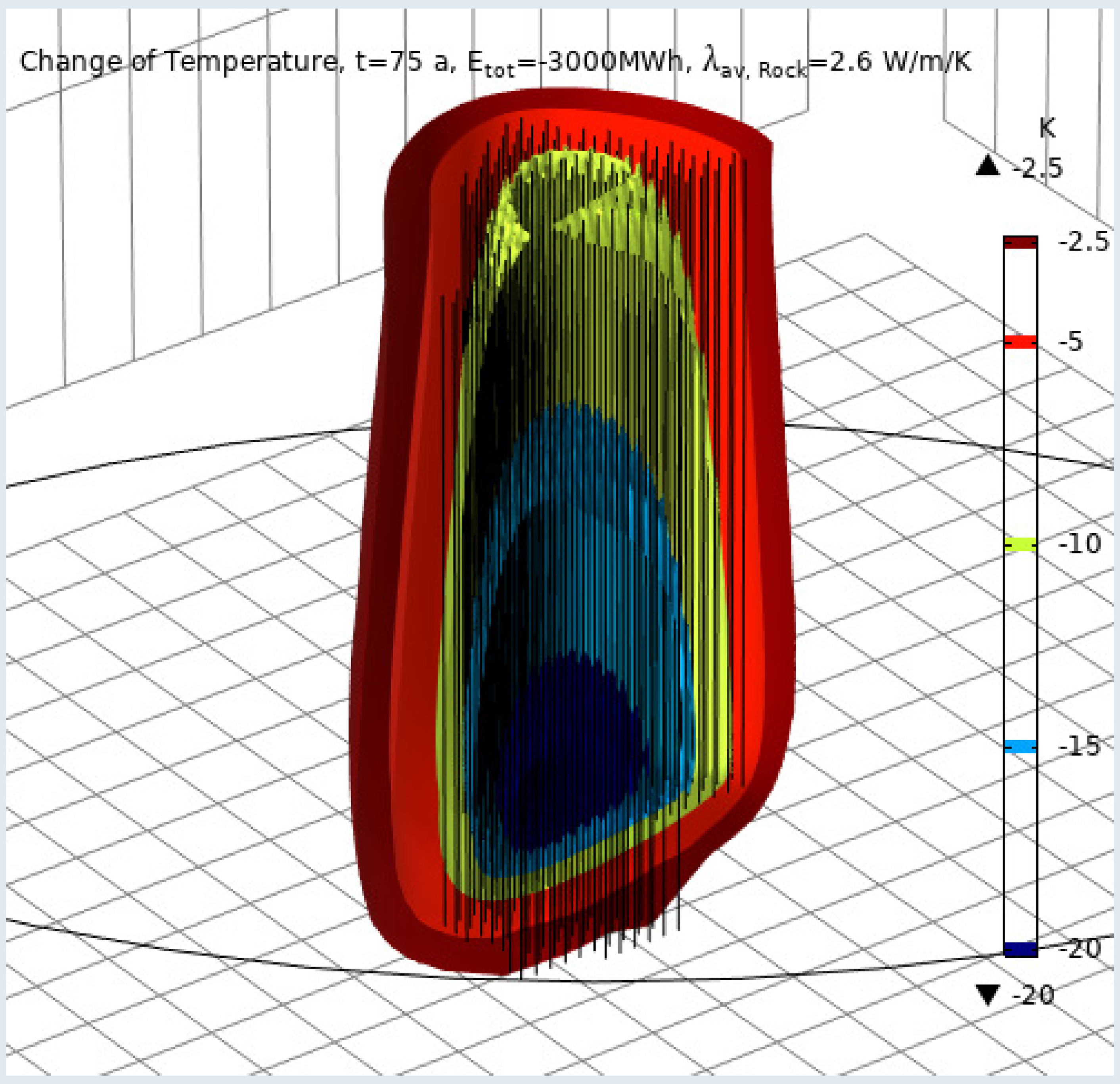

A Modeling Approach for Simulating Geothermal Energy Utilization by Borehole Heat Exchangers and Borehole Heat Exchanger Arrays

Decarbonization of the heating sector requires the exploitation of climate-neutral energy sources and the use of natural heat storages. Shallow and deep geothermal energy can make a valuable contribution to this.

