

# Use of renewable sources with thermal accumulation of solar energy for the energy consumption of buildings

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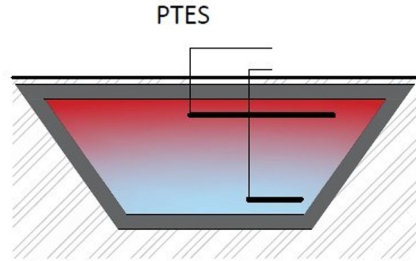
**Abstract.** Today, there is an increasing demand for renewable energy sources in Europe to minimise the carbon footprint and achieve a sustainable energy supply. One of the cleanest and most affordable energy sources is solar energy, which can be used efficiently for heating and hot water in buildings. However, efficient storage and use of solar energy is key. This paper focuses on a comparison of two main solar thermal energy storage systems: Pit Thermal Energy Storage (PTES) and Tank Thermal Energy Storage (TTES). The case studies include an analysis of the effectiveness of these systems in real scenarios, along with their advantages, disadvantages and potential future applications.

## 1 Thermal energy storage

Today, the world is trying to reduce its dependence on fossil fuels and find greener ways to produce energy. One of the most important steps towards a sustainable future is the increased use of renewable energy sources. Solar energy is one of the most important renewable energy sources and has a huge potential to meet the energy needs of homes and buildings. However, its efficient use requires not only the ability to harvest energy during the sun's hours, but also to store and distribute it efficiently for use at later times [1].

### 1.1 Pit thermal energy storage

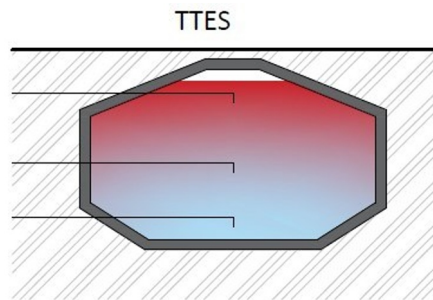
PTES is one of the oldest thermal energy storage systems, shown in the figure 1. Its principle is the use of underground caves or excavated pits as heat reservoirs. During sunny hours, water or other thermal medium is heated by sunlight and then this heat energy is stored in the underground spaces. During periods of low solar activity, this stored heat energy is then used for heating or reheating water [2].



**Fig. 1.** Pit thermal energy system [2,3].

## 1.2 Tank thermal energy storage

Unlike PTES, TTES uses tanks to store thermal energy. These tanks can be located above or below ground and can be of different shapes and sizes. TTES can be equipped with insulation and an intelligent control system to minimize heat loss and increase efficiency, shown in the figure 2 [4,5].



**Fig. 2.** Tank thermal energy system [2].

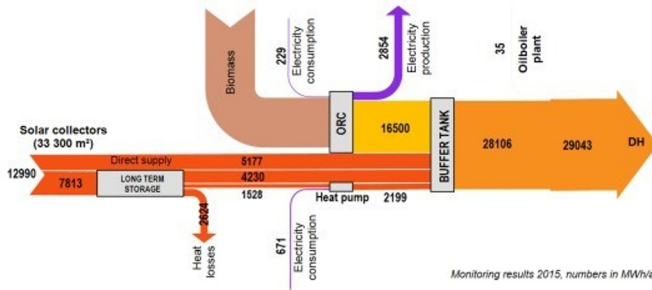
## 2 PTES used in central heating system

For comparison, we selected a working "Marstal District Heating" facility from the period between 2015 and 2017. "Marstal District Heating" is located in Denmark and uses a PTES system to supply heat. The development of the whole system started in 1994 when solar collectors were installed on an area of 75 m<sup>2</sup> and shortly afterwards, after a trial period, up to 8000 m<sup>2</sup> together with a 2100 m<sup>3</sup> tank. Since then, it has undergone developments and changes. Today, the PTES tank has a capacity of 75,000 m<sup>3</sup> and the area of solar collectors is 33,000 m<sup>2</sup>, shown in the figure 3,4 [6].

