LTH group has for many years participated in international research collaboration within the IEA Energy Conservation through Energy Storage (ECES) Implementing Agreement. The research group has participated in the following Annexes:

- Annex 7 Innovative and Cost Effective Seasonal Cold Storage Applications
- Annex 8 Implementing Underground Thermal Energy Storage Systems
- Annex 12 High-Temperature Underground Thermal Energy Storage (HT UTES)
- Annex 13 Design, Construction and Maintenance of UTES Wells and Boreholes
- Annex 14 Cooling With Thermal Energy Storage (TES) in All Climates

The research group consists of five researchers and presently one PhD student in Libya:

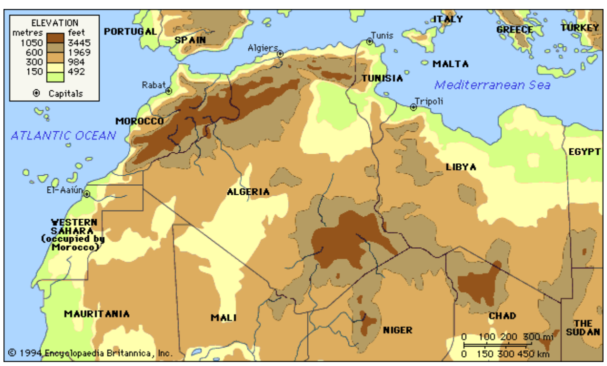
- Prof. Bo Nordell, Div Renewable Energy, Luleå University of Technology
- Doc. Göran Hellström, Mathematical Physics, Lund Institute of Technology
- Prof. Johan Claesson, Mathematical Building Physics, Chalmers University of Technology
- Prof. Abdulsalam M. A. Almathnani, Div of Ecology, Dept of Environmental Sciences. Sebha University.
- Prof. Muntasser, Dept Mechanical Engineering, Al Fatah University, Tripoli
- MSc. Mohamed Grein, Dept of Environmental Science, Sebha University, Sebha

5. PRELIMINARY RESULTS

Design calculations have not yet been performed for this region but LTU/LTH has previously been involved in UTES potential studies in Turkey [Paksoy et. al. 1999] and Portugal [Nunes de Carvalho, 2004], which indicate that this technology would be feasible also in North Africa. So far, necessary Libyan and regional data have been collected and partly compiled.

Geography

Libya is the fourth largest country in Africa with a total area of 1.76 million km^2. It has a 1900 km cost line to the Mediterranean Sea consists and 95% of the area is part of the Sahara desert [FAO, 1995]. The population was 5.7 million in 2004 (3 p/km^2) and 80 percent of the people live in the coastal area [USLC, 2005a].



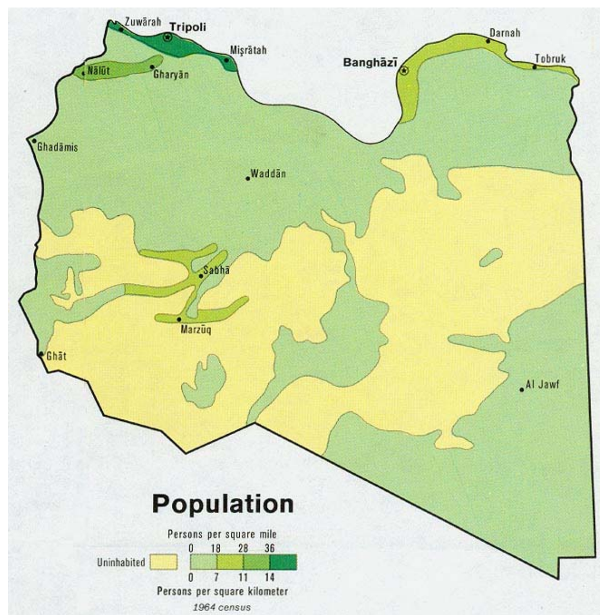


Figure 2. Libya is located in the north of Africa. The majority of the people live in the costal areas

Climate

The climatic conditions are influenced by the Mediterranean Sea to the north and the Sahara desert to the south. The following broad climatic divisions can be made: The Mediterranean coastal strip with dry summers and relatively wet winters; the highlands experiencing a plateau climate with higher rainfall and humidity and low winter temperatures, including snow on the hills and to the south, pre-desert and desert climatic conditions, with torrid temperatures and large daily thermal variations. Rain is rare and irregular and diminishes progressively towards zero. The Sahara is one of the hottest regions in the world, with mean annual temperatures exceeding 30°C. In the hottest months, temperatures can rise over 50°C, and temperatures can fall below freezing in the winter. A single daily variation of -0.5°C to 37.5°C has been recorded.

