

# Review on Thermal Energy Storage and Its Applications

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**ABSTRACT:** This paper describes current developments in seasonal thermal energy storage, which has seen improved interest in recent years due to the growing awareness of global warming and other environmental problems. The main seasonal thermal energy storage system is underground thermal energy storage system aquifer thermal energy storage system, bore hole thermal energy storage system, cavern rock thermal energy storage system, hot water thermal energy storage system, gravel water thermal energy storage system combination with a heat pump and solar thermal collectors. These systems can able to overcome the day-night issues as well as the seasonal difficulties associated with the solar power usage for air conditioning system. In this paper added a detailed description on all the above underground thermal energy storage system and information about solar collector and heat pump used for the transfer of heat energy. This study discussed about the various techniques that can be used to temperature control which have very high demand in the future days.

**KEYWORDS:** borehole thermal energy system, rock cavern thermal energy storage system, aquifer, hot water, gravel water thermal energy storage system, solar collector.

## 1.INTRODUCTION

Solar energy is the most abundant source of energy available in our world. The power of the sun can be efficiently used to harness energy for solving our energy needs. The void of not having efficient technology to tap this abundant energy reservoir has led to search for better technologies and more varied applications. Our primary focus in this paper would be on utilizing solar energy for domestic air conditioning system purpose[18]. Solar energy is very large inexhaustible source of energy. Solar energy is mainly used in two ways. It can be converted to either heat or electricity. Converting solar energy into heat is possible by using solar thermal energy technologies. Converting solar energy directly to electricity is achievable by using photovoltaic cells[19]. Also there are other ways of converting solar energy into electricity by using solar thermal energy technologies. Energy (heat or electricity) obtained from solar energy technologies can be used for many purposes such as drying, heating, cooking, cooling, desalination. Solar thermal energy describes all technologies that collect sunlight and convert their electromagnetic energy into heat, either for directly satisfying heating/ cooling needs or for producing electricity[21]. In order to increase efficiency, high temperatures are necessary for electricity generation from solar thermal processes. These high temperatures can be obtained by using concentrating solar power technologies. Summer air conditioning represents a growing market in building services world-wide in both commercial and residential buildings. Main reasons for the increasing energy demand for summer air-conditioning are the increased thermal loads, increased living standards and occupant comfort demands as well as building architectural characteristics and trends, like an increasing ratio of transparent to opaque surfaces in the building envelope to even the popular glass buildings. [20]Air conditioning includes both temperature and humidity control of indoor air. so, in this paper we explained well about the various refrigeration methods that can be operated using the solar power[22].

## II. UNDER GROUND THERMAL ENERGY STORAGE SYSTEM

Renewable thermal energy is usually available when the energy demand is low. This mismatch can be balanced by seasonal storage of energy in Underground Thermal Energy Storage[2] (UTES) systems. The most common technologies are aquifer storage (ATES)[3], borehole storage (BTES)[4][5][6] and rock cavern storage (CTES) hot water thermal energy storage system(HWTES), gravel water thermal energy system(GWTES). It is not possible, for geological or geo-hydrological reasons, to construct all these systems at any location but one of them can in most cases be realized [1].

### A. AQUIFER THERMAL ENERGY STORAGE SYSTEM

Aquifer thermal energy storage (ATES) is the storage and recovery of thermal energy in the subsurface. ATES is applied to provide heating and cooling to buildings. Storage and recovery of thermal energy is achieved by extraction and injection of groundwater from aquifers using groundwater wells. Systems commonly operate in a seasonal mode. The groundwater that is extracted in summer is used for cooling by transferring heat from the building to the groundwater by means of a heat exchanger. Subsequently, the heated groundwater is injected back into the aquifer, which creates storage of heated groundwater. In wintertime, the flow direction is reversed such that the heated groundwater is extracted and can be used for heating (often in combination with a heat pump). Therefore, operating an ATES system uses the subsurface as a temporal storage to buffer seasonal variations in heating and cooling demand. When replacing traditional fossil fuel dependent heating and cooling systems, ATES can serve as a cost-effective technology to reduce the primary energy consumption of a building and the associated CO<sub>2</sub> emissions [1].

