Planned investigation of UTES potential in Algeria

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Abstract. The unbalance between supply and demand of heat can be managed by thermal energy storage (TES). For large-scale systems the underground is used as storage medium or storage volume. Aquifer storage (ATES) is most suitable for very large applications, Borehole storage (BTES) the most general system in all scales and the rock cavern storage (CTES) is best suited for extremely high loading/extraction loads. The construction of any of these systems requires knowledge about site-specific properties of the ground i.e. geology and groundwater conditions. Current paper gives a brief review of the potential and advantage of Underground Thermal Energy Storage (UTES) technology utilization in buildings for the hard climate.

1. Overview
Energy is the backbone of an economy and solving the energy trilemma of sustainability, affordability, and adaptation to climate change is a huge challenge that the world faces daily. The major part of countries with this problem are located in Sub Saharan Africa. With most of the countries having electricity access rates less 50% and high dependence on traditional biomass for cooking, the need for clean and affordable energy becomes imperative. This, therefore, prompts a need for thorough multidisciplinary research and development in clean and sustainable energy sectors. Consequently, renewable energy resources in Africa must be exploited. These sustainable sources of energy can supply energy demands of different sectors in residential, commercial, and industrial sectors with minimal impact on the environment.

Africa is endowed with various renewable energy resources which the solar resource is more evenly distributed across the continent when compared to others. With issues of deforestation and need for production of food crops which impedes the full exploitation of biomass and intermittency of wind and solar energy, this leaves geothermal energy resource as the one of the least intermittent renewable sources for heating and/or cooling buildings, electricity production and other uses.

Generally, geothermal energy entails the harnessing of thermodynamic quantities which have equal ability of a physical system to generate work or heat; from the earth crust’s underneath. Through the means of conduction and convention, geothermal heat that exists deep inside the earth’s interior emerges close to the earth’s surface. The heat coming from the earth crust is caused by the decomposition of radioactive isotopes of uranium, thorium, potassium and earth crust core which has a temperature of 1000-4500°C [1].
Besides from volcanoes, geothermal energy also appears at the surface in the form of hot springs, steam vents, hot soil, boiling mud, geysers, hydrothermal craters, structures ascribed circulation of hot fluids moving to the surface from the underground. These fluids contain the convective component of the natural heat flow from the earth interior. There is also a conductive component to the natural heat flow of the earth, which arises because of the temperature gap between the deep underground and the soil surface, and is controlled by the thermal conductivity property of the rocks [2].

2. Utilization of geothermal energy

One can harness steam/water heated by the geothermal heat by the mean of different technologies and also use it for several purposes. The use of geothermal fluid relies considerably on its thermodynamic characteristics and chemistry. The geothermal system from which the fluid originated determines these factors. Geothermal fluids have been categorized in a different way by number of authors. Some have done so by using temperatures while others have used enthalpy [3]. The most mutual criterion is based upon enthalpy. The resources are divided into low, medium and high enthalpy resources. Table 1 depicts the classifications proposed by several authors.

| Classification of resources | Muffler and Cataldi [4] | Hochstein [5] | Benderitter and Cormy[6] | Nicholson [7] | Mburu [8] |
|-----------------------------|--------------------------|---------------|--------------------------|----------------|----------|
| Low Enthalpy Resources      | <90                      | <125          | <100                     | ≤150           | ≤190     |
| Intermediate/ Medium        | 190-150                  | 125-255       | 100-200                  | -              | -        |
| High Enthalpy Resource      | >150                     | >255          | >200                     | >150           | >190     |

Depending on the enthalpy, geothermal fluid can be used either to generate electricity or for direct applications. Electricity generation is the common and dominant form of utilization of high-temperature geothermal resources while low to medium resources are better suited for non-electric (direct) application (Table 2).

