Thermal Impact of Medium Deep Borehole Thermal Energy Storage on the Shallow Subsurface

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1. Introduction

Borehole heat exchanger (BHE) arrays are a well-suited and already a widely applied method for exploiting the shallow subsurface as seasonal heat storage. However, in most of the populated regions the shallow subsurface also comprises an important aquifer system used for drinking water production. Thus, the operation of shallow borehole thermal energy storage (BTES) systems leads to a significant increase in groundwater temperatures in the proximity of the borehole heat exchanger array. The magnitude of the impact on groundwater quality and microbiology is controversially discussed. Nevertheless, the protection of shallow groundwater resources has a high priority. Accordingly, water authorities often follow restrictive permission policies for installing and operating such storage systems. An alternative approach to avoid this issue is the application of medium deep (400 m – 1500 m) BHE arrays instead of shallow ones (Bär et al. 2015, Welsch et al. 2016). The thermal impact on shallow aquifers can be significantly reduced as most of the heat is stored at larger depth. Moreover, it can be further diminished by the installation of thermally insulating grouts in the upper section of the BHE. Based on a numerical simulation study, the advantageous effects of medium deep borehole thermal energy storage (MD-BTES) are demonstrated and quantified.

2. Numerical simulation study

The finite element software Feflow (Diersch et al. 2014) is used to model the heat transport in the subsurface, while the heat transport in the BHE is solved analytically. For this purpose, the extended analytical solution after Schulte et al. (2016) is implemented into Feflow, which also allows for the consideration of a thermally insulating borehole section. Three different storage systems are compared: A shallow BTES (217 BHE, 85 m each) and two MD-BTES (37 BHE, 500 m each), one with and one without an insulation in the upper BHE section.