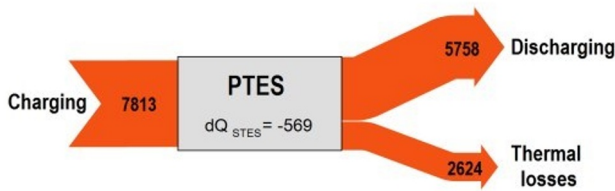


## 2.1 Energetic balance of the PTES system

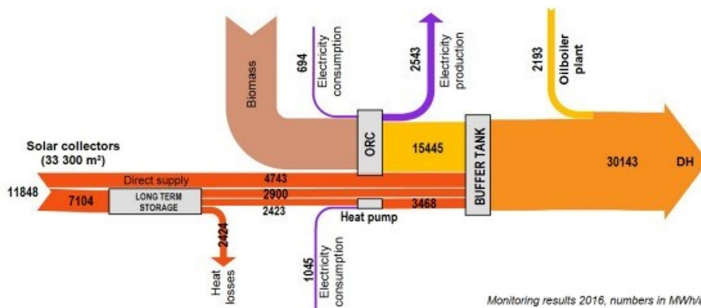
The displayed annual energy balance for PTES for 2015 shows that 7,813 MWh of solar heat were fed into the storage and 5,758 MWh were released from the system, shown in the figure 5, 6,. The internal energy content of the storage was calculated on the basis of temperature sensors installed in the water volume every 0.5 m in the vertical direction. At the end of 2015, the energy content in the reservoir was 569 MWh lower than at the beginning of the year. According to the storage heat balance, the heat losses that were transferred to the surrounding soil and air amounted to 2624 MWh. The maximum and minimum temperatures in the storage volume in 2015 were 84 °C and 20 °C, respectively. [7]



**Fig. 5** Energy balance of the PTES system for 2015 [7].



**Fig. 6** PTES system efficiency 66% in 2015 [7].



**Fig. 7** Energy balance of the PTES system for 2016 [7].

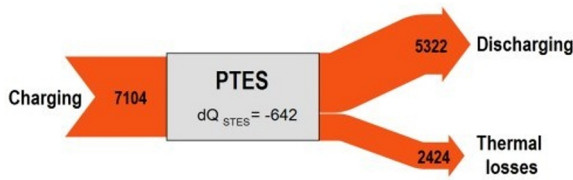


Fig. 8 PTES system efficiency 66% in 2016 [7].

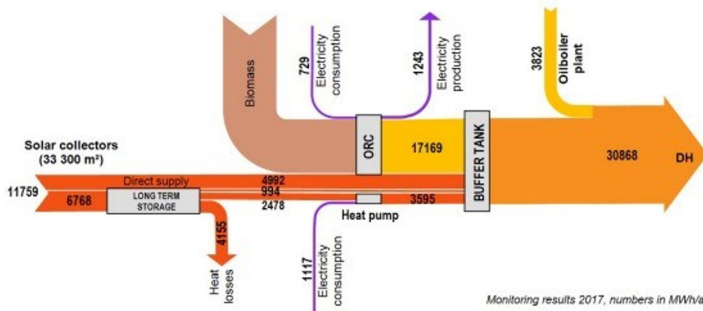


Fig. 9 Energy balance of the PTES system for 2017 [7].

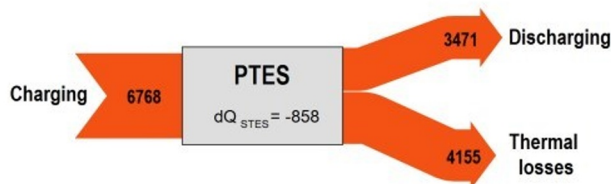


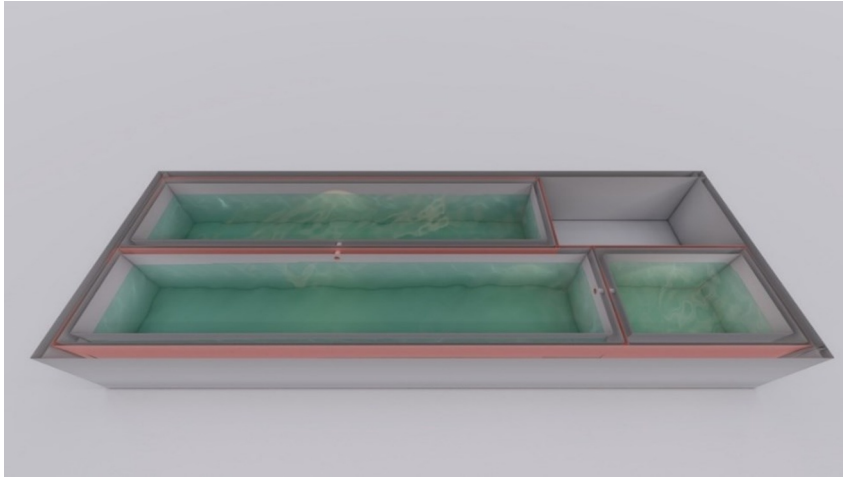
Fig. 10 PTES system efficiency 39% in 2017 [7].

