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Comparison Between Different Generations of BTES (Borehole Thermal Energy Storage) and Geothermal Heat Pumps

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ABSTRACT

Borehole Thermal Energy Storages (BTES) are becoming more common as it is cheap to store energy in the form of heat. They are naturally suitable for various applications. One application is covering seasonal heating needs of buildings with the stored heat either directly or with heat pump. In recent decades, many kinds of BTES systems have been suggested, developed, and implemented with some common features. We suggest that these systems could be categorized into different generations. These different generations can be separated by their borehole parameters, auxiliary equipment, maximum temperature, and costs. Heat pump use with different generations is also considered. The goal is to find the most suitable BTES generation for different applications. An example of each generation is described: for the 1st generation, the example is Inex Lohja, Finland (1990s), for the 2nd generation Drake Landing, Canada (2005) and for the 3rd generation Finnspring, Finland (2016).

1. INTRODUCTION

Approximately half of the European energy use goes to heating and cooling in buildings and in industry (Heating and cooling | Energy (europa.eu)). Residential space and water heating cover 92 % of the energy consumption (Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables) | Energy (europa.eu)). Eurostat statistics from year 2018 indicate that fossil fuels contribute 75 % for heating and cooling. Since fossil fuels cause greenhouse and particle emissions, there is a clear need to reduce their use. One way is to employ heat storage.

There are many different forms of heat storages from water tanks to phase change materials as well as implementation sites. This study is limited to BTES systems which are then studied and compared. Several aspects of BTES systems have been already reviewed by many authors. Welsch et al. 2016 provides a good review of medium deep BTES storages in which a comparison of over 250 numerical models is made. It is common to classify BTES systems according to their depth: shallow, medium deep and deep ones. Lanahan and Tabares-Velasco 2017 analyzed BTES for heating and hot water usages with solar thermal as a heat source. According to them, large BTES systems require initial loading time of several years and energy utilization is optimized with diurnal and seasonal storages.

We suggest here that BTES systems can be categorized into three different generations which each have their own typical features. These features include borehole parameters and auxiliary devices. A comparison is made between different generations. This can be used to determine which generation is suitable for a specific application. After the comparison, an example from each generation is introduced shortly.

2. COMPARISON OF DIFFERENT GENERATION

Different generations of BTES systems have different parameters for boreholes design. They are presented in Table 1. Length of boreholes have been affected by environmental issues as well as design. The 2nd and 3rd generation BTES systems have typically shorter lengths than the 1st generation ones. Boreholes can be connected and spaced differently depending on the design. The 1st generation systems have a very long spacing between boreholes.

The maximum temperature of BTES is an important parameter as it affects available heat energy. Reuss et al. 1997 has already temperatures around 90°C have good economical and technical potential. Thus, they are becoming more common. Different generations have also different auxiliary devices. Since the 1st generation systems have lower maximum temperature, a heat pump is essential. The latter generations have higher maximum temperatures, so this makes it possible to use them even without a heat pump. The heat is transferred with a circulation pump. If a heat pump is used, the COP is now higher. Since the maximum temperature is around 90°C, a heat pump can be used to increase the temperature so much that it is usable even in a high temperature district heating network. The heat pump should be selected based on the intended application.

Naturally, different generation BTES have different costs. CAPEX and OPEX parameters were selected for this evaluation.

Table 1. Parameters for different BTES generations.

	1st generation	2nd generation	3rd generation
Borehole length	200 m - 300 m	35 m - 100 m	35 m - 70 m
Borehole spacing	20 m - 30 m	2,25 m	2 m - 5 m
Borehole connection	Parallel matrix	Serial radial	Parallel circle
Auxiliary equipment	Heat pump	Large water tank	Controller
Max. temperature	20 °C	85 °C	85 °C
CAPEX	High	3 euros/kWh	1 euro/kWh
OPEX	50 euros/MWh	10 euros/MWh	3 euros/MWh

3. EXAMPLES FOR DIFFERENT GENERATIONS

This chapter provides examples of the 1st, 2^{nd}, and 3rd generation BTES systems. The selected examples are considered to be typical ones for each generation.

3.1 The 1st generation BTES: Inex Partners Ltd logistics center, Sipoo, Finland

The biggest retailing cooperative organisation in Finland is S Group. The corporation's fully owned subsidiary Inex Partners ltd has a logistics center in Sipoo. It was constructed in 2010-2012. The size of the building is 75 000 m^2 and 1100 000 m^3. It is the largest logistics center in Finland/Europe? For heating and cooling it utilizes geoenergy and bioenergy.