| Reservoir temperature       | Reservoir fluid | Common use       | Technology commonly chosen                                      |
|-----------------------------|-----------------|------------------|-----------------------------------------------------------------|
| High temperature, >220°C    | Water or Steam  | Power generation and Direct use | Flash steam; Combined (flash and binary) cycle Direct fluid use; Heat exchangers; Heat pumps |
| Intermediate temperature, 100-220°C | Water | Power generation and Direct use | Binary cycle Direct fluid use; Heat exchangers; Heat pumps |
| Low temperature, 30-150°C   | Water           | Direct use       | Direct fluid use; Heat exchangers; Heat pumps                   |
### Table 3. Applications of geothermal energy.[9]

| Application                  | Description                                                                                                                                 |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Electricity production       | Wells drilled into a geothermal reservoir produce hot water and steam from depths of up to 3 km. The geothermal energy is converted at a power plant into electric energy, or electricity. Hot water and steam are the carriers of the geothermal energy. |
| Direct use                   | Applications that use hot water from geothermal resources directly. Examples: space heating, crop & lumber drying, food preparation, aquaculture, industrial processes, greenhouses etc. Historical traces back to ancient Roman times, e.g. |
| Geothermal heat pumps        | Taking advantage of relatively constant earth temperature as the source and sink of heat for heating and cooling, as well as hot water provision. It is one of the most efficient heating and cooling systems available. |

3. **Underground Thermal Energy Storage (UTES)**

Energy is needed to heat or cool space, but mostly, its availability is always a constraint. The gap between energy supply and demand issues is solved by the energy storage. The potential of using renewable energy sources as geothermal energy, solar heat and waste heat has been in escalate thanks to the energy storage system. Underground Thermal Energy Storage (UTES) is the most often used storage technology for heat and “cold”. It has been proven that the ground is the best candidate of storing heat or cool in great quantity and for long period of time[10]. The use of bedrock, sediment and groundwater in the subsurface as a huge UTES system allows for storage of surplus heat (regardless of whether it is solar in origin, radiogenic (geothermal), or simply waste summer heat from buildings) until a time when it is needed. To put it another way, the ground can be turned into a heat store; it can preserve summer heat until winter and winter cold until summer, letting us to correspond supply and demand for minimum one year. Ground-Source Heat Pumps (GSHP) are frequently used to ‘pump’ excess heat into the ground and to draw out heat when needed for space heating. For the most optimum, it can be used to procure a balanced combination of both heating and cooling, with surplus summer heat being stored in the ground for next extraction in winter.

Many different UTES systems have been created and tested. Two types of system, Aquifer (ATES) and Borehole (BTES) storage.
- Aquifer Thermal Energy Storage (ATES), where heat transfer and storage are by warm or cold groundwater.
- Borehole Thermal Energy Storage (BTES), where boreholes are used as heat exchangers for transfer of thermal energy to/from the ground. The volumetric heat capacity of the rock is used to store the heat.

4. **Research design and methodology.**

The objective of this research is to estimate the geothermal resource potential in several regions in Algeria and to estimate the applicable UTES in the said regions. This means identifying the geothermal resource potential, in terms of rock and fluid properties, surface extent, volume, and collect necessary information for decision making on developing geothermal power plants and also direct use of available resources. To achieve this, the following surveys should be taken in consideration according to [2]:

4.1. **Geological survey**

The geological survey will include the study of surface rocks in terms of mineral content, fluid inclusions, as well as studying the hydrology of the area, aiming at:
- Mapping surface geology.
- Identifying the age of rocks.
- Establishing local stratigraphy and possible permeable deep zones for geothermal exploitation.
- Identifying volcanic formations of recent geological age, which indicate the presence of hot magma chambers close to the surface.
- Identifying hydrothermally altered rocks, which are a product of a fossil or active hydrothermal system.

The data of this survey will be gotten from literature as well as from the oil exploration companies in Algeria if available.

4.2. Mapping thermal manifestations
Thermal manifestations (steam vents, geysers, hot springs, hot ground, boiling mud, hydrothermal craters) are the outlet of rising hot fluids that prove the presence of an active hydrothermal system in an area, which may be the target for geothermal power generation. They may provide useful clues concerning the location, the temperature, the chemistry and the depth of the deep geothermal resource. In addition, the flow of each thermal manifestation is measured, which is necessary for calculating the convective heat flow from the area.