M. Rembe
Rembe Consulting Partnerschaftsgesellschaft für Geologie, Geoströmungstechnik, Umweltplanung und numerische Simulation mbB, Nordhausen, Germany

Introduction & Goals

The dimensioning and design of geothermal boreholes and larger borehole heat exchanger arrays require efficient and flexible simulation tools. They should meet a wide range of configurations (depth and diameter of the geothermal borehole, different types of borehole heat exchangers, flexible arrangement of borehole heat exchangers, etc.).

COMSOL Multiphysics® is generally very well suited to meet a wide range of requirements:

- different types and diameters of heat exchangers (U-pipes, coaxial, annular pipes)
- flexibly arranging many boreholes as a borehole heat exchanger array
- taking phase change of pore water of the surrounding rock into account.

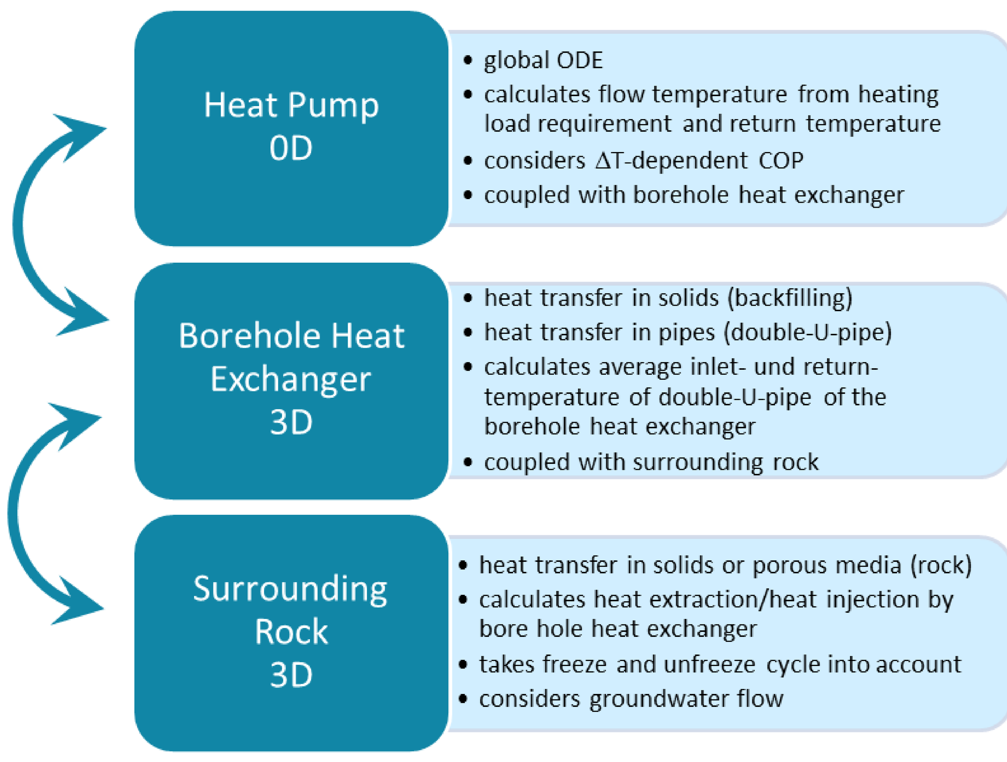

Figure 1: Modelling concept

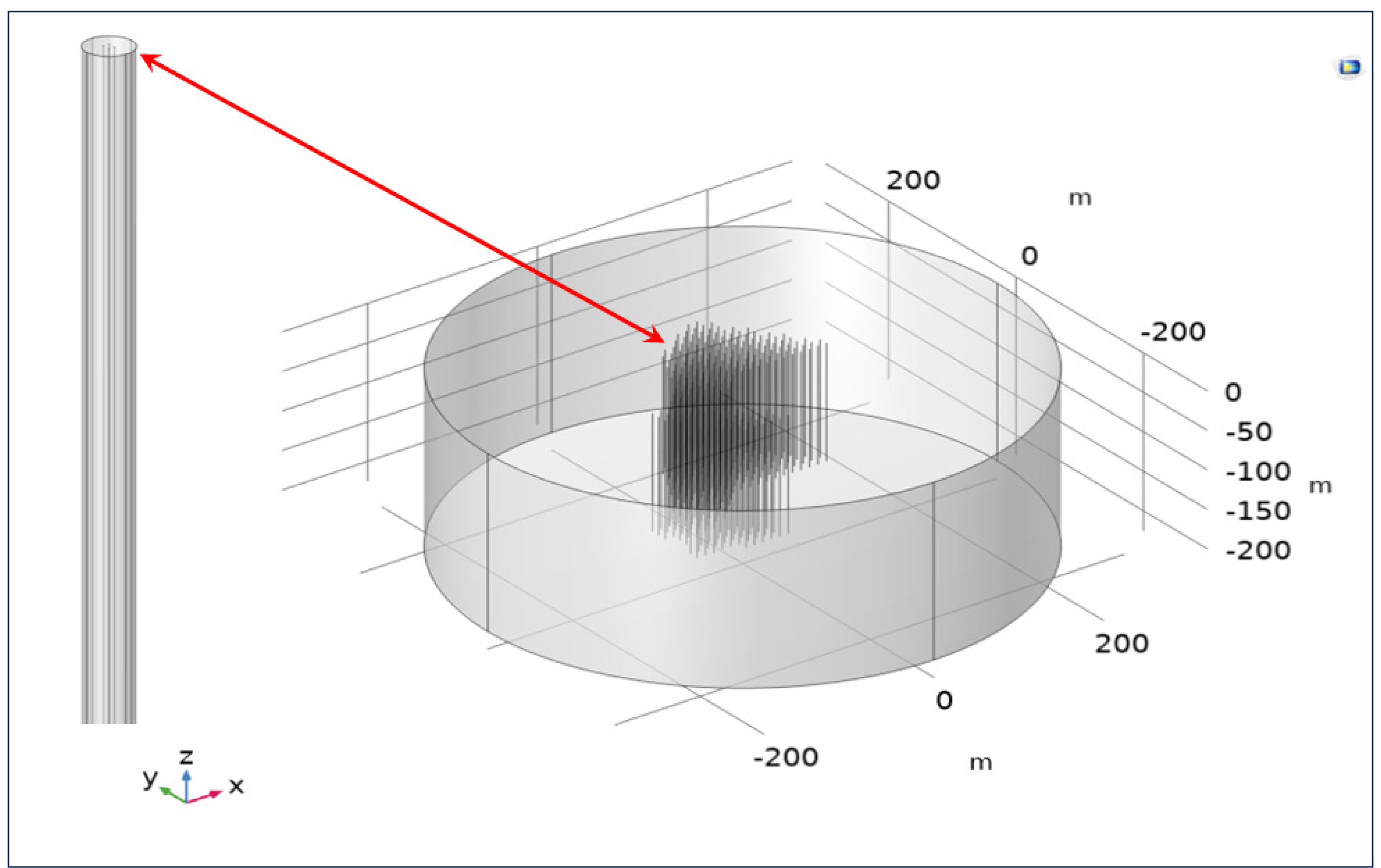

Figure 2: Borehole heat exchanger (BHE), BHE-array and surrounding rock

Methodology

Due to the strongly varying dimensions of lengths, diameters and the dimensions of the surrounding rock to be considered, the simulation with the Method of Finite Elements is a great challenge due to the required resolution of the mesh (diameter/length). With COMSOL Multiphysics®, a closed-form methodology has been developed to deal with the disproportions and multiplex requirements.