The BTES under the logistics center has 163 energy wells, spacing between wells 20 meters and the depth of each well 300 meters. https://www.motiva.fi/files/5124/Case_S_GeoBio_SU.pdf

According to energy operator Fortum and geodesigner Geological Survey of Finland, the borehole heat exchangers are double U-tubes installed like parallel matrix. This type of configuration is typical in early BTES systems.

3.2 The 2nd generation BTES: Drake Landing solar community, Okotoks, Canada

This particular 2nd generation BTES is one of the most famous BTES systems in the world located in Okotoks, Alberta, Canada.

The BTES in the Drake Landing Solar Community (DLSC) consists of 144 boreholes, each stretching to a depth of 37 meters and planned in a grid with 2.25 meters between them. The BTES field covers 35 meters in diameter. At the surface, the U-pipes are joined together in groups of six that radiate from the center to the outer edge, and then connect back to the Energy Centre building. The entire BTES field is then covered in a layer of insulation and then soil – with a landscaped park built on top. 52-house subdivision to have space and water heating supplied by solar energy. An array of 800 solar panels located on garage roofs throughout the community generate 1.5 megawatts of thermal power during a typical summer day and supply heat to the district heating system.

The 2nd generation is in many ways an improved system compared to the 1st generation. Firstly, the boreholes locate closer to each other. Secondly, the boreholes are not as deep as earlier and thirdly, BHE configuration is radial. These improvements make the entire system smarter.

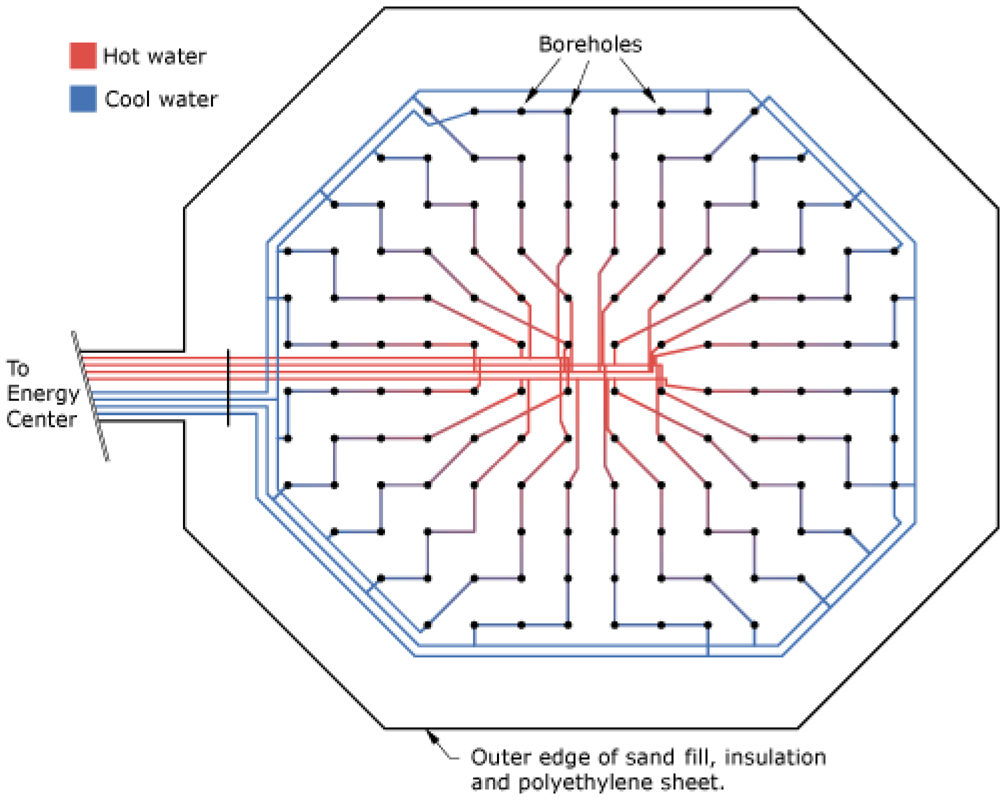

Figure 1: The figure shows the borehole heat exchanger (BHE) configuration in Drake Landing BTES.

3.3 The 3rd generation BTES: Spring water bottling factory Finn Spring Ltd, Toholampi, Finland.

Finn Spring is the largest spring water manufacturer in Finland. SPRING AQUA Premium is exported almost all over the world. The company bottles more than 80 million liters of spring water-based products annually. The factory is located at Toholampi, in the central part of Finland.

The 3rd generation BTES consists of three distinct components: heat source, controller for heat transfer as well as storage (Fig. 1). This kind of system has been implemented to Finn Spring by Heliostorage Ltd. Its power is 500 MWh and it was commissioned in 2018. The energy is collected from industrial waste heat (3 x 75 kW) and solar collectors (140 m^2). The storage has 63 boreholes which are 50 m deep. The core temperature is 45 ºC (August 2020).