The lowest monthly mean temperature is 12.1°C (January) and the warmest month is August with a mean temperature of 27.4°C. The average precipitation in the costal region of Libya is annually about 350 mm with almost no rain during June-August. The overall precipitation is, however, extremely low, with about 93 percent of the land surface receiving less than 100 mm/year and the mean precipitation for the country as a whole is 26 mm. [USLC, 2005b]

Heating and cooling demand

In Libya and most of North Africa cooling and heating are needed during some months of the year (Figure 3) though the eastern part of North Africa is considerably warmer and dryer. In fact the heating demand is greater that the cooling demand in Algeria.

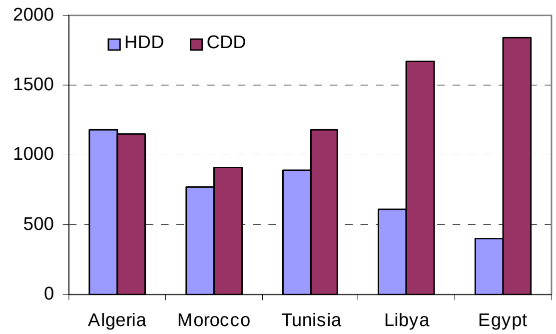


Figure 3. Heating and cooling degree days in North African countries. [WRI, 2002]

There must be seasonal temperature variations to utilize the thermal energy that is naturally stored in the ground. In Tripoli, the mean temperature difference between the coldest and warmest month is about 20^{o}C, i.e. equal to that in Stockholm, which is favorable. Even more favorable is that the diurnal temperature variation shows even greater amplitude (during the cooling season), which indicates that diurnal storage of thermal energy would also be an option.

Building

It is not possible to implement UTES without considering the buildings to be heated and/or cooled. Modern residential buildings in the area are constructed of concrete while traditional buildings were built of clay and traditionally without heating system. The clay structure used meant that the houses were relatively warm during the winter and cool during the summer. In the modern concrete buildings, both heating and cooling demand has increased. Heating is usually supplied by electrical heaters during the short heating period, while cooling is supplied by air/air cooling machines. About 87% of produced electricity in Libya is for residential heating and cooling. The heavy concrete structure however has large thermal storage capacity. Since there is usually no heat distribution system installed it should be favorable to use in-the-floor pipe systems for both heat and cold distribution. Then the storage capacity of the building will reduce the peak power demand.

Current Energy Situation

During the seventies and early eighties, the annual electricity consumption growth was about 15% in Libya. This was a result of the population growth but mostly due to the rapid growth of the oil sector and its influence on the economic and social development of the country. Somewhat lower growth rates occurred during the late eighties and early nineties. In 2000, total primary energy supply was 679 PJ and energy exports were 2652 PJ. Crude oil and refined petroleum products constituted about 60 percent of primary energy supply with the remainder being natural gas. Presently, the increase in electricity demand is growing at an annual rate of around 8%. It is expected to reach 5,800MW by 2010, surging to 8,000MW by 2020. The current production capacity is approximately 4,700 MW, but plans have been set in motion by the state-owned General Electricity Company of Libya (GECOL) to generate an additional 5,000 MW within the next five years [LNEC, 2005].

Table 1. Electricity Generation in Libya (1996-2004)

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
Produced power (GWh)	12,086	12,620	13,528	14,407	15,496	16,111	17,531	18,943	20,202
Peak Load (MW)	1977	2140	2360	2448	2,630	2,934	3,081	3,341	3,612

Source: General Electricity Company of Libya [GECOL, 2005]

6. SUMMARY

This PhD project is still in its initial phase. So far the work is focused on obtaining relevant data considering geology, groundwater, heating and cooling demand in North Africa and Libya in particular. Even though this is not an easy task some data have already been compiled. One surprising fact was the great difference in heating and cooling demand along the North African Mediterranean coast.
Our experience is that UTES has been utilized in many countries where the natural conditions are less favorable than in the North African countries. Therefore we believe that UTES will have a great future in this rapidly developing region. In many of the countries the ground could be used directly for both heating and cooling. When it comes to underground seasonal storage of solar heat the conditions are better than anywhere else. The climate makes solar collectors most efficient and the storage conditions are even better with an undisturbed ground temperature of 20-25^{o}C and the. In Libya the objective is to use the ground directly for heating and cooling. In another project in Tlemcen, Algeria, a seasonal storage for solar heat is planned.
A successful transfer of UTES know-how would lead to the implementation of UTES in North Africa. This would have a great economical and environmental impact on these countries. UTES is a technology where local companies and labor would be engaged in design, development, and construction. Natural cooling and heating system with very low operation cost and also active seasonal storage of thermal energy would release economic resources to other important areas.

ACKNOWLEDGMENTS

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