4.3. Geochemical survey
It includes sampling of surface and near surface waters, chemical analysis and application of geo-thermometers. The latter presumes that the chemical equilibrium of dissolved species stays unchanged during their ascent from depth towards the surface, and as chemical equilibrium is a function of temperature, the deep temperature of the fluids can be obtained. An experienced geochemist will be enquired to assist in the derivation of credible estimations pertaining the temperature and chemistry of the deep fluids.

4.4. Thermal gradient measurements
It consists of drilling different shallow bores, of depths 50-100m, measuring downhole temperature, and defining the distribution of the geothermal gradient in the area, which, along with the thermal conductivity of the rocks, are the factors of conductive heat flow from the area.

4.5. Gravity survey
It implies measuring the local gravity field, which depends on the density of subsurface layers. In volcanic environments where there is a large difference in the density between the upper volcanic formations and the deeper basement of metamorphic rocks, the gravity survey provides useful information concerning the thickness of the volcanic formations.

4.6. Deep exploration drilling and testing
A geothermal resource is proven only if there is at least one deep geothermal production well. In addition to proving the resource, deep exploratory wells give important information on subsurface geology, properties of the rock, minerals present, fluid inclusions, as well distribution of key reservoir parameters, such as temperature, pressure, porosity and permeability, which are essential to evaluate both quantity and quality of the geothermal resources. Related tests include sampling of rocks (cores), and fluid, wire line logging, production tests, pressure drawdown and build-up tests, injection tests and interference tests.

After data collection, several statistical and mathematical models would be applied to estimate the natural heat flow, stored heat, reservoir volume, qualitative thermal recovery factor for each area. Also the Kehle temperature correction to downhole temperatures would be applied.

4.7. Thermal response test (TRT)
To find out the suitability of the UTES especially the BTES, the thermal response test (TRT) will be used to determine the ground thermal properties. The TRT is an indirect (in-situ) measurement approach, which is the easiest and most accurate way to determine the effective thermal properties.

The methodology of TRT include [11]:

4
Drilling of a test borehole and inserting with U-tube of a particular size.

- The test borehole is filled with (ground)water or some grouting
- The tube and fluid is left to stabilize for several days.
- The initial temperature along the borehole will be noted.
- A circulation pump is used to circulate the heated fluid through the borehole
- Heat is supplied by some kind of heater usually a heat pump
- The inlet outlet temperature is monitored and the ground thermal conductivity and borehole resistance are estimated from this temperature response
- Other information such as the initial ground temperatures and indications of groundwater flow would be noted and taken into consideration.

4.8. Data Analysis using GIS

Geographic Information System (GIS) Model for Geothermal Resource Exploration (GM-GRE) toolbox will be used for data integration and analyses to identify the suitability of a particular geothermal resource type and the extent of areas that warrant further detailed investigation. Digital data layers and maps can be used in the GIS environment to develop a geothermal favorability map. It integrates three different data sources, namely geological and geochemistry sources and the geothermal gradient, are applicable to the tool to assess the geothermal potential on a regional scale [12]. All these systems and steps took a lot of time and are very expensive and also the difficulty to obtain authorization from the government.

5. CTES potential in Algeria

CTES still have a big advantage – the powers of injection and extraction are very high. In the Rock Cavern Thermal Energy Store (CTES) energy is stored at a constant temperature during the year in an underground cavern. In such a system with a large volume of air or water it is of great importance to maintain a stratified temperature profile in the cavern that cannot be obtained.

Figure 1 and 2 show the potential of different existing caverns in Algeria country that are characterized by a constant temperature. This system (Caverns) means available underground duct systems that could be used as a source for heating and cooling. Such a system would be made simply by pumping air through the Cavern and conducting this air to the air conditioned building. For example the BeniAad Cavern at Tlemcen in North West Algeria is characterized by a temperature about 13°C during all the year where the ambient temperature varies from -6°C in winter to 40°C in summer. The ambient air then approaches the temperature of the Cavern (~13°C) during the passage through the ground before used for ventilation, heating, and cooling of buildings that can reduce energy consumption inside the building [14].