The BTES system is a concept of a company called Heliostorage Ltd.(http://www.heliostorage.com/). 3rd generation BTES is a smart rechargeable earth battery: dense borehole grid and smart control.

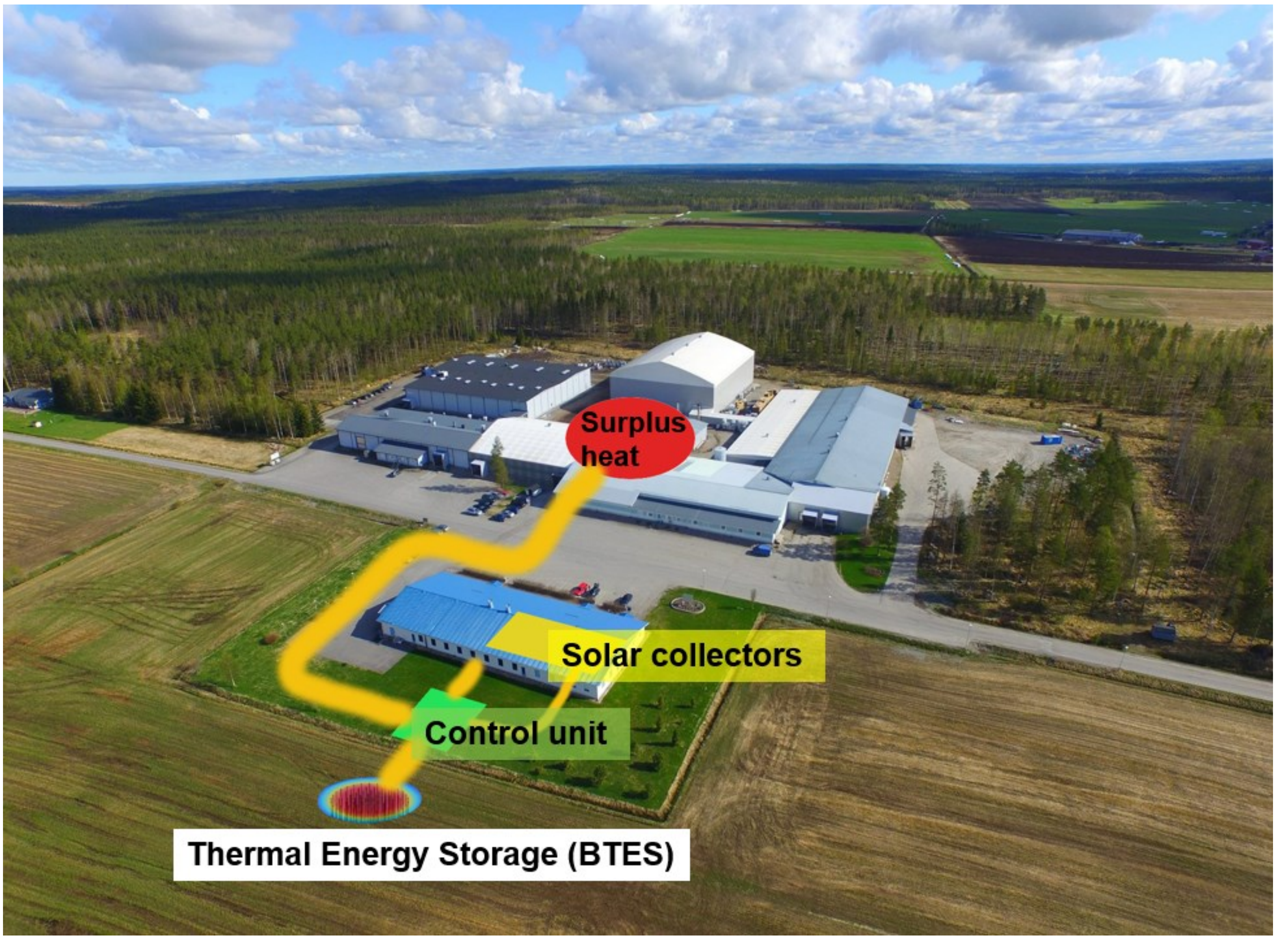

Figure 2. BTES and system settings at Finn Spring bottling factory.

Figure 3. Components of third generation BTES: heat source, controller and storage.

4. CONCLUSIONS

BTES systems have been developed for different kinds of approaches. They have been implemented with different parameters and characteristics. We suggest classifying them into three different generations based on their typical features. These features include naturally borehole design parameters as well as costs. An example of each generation is provided, and this indicates that costs are coming down and maximum temperatures are going higher. This suggests that BTES are becoming an even more viable solution for energy storing and use.

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