The PTES heat balance for 2017 shows that PTES heat losses increased in this period compared to previous years, causing a decrease in energy storage efficiency, shown in the figure 7, 8, 9, 10. The likely cause of this increase is rainwater infiltration through leaks in the enclosure insulation. This problem is currently being further investigated and measures will be taken in the near future to correct and resolve it in order to restore the system to optimum efficiency [7].

### 3 TTES research measurement

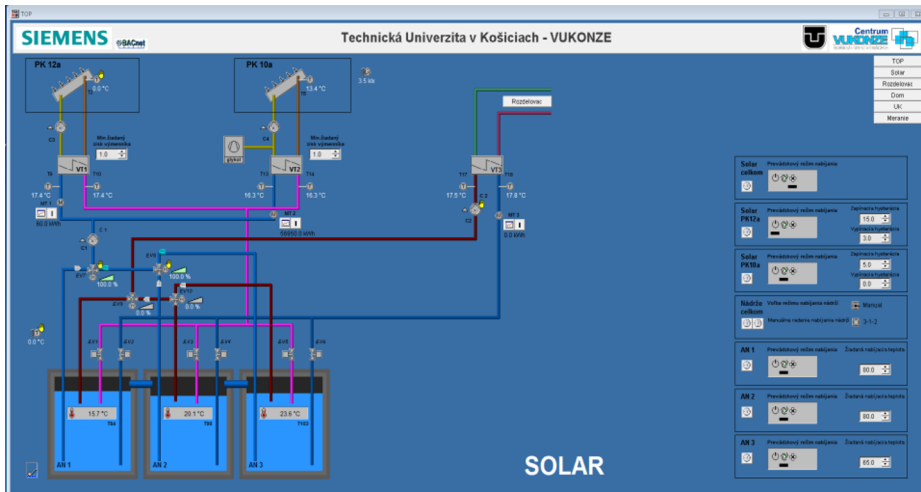
The primary charging sources for our storage tanks are surface-selectively heated collectors with a surface area of 225 m<sup>2</sup>. These collectors allow the circulation of water mixed with glycol. Heat is exchanged in these collectors, with the thermal energy being transferred to the water. The heated water is then stored in three thermal storage tanks with a capacity of 178m<sup>3</sup>, shown in figure 11. These thermal storage tanks are of different sizes, which allows

for different applications. Constructed of special concrete and insulated with thermal insulation, the thermal storage tanks are located underground beneath the floor of the building [8].



**Fig. 11** Thermal energy storage in 3 different sizes.

The storage management system allows manual adjustment to regulate charging and discharging as required, shown in figure 12. Switching of the storage tanks is necessary according to seasonal changes. To simulate seasonal conditions for energy consumption, an experimental house was built over the storage tanks. These settings are carefully designed to accurately reflect real situations.

