The reuse of the former Markgraf II colliery as a mine thermal energy storage

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ABSTRACT

The aim of the **German HEATSTORE sub-project** is to create a technically and fully functional high temperature mine thermal energy storage (HT-MTES) pilot plant (see fig. 1) for the energetic reuse of the abandoned Markgraf II colliery, with the emphasis on a two year operating and monitoring phase during the project lifetime of three years. The generated data can be exploited for the implementation and dissemination of future deep geothermal storage systems. The conceptual idea is based on the storage of seasonal unutilized surplus heat during the summer from solar thermal collectors within the mine layout and to use the stored heat during the winter for heating purposes of the institute buildings of the International Geothermal Centre (GZB).

1. CONCEPT

The concept of this pilot plant aims at the reutilization of the abandoned Markgraf II colliery, which is directly located under the premises of the International Geothermal Centre (GZB) in Bochum (see fig. 2), as a high temperature mine thermal energy storage. This area also includes the drilling and test facility site of the GZB, on which the Bochum Research and Exploration Drilling Rig (Bo.REX) is currently located. This leads the way of a very cost effective exploration of the flooded Markgraf II colliery in a depth of approximately 75 m below ground. Currently, the groundwater level resides at a depth of approximately 21 m below ground. This is constantly measured in the monitoring wells R1 and O1-4 (depicted as blue circles in fig. 2). Overall, the Markgraf II colliery produced 37.043 tons of coal during its life cycle. Based on a calculation with a coal density of 1,35 g/cm³, we can

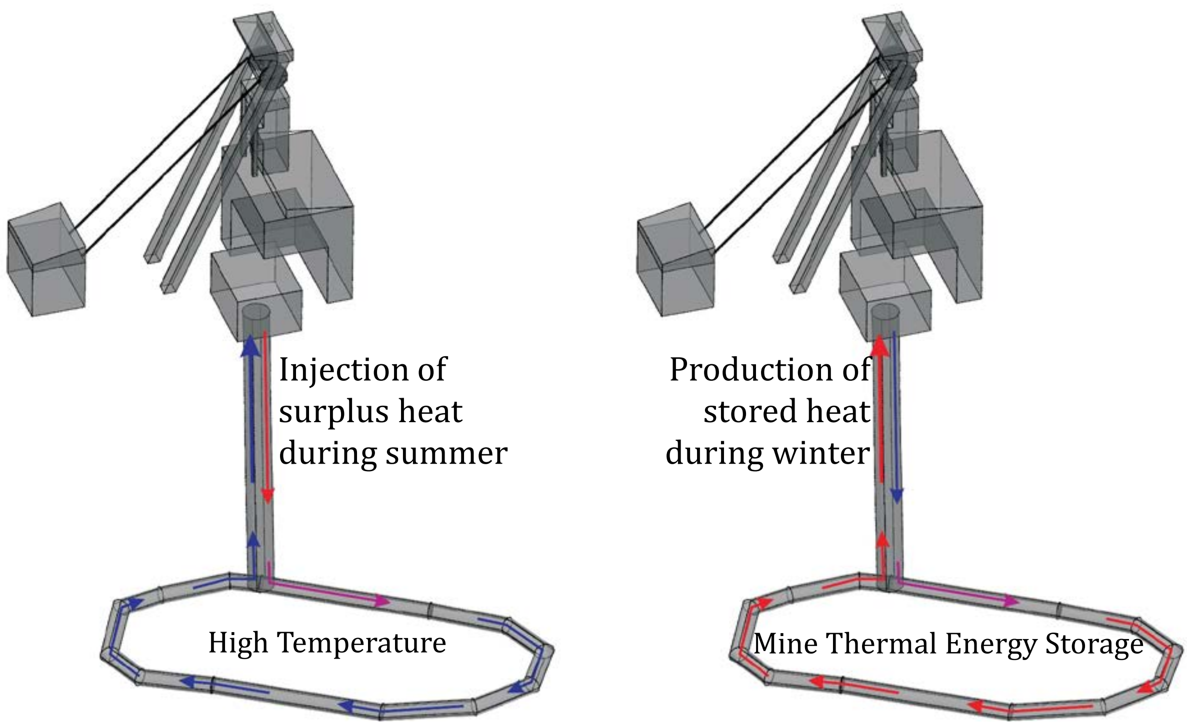

Figure 1: Conceptual model of a HT-MTES (GZB)