Aquifers are below-ground widely distributed sand, gravel, sandstone or limestone layers with high hydraulic conductivity which are filled with groundwater. If there are impervious layers above and below and no or only low natural groundwater flow, they can be used for heat (and cold) storage. In this case, two wells or groups of wells are drilled into the aquifer and serve for extraction or injection of groundwater. During charging periods cold groundwater is extracted from the cold well, heated up by the solar system and injected into the hot well. In discharging-periods the flow direction is reversed. Because of the different flow directions both wells are equipped with pumps, production- and injection pipes. Especially for high temperature heat storage a good knowledge of the mineralogy, geochemistry and microbiology in the underground is necessary to prevent damage to the system caused by well-clogging, scaling etc.[2]

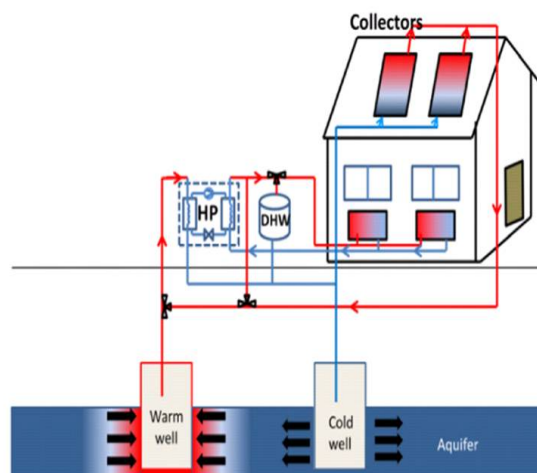


Figure 1: Aquifer thermal energy storage system

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Vol. 6, Issue 1, January 2017

### **B. BORE HOLE THERMAL ENERGY STORAGE SYSTEM**

In borehole thermal energy storage the heat is directly stored in the ground. Suitable geological formations are e.g. rock or water-saturated soils. U-pipes, so called ground heat exchangers, are inserted into vertical boreholes, into a depth of 30-200 m, to build a huge heat exchanger. The boreholes are usually filled with groundwater, or with betonies, quartz sand or thermally enhanced grouts. While water is running in the U-pipes heat can be fed in or out of the ground. The heated ground volume comprises the volume of the storage. At the top of the store there is a heat insulation layer to reduce heat losses to the surface. One advantage of this type of storage is the possibility for a modular design. Additional boreholes can be connected easily and the store can grow with e.g. the size of a housing district. The size of the store has to be three to five times higher than that of a hot water heat store to obtain the same heat capacity. Because of the lower capacity at charging and discharging usually a buffer store is integrated into the system.[13][14] The performance of Ground Source Heat Pumps (GSHP) coupled to vertical energy wells partially depends on the thermal resistances in the ground and in the borehole. Different locations may imply different design needs and the thermal response of the ground at a certain location is difficult to control by other means than changing the position of the boreholes and controlling the heat rates from and to the ground[1][5][8][2][3][4][6][12].

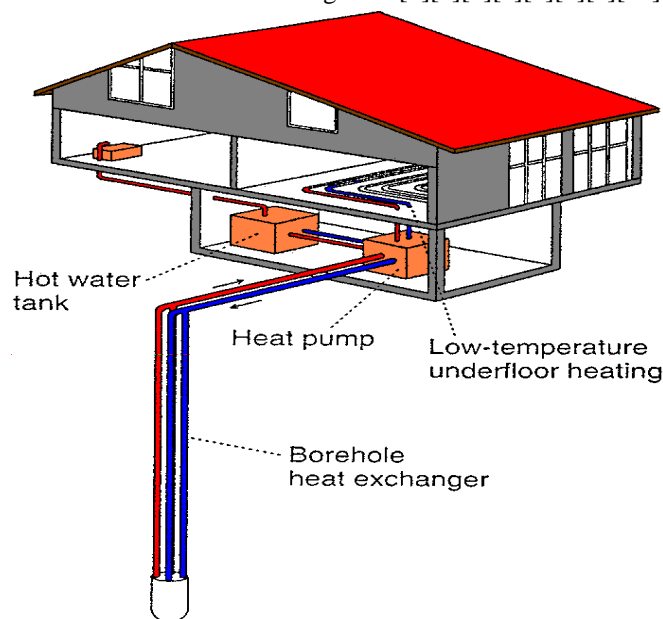


Figure 2: Borehole thermal energy storage system

### **C. ROCK CAVERN THERMAL ENERGY STORAGE SYSTEM**

In the Rock Cavern Thermal Energy Store (CTES) energy is stored as hot water in an underground cavern. In such a system with a large volume of water it is of great importance to maintain a stratified temperature profile in the cavern. During injection hot water is injected at the top of the store while colder water is extracted from the bottom. Two such storage systems were built in Sweden, Avesta with a volume of 15,000 m<sup>3</sup> and Lyckebo with a storage volume of 115,000 m<sup>3</sup>.

