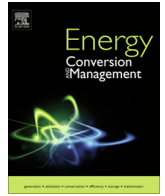




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## Energy Conversion and Management

journal homepage: [www.elsevier.com/locate/enconman](http://www.elsevier.com/locate/enconman)

# Sensitivity analysis of efficiency thermal energy storage on selected rock mass and grout parameters using design of experiment method

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## ARTICLE INFO

### Article history:

Available online xxx

### Keywords:

Underground thermal energy storage  
Sensitivity analysis  
Borehole heat exchanger  
BTES  
MDF model  
Numerical model

## ABSTRACT

The aim of this study was to investigate the influence of selected parameters on the efficiency of underground thermal energy storage. In this paper, besides thermal conductivity, the effect of such parameters as specific heat, density of the rock mass, thermal conductivity and specific heat of grout material was investigated. Implementation of this objective requires the use of an efficient computational method. The aim of the research was achieved by using a new numerical model, Multi Degree of Freedom (MDF), as developed by the authors and Design of Experiment (DoE) techniques with a response surface. The presented methodology can significantly reduce the time that is needed for research and to determine the effect of various parameters on the efficiency of underground thermal energy storage. Preliminary results of the research confirmed that thermal conductivity of the rock mass has the greatest impact on the efficiency of underground thermal energy storage, and that other parameters also play quite significant role.

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## 1. Introduction

Issues connected with energy saving, sustained development and reduction of CO<sub>2</sub> emission have recently resulted in the implementation of more efficient technologies of energy production from renewable sources [1]. One such technology are heat pumps that are installed with borehole heat exchangers. The first theoretical works on borehole heat exchangers appeared in the 1940s and 1950s. Ingersoll and Plass [2] presented theory of the ground pipe heat source for the heat pump the so-called line source model and Carslaw and Jaeger [3] presented the so-called cylindrical source model. Whereas the most important works on the Borehole Heat Exchanger (BHE) were written in the 1980s and 1990s. Eskilson [4] presented the so-called g-function which is the dimensionless temperature response at the borehole wall. Kavanaugh [5] used the two-dimensional model of finite differences to test the efficiency of the concentric borehole heat exchanger. Based on the theory of cylindrical source model Kavanaugh [6] presented a model to determine the temperature in the ground. Hellström [7] describes the transformation of the internal thermal resistance between two pipes and the borehole thermal resistance between pipes and the borehole wall into the thermal resistances of the

Delta-circuit. Kujawa et al. [8] presented mathematical model of a geothermal field exchanger.

Recent research has contributed to broad application of this technology. For example paper [9] presents an innovative Borehole Heat Exchanger (BHE) configuration in which the U-tubes are immersed in an artificial fluid, contained in a case separated from the ground by the usual filling material. In work [10] author shown how spacing of adjacent boreholes and thermal interferences influence required borehole length for heat transfer. In work [11] a combined simulation–optimisation procedure is presented to regulate the operation of Borehole Heat Exchangers (BHEs) in a multiple BHE field when groundwater flow exists. A number of analyses and investigations of borehole heat exchangers were also performed in Poland. For example in the work [12] author presented theoretical model of borehole heat exchanger and [13] where author present possibility of adaptation existing wells to borehole heat exchanger.

Still, modelling is an important area of research, as it has been a significant instrument for system optimisation, long-term efficiency testing and for determining effective thermal conductivity of rocks. Some detailed simulations are also necessary to estimate the economic and ecological benefits of these systems. An oversized system or a system with an insufficient number of exchangers will lead to an increase in costs and losses. That is why the development of existing models and accurate calculation instruments is required, in order to reduce computation time while maintaining a high level of accuracy.

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