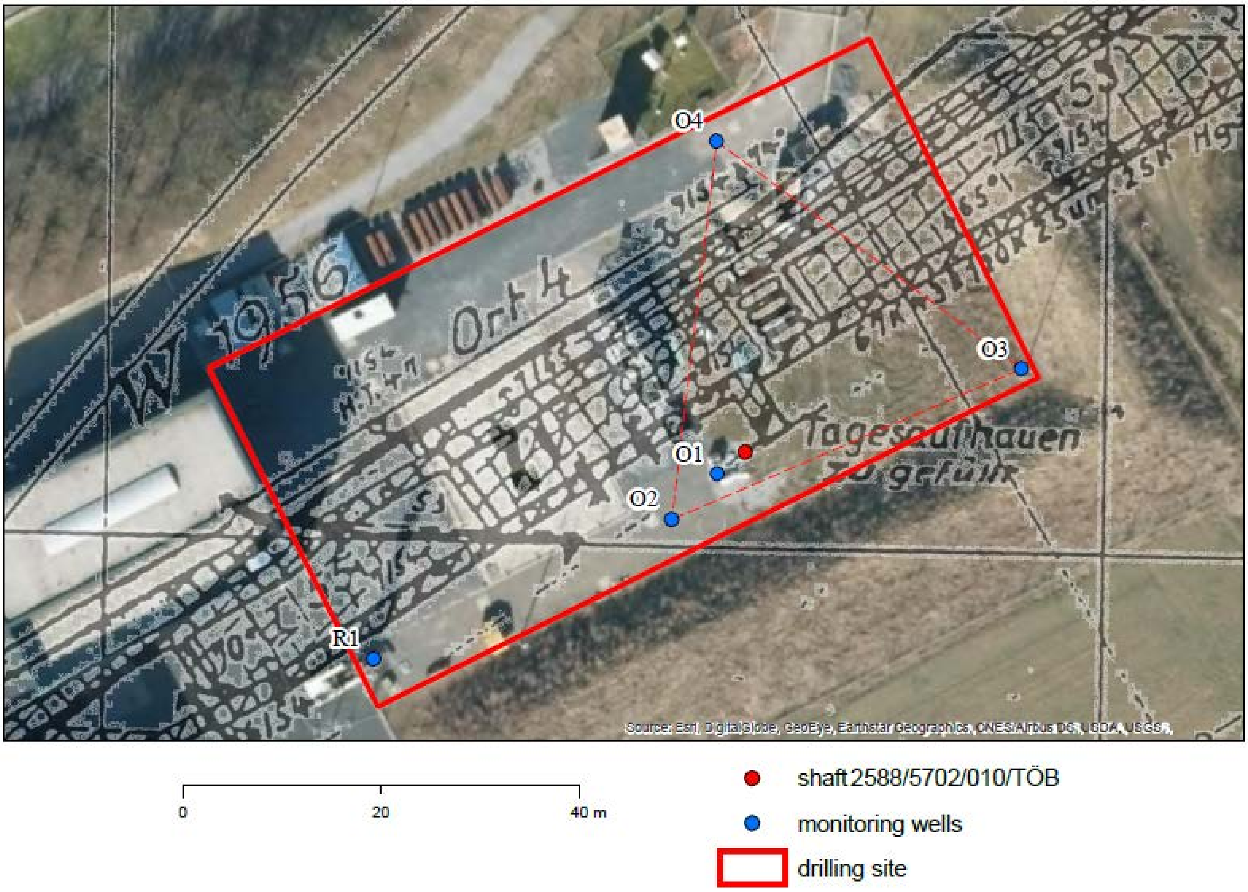

Figure 2: Location of the Markgraf II colliery below the GZB premises (GZB)

assume a void volume of approx. 27.439 m^3. This volume does not include any drifts and shafts.

Considering the effect of mine subsidence, the remaining void volume will most likely be in the range of approx. 10 %. Utilizing a Δt of 50 K within the mine water, a heat capacity of approx. 165 MWh, which resembles the yearly heat demand of the GZB compound, could be stored within dedicated drifts and former mining areas of Markgraf II for the winter heating season. Based on this first evaluation, the yearly GZB heat demand could be substituted by emission free solar thermal energy. After the two year pilot phase is concluded the integration of the Markgraf II mine thermal energy storage into the district heating network of the “unique Wärme GmbH” could be tackled, as two CHP plants (7,2 MW_{th}) were put in operation in July/2018 in a very close proximity of approx. 350 m to the foreseen high temperature mine thermal energy storage pilot plant.

