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Integration of geothermal energy systems into large residential development areas in Germany

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ABSTRACT

With the structural change in parts of Germany abandoned industrial and mining sites became available for a new utilization. In many cases the activation of these brown fields as residential development areas represents a favorable field for geothermal energy supply. On the one hand these areas are sufficient large for the classification of independent planning areas and furthermore the energy supply of these areas is often not adequately available. Currently in Germany Geothermal is mostly used for single building supply with ground heat exchanger and heat pumps. The plant design is made, depending on the energy demand of the buildings, by tables or via simulation. In larger development areas with many decentralized geothermal heat generators the transient and control-technique influences of the buildings and the low-temperature heat supply nets must be considered. The large scale integrated usage of geothermal energy for urban districts is in an early stage of development. Linked to this situation a number of feasibility studies were carried out by the GeothermalCenter in Bochum. In this paper an overview of a selected planning area with the geological conditions, the accomplished geothermal simulations and the plant concept will be presented.

1. GEOGRAPHICAL OVERVIEW

The revitalisation of the two disused working areas of the Hermannshütte steel works is being run as an integrated project of the authorities of the City of Dortmund. The focus of the eastern part area, approx. 96 hectares in size, is the planned Phoenix-See with numerous water and leisure time related purposes. Around this water body of about 25 hectares, areas for attractive living at the water, office and service companies and leisure time orientated uses - hotel and gastronomy companies - are being created. Between 900 and 1,300 residential units will be built in form of multi-family houses, duplex and terraced houses as well as single-family houses. In the western part of the planning area, industrial and public buildings are planned on a ground area of 5 hectares.

Figure 1: Overview of the plan area "Phoenix-See"

2. GEOLOGY

According to the spacious geological classification Dortmund-Hörde is assigned to the Ruhr carbon, the boundary region of a shale region in the south and a chalk-basin in the north.

Since the project will be planned close to former coal mines the geological data basis is appropriate. The geological model was developed stepwise. First, a geological profile from the geological map was determined and coordinated with existing drillings. Later on, cores from several outcropping strata were petrophysically analysed. The presented table shows the stratigraphy with the appropriate lithological classifications.

Table 1: Geological profile of the "Phoenix-See" area

m	Stratigraphy			Lithology
200	Upper Carboniferous	Westfal A	Bochum fomation	Alternating Layers of shale, silt- and sand-stone (30% sand-stone), max 5% coal
1000	Upper Carboniferous	Westfal A	Witten fomation	Alternating Layers of shale, silt- and sand-stone (30% sand-stone), max 2,5% coal
1550	Upper Carboniferous	Namur C	Sprockhövel fomation	Alternating Layers of shale, silt- and sand-stone (25% sand-stone), max 1% coal
1600	Upper Carboniferous	Namur B	Kaisberg formation	Alternating Layers of shale, silt- and sand-stone (40% sand-stone), coal <<1 %
2000	Upper Carboniferous	Namur B	Greywacke-Quarzite formation	Alternating Layers of shale, silt- and sand-stone, partly quarzitic sandstone beds
2150	Upper Carboniferous	Namur A	Overlying Alaunschiefer	Dark, high-pyrite shale, siltstone, several Beds of sandstone- or chert
2350	Lower Carboniferous			bedded limestone (Kulm-Plattenkalk), Siliceous limestones (Kieselkalk), lydite, underlying alum shale
3000	Upper Devonian			Claystone, sandy claystone, bedded limestones, nodular limestones, thin sandstone beds

3. GEOTHERMAL SIMULATIONS

To utilize the geothermal potential of the development area vertical ground heat exchanger are intended. For the determination of the heat extraction from borehole heat exchangers different procedures are available. For small plants (<30 KW) and shallow depths (between 40 m - 100 m) the design can be carried out using specific heat extraction values from the VDI 4640. In the case of larger depths, an increased number of heat exchanger and bigger plants the use of simulation software is required. Within the study borehole heat exchanger from 100 m to 2300 m were examined. Therefore two simulation programs were employed.

The simulations for the shallow systems (100m and 250m) were provided with the program EWS from Switzerland. For the deep borehole heat exchanger (400 m, 1000m and 2300 m) the software SHEMAT was used.

With EWS it is possible to calculate the supply and the return temperatures of the fluid as well as the heat extraction from single borehole heat exchangers and ground heat exchanger fields. In SHEMAT the geological profile is transferred into a cylinder-symmetrical model and the heat transfer equation is solved with a finite-difference-method. On the basis of the geological profile and the necessary technical data (geometry, grout, working fluid etc.) the models for the simulations were build up. In Table 1 the initial parameter for a 500 m deep borehole heat exchanger are shown. The following Figure3 presents the simulation result for January after 15 years of operation.

Table 2: Input Parameter for the 500 m deep ground heat exchanger simulation

Borehole depth	[m]	**500**
Fluid	[-]	Water
Mass flow rate	[m³/h]	7
Grout		
-thermal conductivity	[W/(mK)]	2
-density	[kg/m³]	2100
-thermal capacity	[J/(kgK)]	1000
Operating hours/a	[h]	2364
Simulations period	[a]	15
Heat Extraction	[kW]	**37,5**

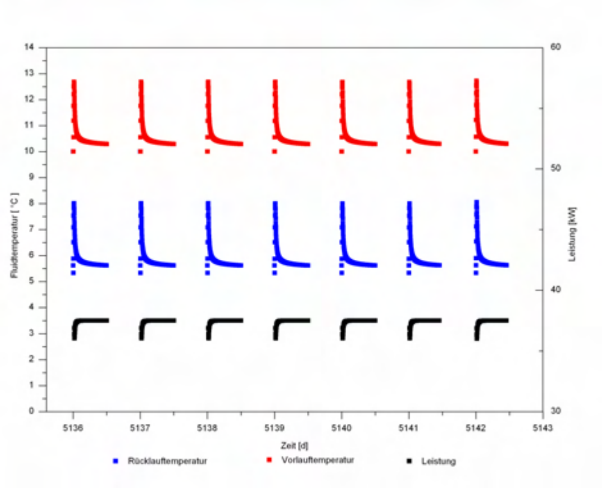

Figure 2: Simulation result for a 500 m deep borehole heat exchanger in January after 15 years of operation

4. PLANT CONCEPT

To supply the development area with geothermal energy the plant concept is designed for central heat pump stations. The individual supplying groups are connected by a local heat supply net. Due to the selected heating systems with low supply temperatures the heat pumps in the heat supply net will work very efficient. The heat pump stations are located in such a way that the distance to the buildings and the ground heat exchanger fields are optimized.

In this way between 100 and 150 housing units are connected to a central heat pump station.

The heating of the domestic water takes place within the single buildings. To cut off the peak loads in the morning and in the evening, in the buildings different heating systems are combined.

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