The Avesta CTES was built in 1981 for short-term storage of heat produced at an incineration plant. The Lyckebo store, which is partly heated by solar energy, has been in operation since 1983. There are a few more CTES systems built but in these cases the caverns used were not initially constructed for CTES. There are examples of shut down mines and oil storage caverns that have been reconstructed for hot water storage. (Gustafson G, 1985) Rock caverns are very expensive to construct. CTES still have a big advantage - the powers of injection and extraction are very high. So,

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Vol. 6, Issue 1, January 2017

CTES can be used to meet very high powers. It is also possible to use CTES as part of a system for ice/snow storage [1][2][5][14][12].

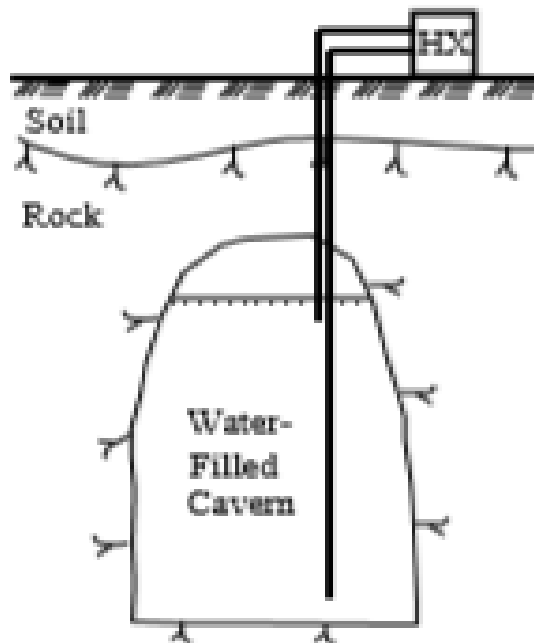


Figure 3: Rock cavern thermal energy storage system

### ***D. HOT WATER THERMAL ENERGY STORAGE SYSTEM***

The hot-water heat store has the widest range of utilization possibilities. Because of the high specific heat capacity and the high capacity rates for charging and discharging it is the most favorable of the four storage types from the thermodynamic point of view. The water filled tank construction of usually reinforced concrete is partly embedded into the ground and can be built almost independently from geological conditions. It is heat insulated at least in the roof area and on the vertical walls. To guarantee water tightness and to reduce heat losses caused by vapour transport through the walls. The compound wall made of glass fibre reinforced plastics with an integrated heat insulation layer is prefabricated in cylindrical segments which are mounted together on site. It usually have a tank construction built of reinforced concrete, heat insulated at least in the roof area and on the vertical walls, to reduce heat loss, fully or partially buried in the ground. It mainly consist of two levels for charging and discharging (on top and at the bottom), a third device which is located below the upper third of the storage volume. It enables low temperature heat can be charged into the store without disturbing higher temperature layers on top of the store. In addition simultaneous charging and discharging of the store at different temperature levels becomes possible. [22][23][1][2][5][4].

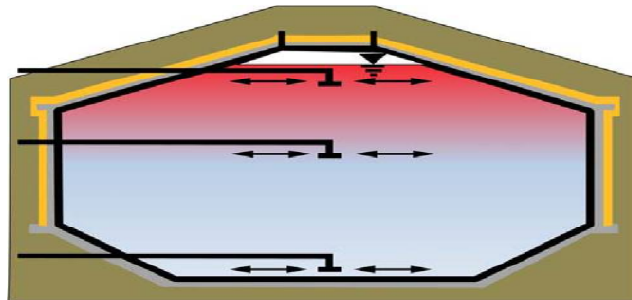


Figure 4: hot water thermal energy storage

#### D. GRAVEL WATER THERMAL ENERGY STORAGE SYSTEM

A pit with a watertight plastic liner is filled with a gravel–water mixture forming the storage material. No load-bearing frame structure is required because forces are taken down to the side walls and to the bottom by the gravel. The store has a heat insulation, at least at the side walls and on the top. Heat is charged into and discharged out of the store either by direct water exchange or by plastic pipes installed in different layers inside the store. Because of the lower specific heat capacity of the gravel–water mixture, the volume of a gravel–water heat store has to be approximately 50% higher compared to a hot-water heat store to obtain the same heat capacity for the whole store. It is normally buried in the ground, but close to the surface in order to reduce excavation costs. Plastic linear separating material and soil and insulated on both top and inclined walls. The storage material usually is a mixture of gravel and water. Heat is charged into and discharged out of the store by direct water exchange or by plastic pipes installed in different layers inside the store.