2. HISTORICAL BACKGROUND

During the years of the coal shortage after the Second World War, many small coal mining operations were established throughout the Ruhr area. This period lasted for approximately fifteen years, until the beginning of the coal crisis in 1957, which made these small coal mines highly unprofitable.

The Markgraf II colliery was part of this development. It was owned by the spinning mill company Ackermann A.-G, which was located in Heilbronn, Germany. Daily production rates were between 40 to 50 tons, which didn’t fulfil the expectations of the owner, as these production rates didn’t recover the substantial investment costs. Table 1 gives an overview of the life cycle of the Markgraf II colliery, during its operational phase from 1953 till 1958 (Viëtor, 2012).

Year	Production in t	Comment	Employees
1953		Commission-ing	
1954	10.528	Max. production	49
1955	10.250		57
1956	8.346		54
1957	7.919		48
1958		Closure	

Table 1: Production summary of the Markgraf II colliery

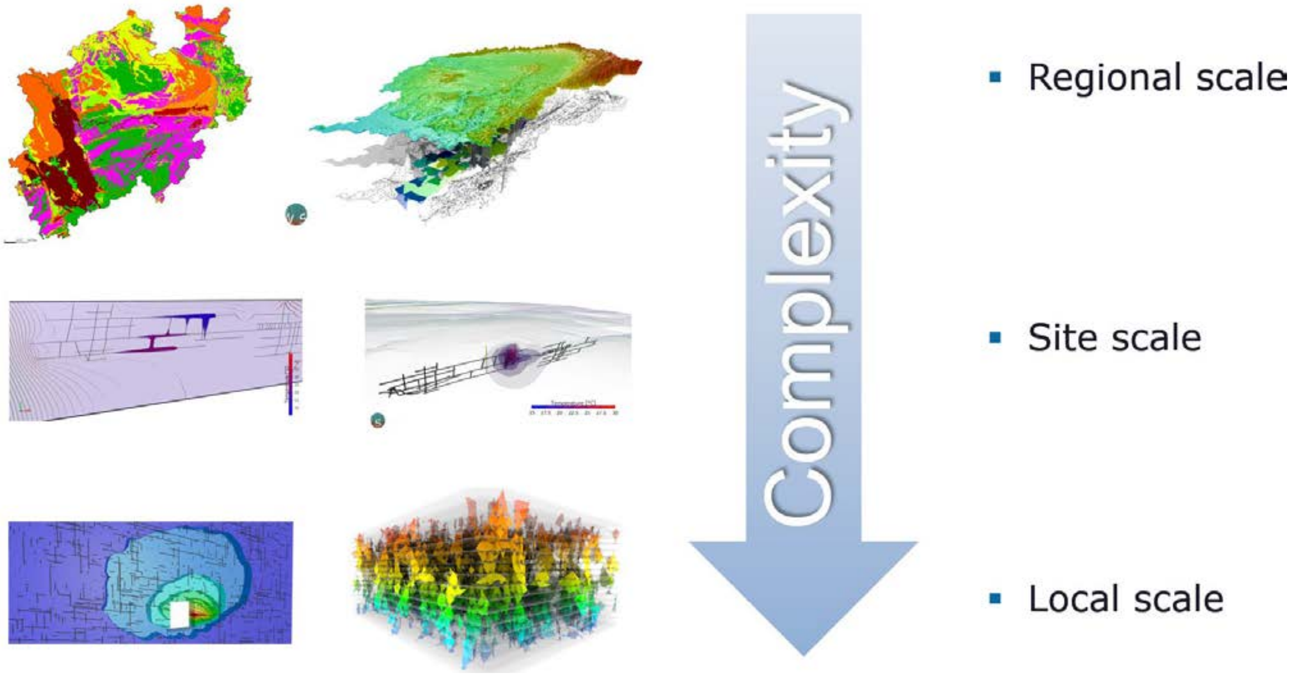

Figure 3: Stepwise modelling approach (delta h)

3. MINE WATER STATE OF TECHNOLOGY

The idea of obtaining thermal energy from an inoperative colliery has already been pursued for a long time, although to a comparatively limited extent in the present time. Up to this point a pilot plant has not been established, in which the possibility of thermal energy storage in a former colliery has been considered. Well-known executed projects concerning the utilization of mine water include:

• The Mijnwater-project in Heerlen (Netherlands), whereby an already completely flooded and no longer accessible mine layout was accessed through directional drilling technology.