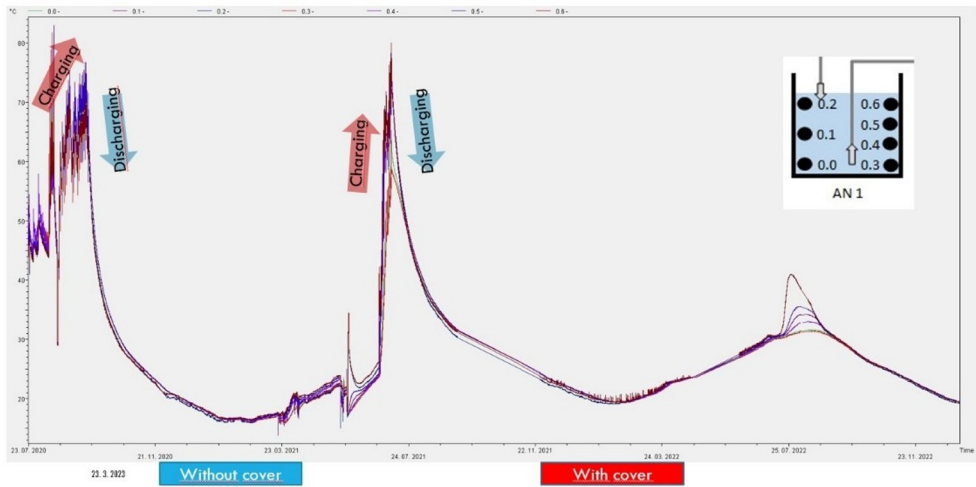


**Fig. 12** TTES system control scheme.

### 3.1 Measuring and improving system performance

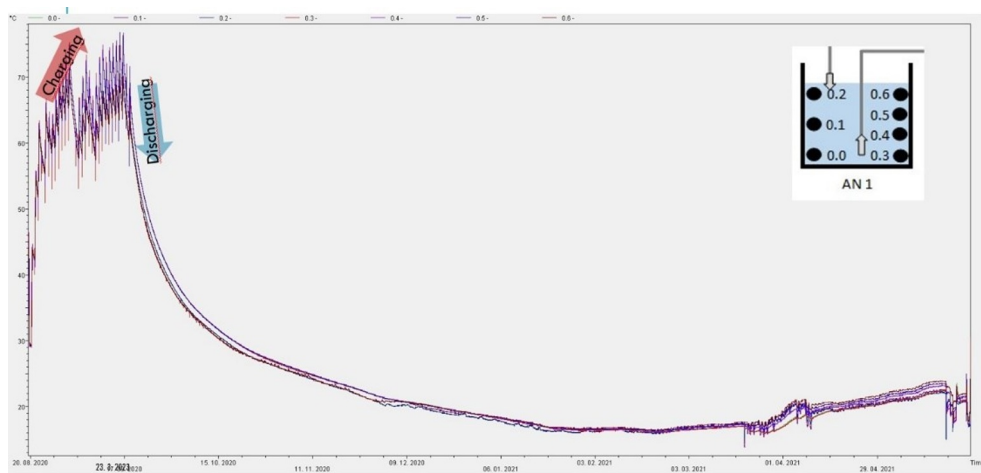
The AN1 reservoir analyzed, with a volume of 24 m<sup>3</sup>, is therefore the smallest thermal reservoir we have investigated. In this thermal reservoir we encountered large heat losses due

to the evaporation process. The data measurements were carried out over a period of 2 years, shown in figure 13.



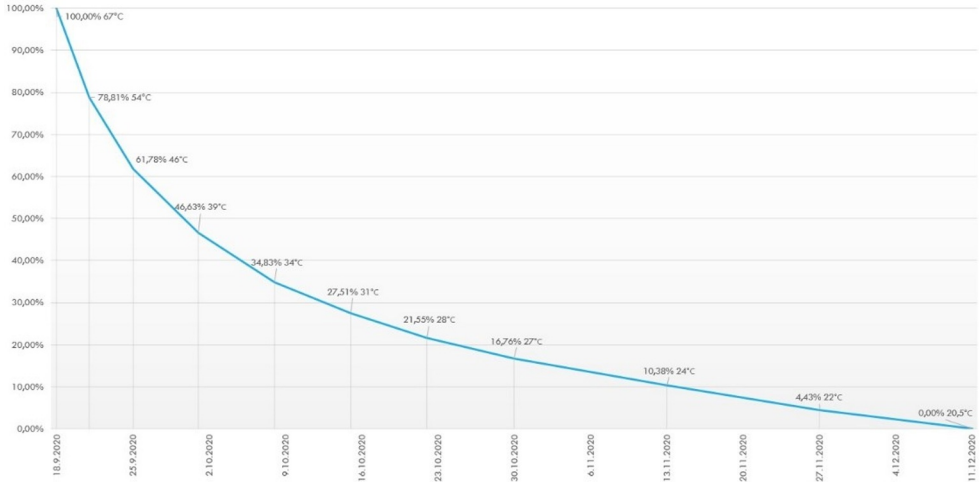
**Fig. 13** Temperature measurements taken over a period of 2 years in the AN1 tank.

In the first measured year, we found significant heat losses related to the evaporation process through the water surface.