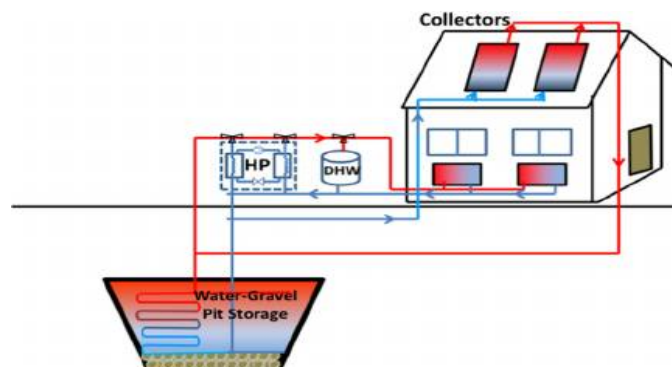


Figure 5: gravel water thermal energy storage system

### III. SOLAR COLLECTORS

Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major component of any solar system is the solar collector. This is a device which absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid (usually air, water, or oil) flowing through the collector. The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment or to a thermal energy storage tank from which can be drawn for use at night and/or cloudy days. There are basically two types of solar collectors: non-concentrating or stationary and concentrating. A non-concentrating collector has the same area for intercepting and for absorbing solar radiation, whereas a sun-tracking concentrating solar collector usually has concave reflecting surfaces to intercept and focus the sun's beam radiation to a smaller receiving area, thereby increasing the radiation flux. A large number of solar collectors are available in the market.[20][5][22][4][7][19][25]

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Vol. 6, Issue 1, January 2017

## IV. CONCLUSION

This paper describes current developments in seasonal thermal energy storage. Solar energy is very large inexhaustible source of energy. The power from the sun intercepted by the earth is approximately  $1.8 \times 10^{11}$  MW which is much larger than the present consumption rate on the earth of all commercial energy sources. Thus, solar energy could supply all the present and future energy needs of the world on the continuing basis. This makes it one of the most promising of the unconventional energy sources. In addition to its size, solar energy has two other factors in its favor. First unlike fossil fuels and nuclear power, it is an environmental clean source of energy. Second, it is free and available in adequate quantities in almost all parts of the world where people live. In the future days all the energy consumption will be carried out using solar energy. Also we understood that the solar energy can be stored and used any time we need but the system used for solar thermal energy storage are different in different places according to the geographical and geo thermal conditions of each places.

