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GIS-supported mapping of shallow geothermal potential of representative areas in south-western Germany—Possibilities and limitations

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Abstract

The increasing interest in the utilization of shallow geothermal energy comes with the wish for better knowledge about the factors influencing its efficiency. For this purposes we focused on the subsurface condition's influence on the use of borehole heat exchangers (BHEs) coupled with a heat pump for heating purposes, since this is the most popular heat-extracting technique. We created maps showing the potential for this technique provided by the thermal underground properties. Therefore, we established an underground model for two study areas in south-western Germany with different geological settings using a geographic information system (GIS). The subsurface has been divided into layers with similar thermal properties based on geological, hydrogeological and lithological information. The layers have been attached with specific heat extraction values, according to the German VDI guideline 4640. For depths of 50 and 100 m, the weighted mean value of the specific heat extraction was calculated and presented within maps. These maps point out how the heat-extraction potential differs within and between the study areas and how it depends on depth.

Keywords: Shallow geothermal energy; Borehole heat exchangers; Potential mapping; Underground model

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1. Introduction

1.1. Ground-coupled heat pumps and borehole heat exchangers

Space heating with ground-coupled heat pumps is a long known technique and again became attractive in the last decade. The most common system is the ground-coupled heat pump with borehole heat exchanger (BHE). BHEs mostly consist of double U-pipes made of high-density polyethylene (PE 100 SDR 11) with standardised diameters between 20 and 40 mm, which are inserted in boreholes of about 100 m to maximal 400 m depth. A fluid of water and optional antifreezes circulates in the pipes and is heated up while passing through the underground. The extracted geothermal heat is used by a heat pump to provide heating energy on a temperature level sufficient for common heating installations. Other heat sources for heat pump systems are horizontal ground heat collectors and ground water wells. The well systems require special hydrogeological settings as small depth to the water table and sufficient transmissivity to run successfully. This study only covers installations with BHEs since they are currently the most prominent heat sources.

In Germany the installed ground-coupled heat pumps for space heating reached the amount of approximately over 60,000 units at mid-year 2006 [1]. The averaged annual growth rate has been more than 35% in the last decade and, starting from a distinctly higher level more than 20% in the last 5 years. These numbers do not include the installations made before 1994 because of missing reliable information about their heat sources and closure rates. The heat source of ground-coupled heat pumps includes BHEs as well as collectors and other types. However, the BHE can be regarded as the currently most widespread heat source installation [2]. The major reasons for this boom are the possible energy and cost savings. A stronger environmental awareness and the availability and feasibility for the majority of house owners should also be taken into account. A correct dimensioning of the whole heating system is required to avoid the financial and environmental boomerang. That is why there is a request for improved planning support.

A decentral, localized heating system that uses the underground as an energy source depends on site-related factors. The better the knowledge of the specific on-site conditions, the better the adjustment of the BHE type and its length to the heat demand. There is also the necessity for a reliable comparison between competing heating systems and their long-term performance.

1.2. Factors influencing the specific heat extraction

In general the efficiency of the BHEs is governed by design and depth of the borehole and is dependent on thermal conductivity, thermal capacity, annual mean temperature of the ground, exposition to sun (topography), humidity of the ground and groundwater flow. Traditionally, geothermal direct use aims to utilize the heat content of formation fluid, if present. However, the heat content of the rock matrix is generally higher. This heat is the target of shallow resource utilization [3].

As stated before BHEs are typically made of plastic pipes inserted in boreholes. For good thermal contact between the pipes and the surrounding rock the borehole should be grouted with a special material of high thermal conductivity, which additionally tightens the pipes [4]. The advantage of thermally enhanced grouting material is a significant reduction in the borehole thermal resistance, which governs the temperature losses between