Figure 1. Potential of different existing caverns in Algeria, (a) Grotte de Cervantes at Algiers, and (b) Grotte de Ziama Mansouriah at Jijel
Figure 2. Potential of different existing caverns in Algeria, (a) Grotte de Beni Aad Tlemcen, and (b) Ghar Boumaaza Tlemcen

Figure 3. Potential of CTES that can be used for heating and cooling

Another old existing system has been studied called Fouggara situated in the desert of Algeria [15]. This study shows the feasibility of using this system for heating and cooling buildings where the temperature inside the system is constant about 21°C during the year Figure 4
6. Conclusion

As geothermal energy production and use become more prominent in today’s renewable energy. Many countries are actively exploiting geothermal energy for both electricity generation and other uses but only a limited number of countries use geothermal energy directly for heat production. In Algeria, balneotherapy remains practically the only direct use of this energy with more than two hundred hot springs spread over the northern part of the country. About one third (33%) of them have temperatures above 45°C. There are even high temperature sources up to 118°C in Biskra. Algeria being the largest country in Africa in terms of area, it necessarily has a large potential in Albian nappes (80% of Algerian territory). Geothermal energy remains under exploited in Algeria. Aware of this significant potential of geothermal energy in the energy sector, it is necessary to focus its interest on geothermal energy for the development of the agricultural sector. This is why in this paper we describe different steps to investigate the underground thermal energy storage that can be planned for the near future.

References

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[1] Ikechukwu O, Agbidi D C and Bamisile O O 2015 Exploration And Application of Geothermal Energy in Nigeria 6 2 726–732

[2] Mendrinos D, Karytsas C and Georgilakis P S 2008 Assessment of Geothermal Resources for Power Generation 10 51262–1267

[3] Dickson M and Fanelli 2004 What Is Geothermal Energy Inst. di Geosci. e Georisorse, CNR,
Pisa, Italy

[4] Muffler R, P and Cataldi 1978 Methods for Regional Assessment of Geothermal Resources

[5] Hochstein M P 1990 Classification and Assessment Of Geothermal Resources in: Dickson, M.H. and Fanelli, M., eds., Small Geothermal Resources: A Guide to Development and Utilization,” UNITAR New York 31—57

[6] Benderitter Y and Cormy Y 1990 Possible Approach To Geothermal Research And Relative Costs in Dickson, M.H. and Fanelli MSmall Geothermal Resources: A Guide to Development and Utilization, New York: UNITAR 59–69

[7] Nicholson K 1993 Geothermal Fluids(Berlin: Springer Verlag) vol. 18 264

[8] HUTTRER G WThe Status of World Geothermal Power Generation 1995 – 2000 Geothermics 2001 30 7–27

[9] Mburu M 2012 Geothermal Energy Utilisation

[10] Midttømme K, Banks D, Ramstad R K, Sæther O M and Skarphagen H 2008 Ground-Source Heat Pumps and Underground Thermal Energy Storage — Energy for the future93–98

[11] Gehlin S 2002 Doctoral Thesis Thermal Response Tes 1402–1544

[12] Noorollahi Y, Ghasempour R and Jalilinasrabady S 2015 A GIS Based Integration Method for Geothermal Resources Exploration And Site Selection 33 no. 2243–257

[13] Wikipedia, https://fr.wikipedia.org/wiki/Cat%C3%A9gorie:Grotte_en_Alg%C3%A9rie

[14] Nordell B 2000 Large-scale Thermal Energy Storage, WinterCities'2000, Energy and Environment (Sweden : Luleå)

[15] Amara S, Nordell B and Benyoucef B 2011 Using Fouggara for Heating and Cooling Buildings in Sahara, Energy Procedia, Science Direct Elsevier 6 55 - 64