## REFERENCES

- [1] Bo Nordell "Large-scale Thermal Energy Storage" Division of Water Resources Engineering Luleå University of Technology ,April 2000
- [2] Bo nordell and goranhellstrom "high temperature solar heated seasonal storage system for low temperature heating of buildings" Division of Water Resources Engineering Luleå University of Technology ,april 2000
- [3] Amaya v novo, joseba r bayon and Jorge Rodriguez Review of seasonal heat storage in large basins: water tanks and gravel –water pits
- [4] T. Schmit, D.Mangolid and H. Muller " seasonal thermal energy storage in germany" june 2013
- [5] Goranhellstrom "thermal performance of borehole heat exchangers" department of mathematical ,physics, lund institute of technology Sweden june 2000
- [6] M. Reuss , M.Beck and J.P Muller "design of a seasonal thermal energy storage in the ground" institute of agricultural engineering technical university munichgermanyjune 1997
- [7] Timothy P mcdowell and jeff W Thornton "simulation and model calibration of a large scale solar seasonal storage system" thermal energy system specialists,LLCMadison,WI august 2008
- [8] Dario Bouro, pieropinamonti and ManroReini "optimization of a distributed cogeneration system with solar district heating" engineering and architecture dept., university of Trieste Italy 2014
- [9] G .Hellstrom, B Sanner , M klugescheid, T.gonka, S Martensson "experiences with the borehole heat exchanger software EED" lund institute of technology lundswedan institute of applied geosciences, Justus-liebig-university,Giessengermanyapril 1997
- [10] Per Eskilson and johannaclasson "simulation model for thermally interacting heat extraction boreholes" dept., of building technology and mathematical physics lund institute of technology Sweden October 2007
- [11] J. Acuna and b Palam "first experiences with coaxial borehole heat exchangers" dept., of energy technology/ applied thermodynamics and refrigeration/KTH Sweden april 2011
- [12] M.N Fisch, M.Guigas and J.O Dalenback "A review of large scale solar heating systems in Europe" Tu.Branschweig institute fur and solartechnikBranschwiegggermany august 1998
- [13] Christopher Baldwin and Cynthia A Cruickshank "A review of solar cooling technologies for residential applications in Canada" Carleton university 1125 colonel BY Drive Ottawa Ontario Canada 2012
- [14] T.Schmidt, D Mangold and mullerSteinhagen "seasonal thermal energy storage in germany" solar und Wärmetechnik Stuttgart , a research institute within the Steinbeis-foundation stuttgart, germanyjune 2003
- [15] D Pahud and G hellstrom "development of system simulation tools of central solar heating plants with a seasonal duct store in the ground" dept., of mathematical and physics lund university lund Sweden april 1996
- [16] LaviniaGabrilela "seasonal sensible thermal energy storage solutions" dept. Of mechanical engineering technical university of clij-napoca Romania issue 19 july –december 2011
- [17] Constantinos A balaras, Gershongrossman, Hans-martins Henning, ,Erich podesser Carlos A infant Ferreira and edowiemken "solar air conditioning in Europe-an overview" The joanneum Research institute of energy research graz Austria february 2005
- [18] Simon Chapuis and Michel Bernier "seasonal storage of solar energy in borehole heat exchangers"Dept.,de genie mecaniquecolepolytechnique de Montreal montreal Quebec Candajuly 2009
- [19] Signhild E A Gehlin, PhD, Jeffrey Spittle,PhD,PE, and GoranHellstrom, PhD "Deep boreholes for ground source heat pump systems-scandinavian experience and future prospects" Dept., of mathematical physics at lund university of technology swedanJuly 2014
- [20] Gershon Grossman "solar powered systems for cooling, Dehumidification and air-conditioning" faculty of mechanical engineering, Technion-israel institute of technology, technion city Haifa, Israel July2001
- [21] Hans-martin Henning "solar assisted air conditioning of buildings-an overview" fraunhofer institute for solar energy systems ISE, Heidenhofstr Freiburg Germany July 2006
- [22] ArefehHesaraki, Sture Holmberg and FariborzHaghighat "seasonal thermal energy storage with heat pumps and low temperatures in building projects-A comparative review" Dept.,of building, civil and environmental engineering Concordia university montreal QC Canada December 2014

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(An ISO 3297: 2007 Certified Organization)

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Vol. 6, Issue 1, January 2017

- [23] V. Lottner, M. E Schulz and E. Hahine “solar-assisted district heating plants:status of the german programme solarthermie-2000”institute fur thermodynamic und warnetechnikuniversitat Stuttgart germany vol.6 april 2000
- [24] M.Lundh and J.O Dalenback “Swedish solar heated residential area seasonal storage in rock:initial evaluation” division of solid state physics Dept., of engineering science Uppsala swedan march 2007
- [25] SeamaKoohi-Fayegh and Marc A. Rosen “A Review of the Modelling of Thermally Interacting Multiple Boreholes” Faculty of Engineering and Applied Science, University of Ontario Institute of Technology may 2013
- [26] L.t Terziotti, M.L sweet and J.T Mcleskey “modelling seasonal solar thermal energy thermal energy storage in a large urban residential building using TRNSYS 16” virginta commonwealth university Dept., of mechanical engineering Richmond USA October 2011
- [27] Hywel R. Thomas “non linear analysis of heat and moisture transfer in unsaturated soil” university of uster wales UK January 1987
- [28] J.Xu, R.Z Wang and Y.Li “A review of available technologies for seasonal thermal energy storage” institute of refrigeration and cryogenics, key lab of power machinery,shanghaijino Tong university china 2013
- [29] Pavlov, GeorgiKrasimirov and Olesen, Bjarne W. “Seasonal solar thermal energy storage through ground heat exchangers –Review of systems and applications” technical university of Denmark 2011