**Fig. 14** Temperature measurements conducted during the first year without a cover.

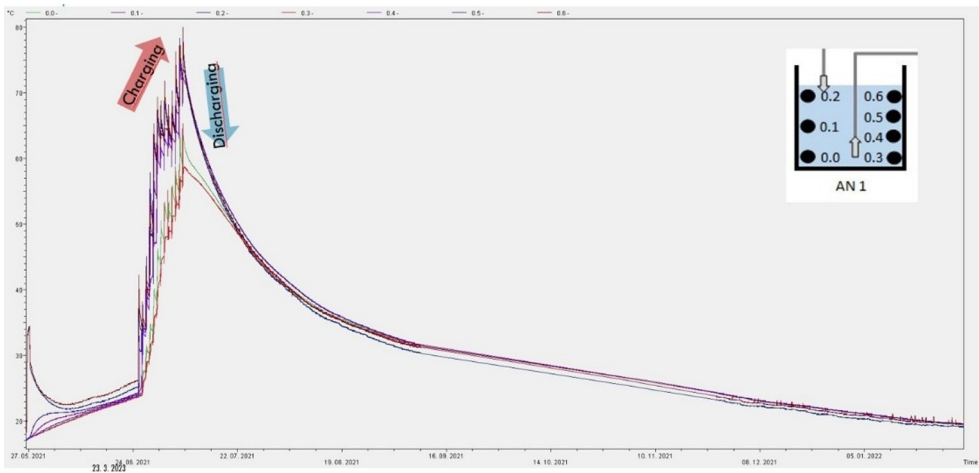
From the data collected, it is clear that the discharge had a rapid decreasing trend quadratically without power consumption, shown in figure 14.



**Fig. 15** Graph of percentages without cover.

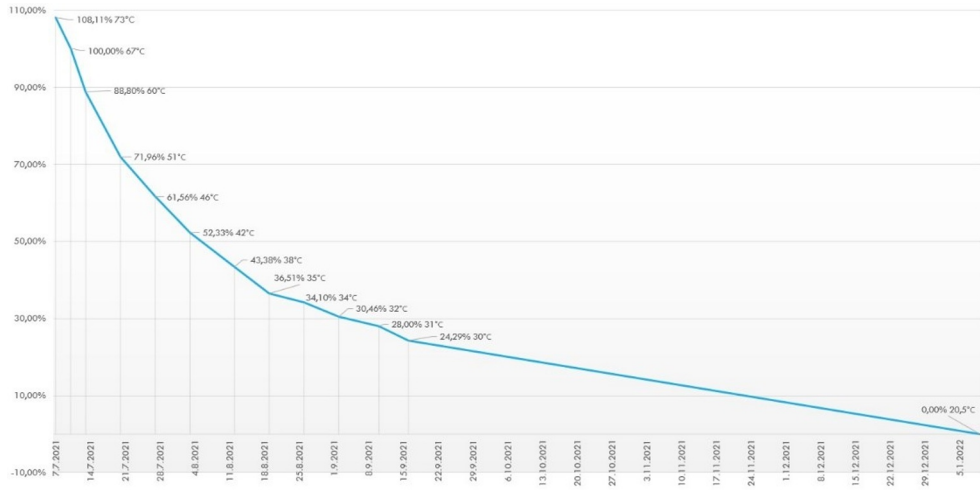
The graph shows the rapid discharge from a maximum mean temperature of 67 °C to the initial charging temperature of 18 °C over 85 days, shown in figure 15. Such a rapid discharge has little efficiency.

In the second year, we applied 20 mm thick thermal insulation to the water surface of the reservoir to minimize heat loss through the water surface.



**Fig. 16** PTES system efficiency 39% in 2017.

The ongoing temperature readings indicate that the discharge rate is slower compared to the previous year, transitioning from a quadratic trend to a linear one at specific temperatures, as shown in figure 16.



**Fig. 17** Presents a percentage graph with the cover.

Although the tank was charged up to a temperature of 73°C during this year, for the sake of comparison, 100% is standardized to 67°C to facilitate comparison across periods. The thermal insulation cover proved to be effective, as evidenced by the temperature readings. For instance, after 3 weeks of discharge, the temperature decreased from 34°C before covering to 46°C after covering. It took 183 days for the tank to discharge back to the original temperature of 18°C, as depicted in figure 17.

## 4 Conclusion

It is important to stress that none of these systems is perfect and their use may have limitations. For example, although these systems can be useful in reducing energy costs in buildings, they can run into limitations during winter periods when solar activity decreases. Although our research on TES does not yet have definitive efficacy, as discharge varies with increasing volume. Therefore, it is important to look for comprehensive solutions that combine multiple energy sources and technologies to minimize the carbon footprint while providing.

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