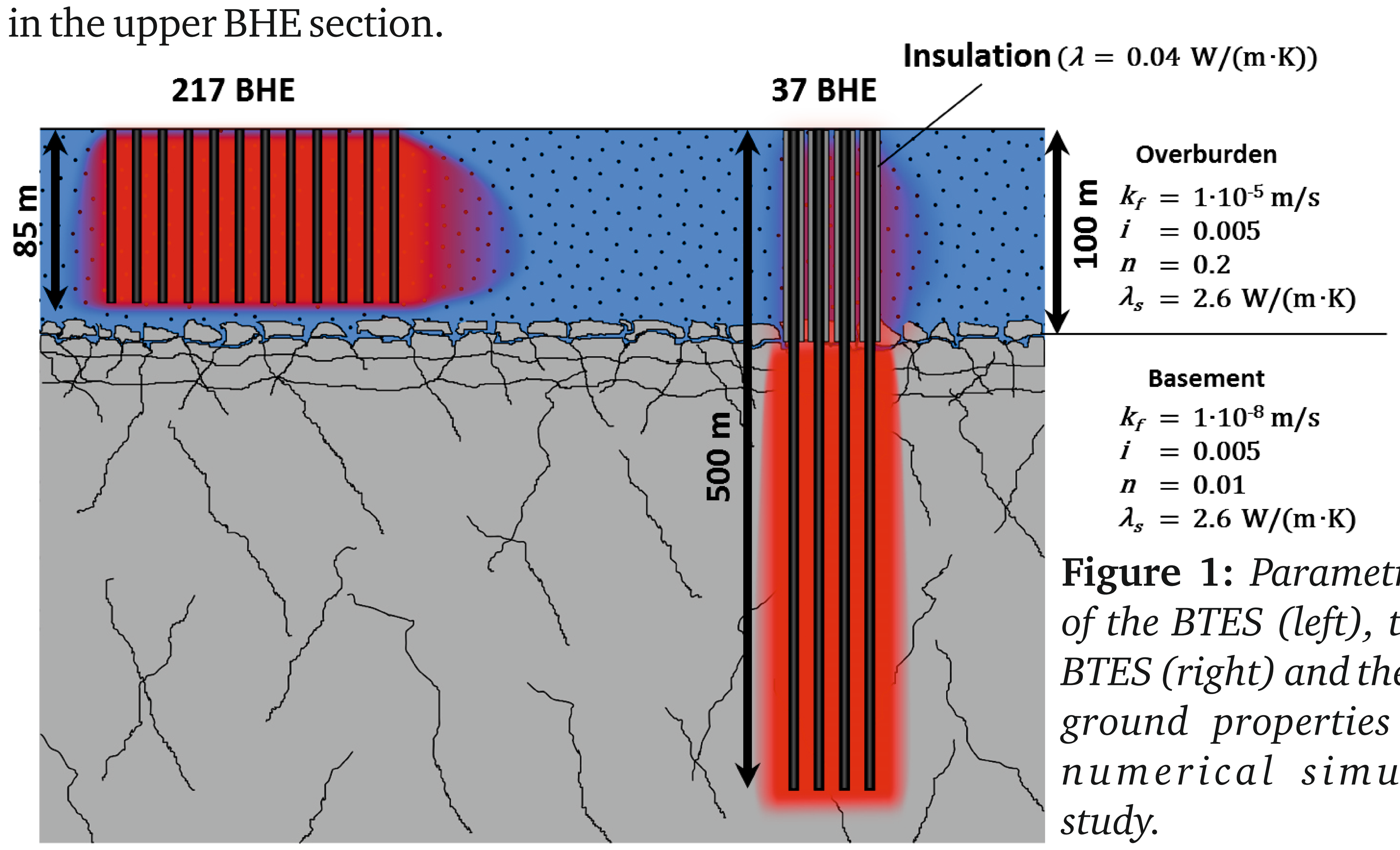


Figure 1: *Parametrization of the BTES (left), the MD-BTES (right) and the underground properties in the numerical simulation study.*

3. Operation scenario

A simplified operation scenario was applied to the storage systems. In order to simulate the alternating storage operation, the fluid inlet temperatures were kept constant during the charging and the discharging cycles at 90 °C and 30 °C, respectively.

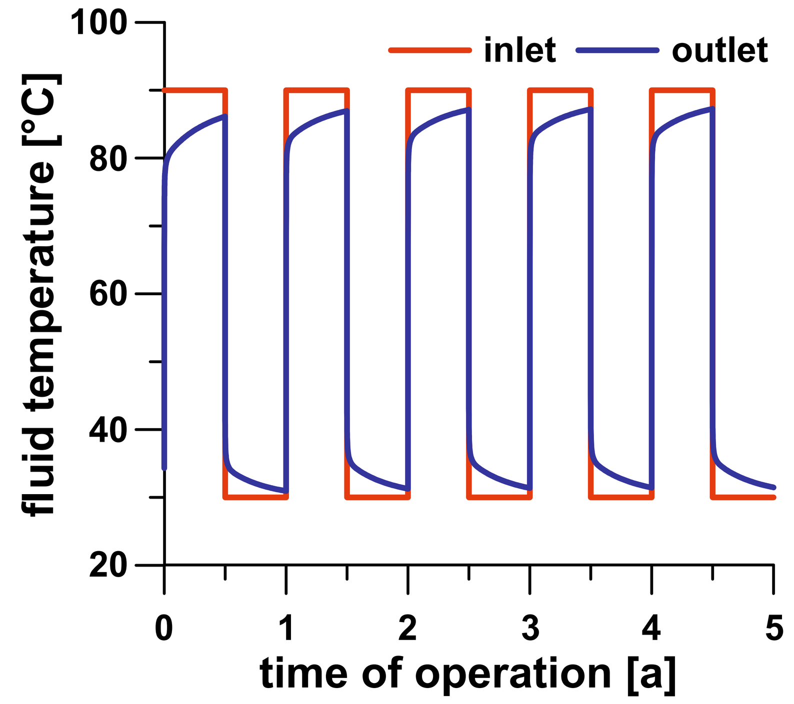


Figure 2: *Applied operation scenario. The scenario was repeated to a simulation time of 30 years.*

4. Energetic comparison

Medium deep borehole thermal energy storage can reduce the unrecoverable heat amounts in the shallow subsurface to about a third of that of shallow storage systems. Additionally, the unrecoverable heat amounts can be further reduced by about 25 % employing a thermally insulating grout in the upper section of the BHEs.