• The building of the School of Design at the Zeche Zollverein in Essen (Germany), which is heated by 28°C warm mine water, originating from the mine drainage of the RAG AG.

• The utilization of mine water of the former Robert Müser colliery in Bochum (Germany) as an energy source for the heat supply of two schools and the mine drainage station in Bochum. Within this pilot plant the 20°C warm mine water, which originates from the mine drainage of the RAG AG from a depth of 570 m below ground, is being used.

• Seven operational mine water utilization plants in Saxony (Germany), which can be categorized as shallow geothermal reservoirs. A deep mine water project is currently being implemented at the West Saxon University of Zwickau, where mine water from a depth of 625 m below ground with a temperature of 26°C is planned to be extracted.

4. MODELLING APPROACH

In this project numerical groundwater flow and heat transport modelling is used to estimate the influence of a mine thermal energy storage pilot plant on the groundwater aquifer, the prediction of the physical environment and the assessment of the impacts of different pumping rates. Later on, monitoring programs will be developed and competing demands on the groundwater resource can be evaluated.

Understanding heat transport during the planning of geothermal plants is complicated by heterogeneities in the subsurface and cyclical plant loads. Based on the extensive mining situation in the Ruhr area within a complex geologic setting a stepwise modelling concept was developed (see fig. 3).

The conceptual model was developed using maps and cross sections, existing data and data gathered during the field investigation of this study. It forms the basis for the understanding of the groundwater occurrence and flow mechanisms of the Markgraf II site, and is used as basis for the numerical groundwater modelling.

The concept comprises the following three scales with an increasing level of detail:

• Regional scale (>10.000 km²)

The Regional scale includes geology and the transient mining (dewatering) influence in the regional area. Large scale transient groundwater models have been built to analyse the regional flow system. They deliver boundary conditions for the site scale.

• Site scale (~10 km²)

The Site scale models the detailed underground mining works at the Markgraf II site within a local geological setting. It enables planning, dimensioning and optimization of the thermal energy storage pilot plant in terms of heating and cooling cycles.

• Local scale (<1 km²)

At the local scale different parts of the pilot plant are modelled with a high detail. It is used to estimate local effects like the influence of fractures or different (residual) mine void volumes.

5. SOFTWARE

The software code chosen for the numerical modelling work was the 3D groundwater flow and transport model SPRING, developed by the delta h Ingenieurgesellschaft mbH, Germany (König, 2018). The program was first published in 1970, and since then has undergone a number of revisions. SPRING is widely accepted by environmental scientists and associated professionals. SPRING uses the finite-element approximation to solve the groundwater flow and transport equations. This means that the model area or domain is represented by a number of nodes and elements. Hydraulic and thermic properties are assigned to these nodes and elements and an equation is developed for each node, based on the surrounding nodes. A series of iterations are then run to solve the resulting matrix problem utilizing a pre-conditioning conjugate gradient (PCG) matrix solver for the current model. The model is said to have “converged” when errors reduce to within an acceptable range. SPRING is able to simulate steady and non-steady flow, contaminant transport, density dependent transport as well as heat transport, in aquifers of irregular dimensions and different model layers with varying thicknesses as well as out-pinching model layers are possible.

CONCLUSION & OUTLOOK

The development of diversified storage capacities will have a great impact on the future promotion of renewable energy sources. Within the Ruhr area, unutilized mining infrastructures in combination with available surplus heat from (solar) power plants and industrial processes, resemble a vast potential for large heat storage capacities. Out of this reason, fundamental research in the field of high temperature seasonal heat storage in abandoned mines has to be conducted for further technology development and establishment of large scale storage systems.

During the upcoming project phase, the implementation of three exploration wells into the existing mine layout of the Markgraf II colliery is foreseen. Pump and tracer tests will determine possible storage capacities.

In the case of a successful technical implementation of the Markgraf II mine thermal energy storage, the design and operation results would be scalable to other locations in Germany and worldwide.

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