The simulation model represents the geothermal heat utilization from the heat pump up to the surrounding rock (Figure 1). The governing differential equations are described by COMSOL Multiphysics®, the Pipe-Flow-Module and the Subsurface-Flow-Module. Three different geometry spaces (3D, 3D, 1D) represent the different compartments (Figure 2). The coupling of the computational variables is done independently from mesh by non-local coupling operators.

Global ODEs and PDEs simulate the heat pump and calculate auxiliary variables. Events ensure the correct consideration of the temporal operating regime.

Results

The analysis of geothermal heat utilization is performed at different time scales. A detailed operating regime (for example, hourly) can be analyzed as well as long-term utilization (several tens of years). This supports efficient planning from a rough to a detailed calculation.

In a 2023 performed study for the Stadtwerke Sondershausen GmbH, the geothermal site potential for a borehole heat exchanger array of 216 boreholes with a depth of 150m to 400m and with different types of heat exchangers was investigated. Due to the planned long utilization time of 75a, the temperature changes in the surrounding rock were calculated by transient compact

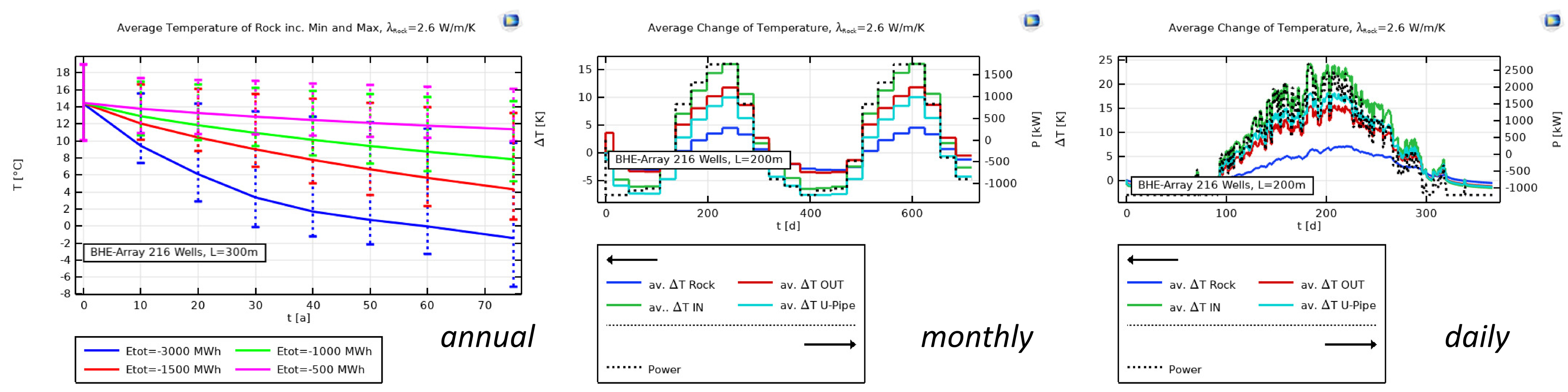

Figure 3: Analysis of the long-term, mid-term and short-term use of geothermal energy

analyses based on years. For the analysis of mid-term and short-term temperature changes by peak loads, simulations were performed based on months and days (Figure 3).

REFERENCES

Rembe Consulting PartG mbB (2023): Untersuchung des nutzbaren geothermischen Potentials am Standort „Auf dem Schwichensberge". Client: Stadtwerke Sondershausen GmbH

Rembe Consulting
Partnerschaftsgesellschaft für Geologie, Geoströmungstechnik, Umweltplanung und numerische Simulation mbB
web: www.rembe-consulting.de / e-mail: rembe@rembe-consulting.de