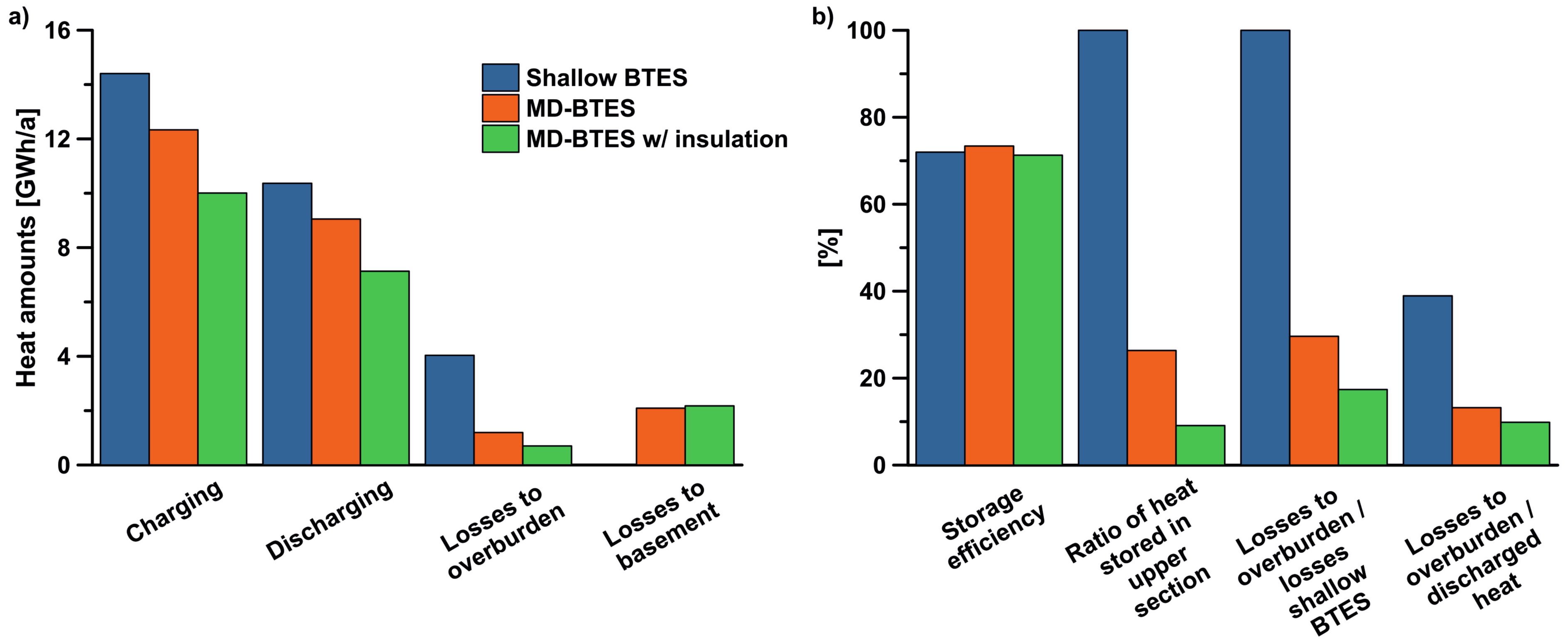
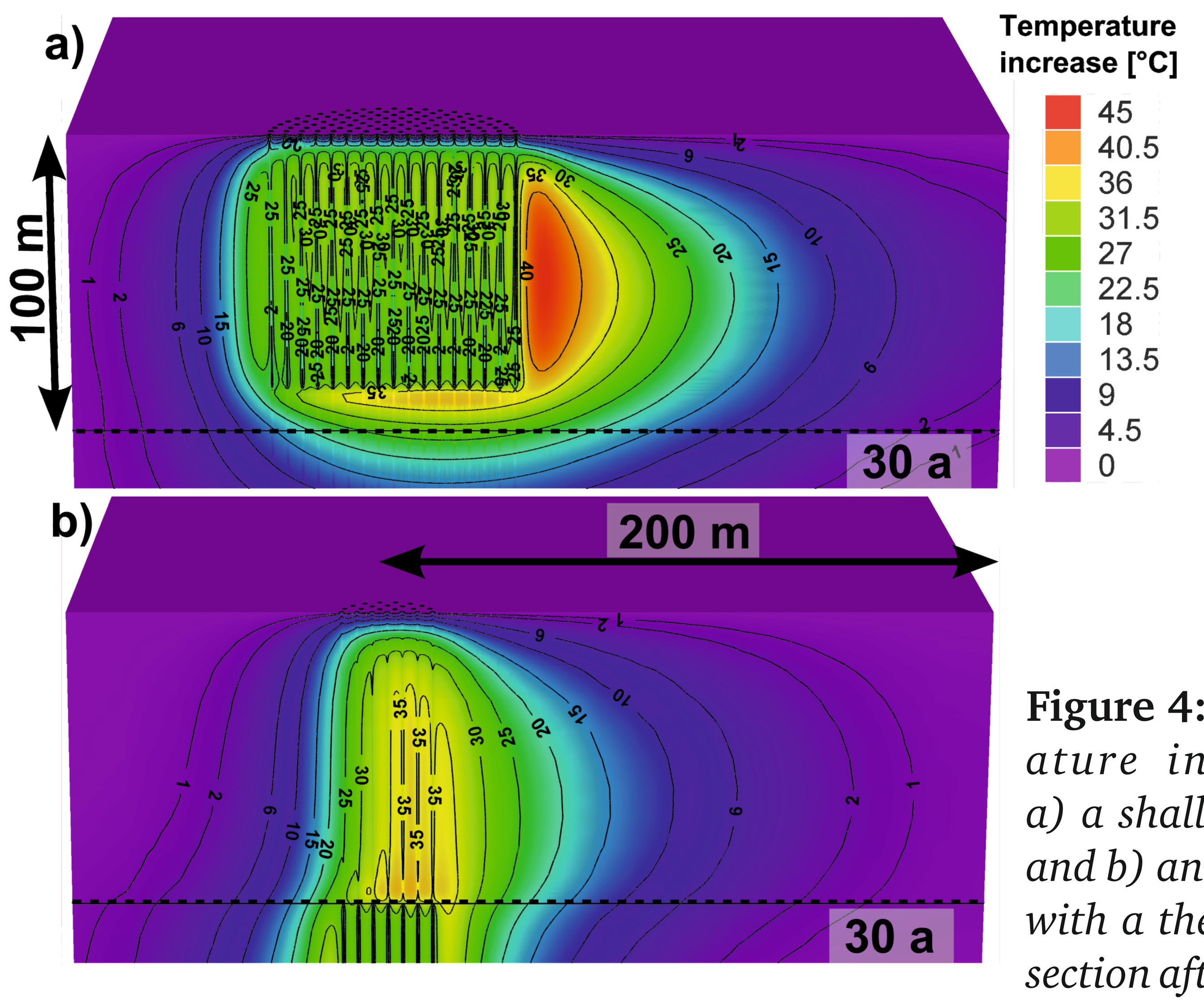


Figure 3: *Comparison of a) absolute heat amounts and heat losses and b) storage efficiencies and relative heat losses. All values are averaged over 30 years of operation.*

5. Temperature influence



The unrecoverable heat that is lost to the shallow subsurface during borehole thermal energy storage operation leads to a persistent increase of groundwater temperature up to a distance of several hundred meters to the storage center. MD-BTES can reduce the thermally influenced underground volume significantly.

Figure 4: *Increase of groundwater temperature in a shallow aquifer around a) a shallow BTES (217 BHE, 85 m each) and b) an MD-BTES (37 BHE, 500 m each) with a thermal insulation in the respective section after 30 years of operation.*

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References

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