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Exploring Geothermal Potential: Drilling and Pumping Tests at the Dannenbaum Mine

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ABSTRACT

Stadtwerke Bochum Holding GmbH is developing a geothermal facility at the Mark 51°7 site in Bochum, Germany, using mine water from the abandoned Dannenbaum coal mine for geothermal heating and cooling. Between 2021 and 2022, directional drilling accessed the 4th and 8th levels, with one well drilled for each level. The first well, GT2, reached 343 m (MD) into the 4th level drift, while the second well, GT1, reached 864 m (MD) into the 8th level drift from the same site. In both wells, a sudden drop in water level and a loss of weight on bit at the expected depth indicated successful intersection with the mine galleries (~3 m high). Pumping tests conducted in 2023 using a 300 m-deep pump confirmed hydraulic accessibility and flow rates up to 160 m^3/h at low differential pressure. The deeper 8th level (GT1) showed superior hydraulic performance compared to the shallower 4th level (GT2). The results confirm the feasibility of using mine water for geothermal applications. Commissioning of the geothermal facility is scheduled for spring 2026. This work is part of the D2Grids project, supported by INTERREG Northwest Europe funding.

1 INTRODUCTION

Abandoned coal mines offer significant potential as low-temperature geothermal reservoirs. After closure, networks of flooded galleries and shafts form large artificial aquifers with stable hydraulic and thermal conditions. Reuse of these reservoirs is increasingly relevant in urban areas seeking low-carbon heating and cooling solutions.

At the Mark 51°7 innovation district in Bochum, Germany, Stadtwerke Bochum Holding GmbH is developing a geothermal system to extract thermal energy from the flooded Dannenbaum mine and supply a 5th generation district heating and cooling (5GDHC) network. To evaluate feasibility, two directional wells were drilled between 2021 and 2022 to access the 4th (343 m TVD) and 8th (807 m TVD) mining levels. In 2023, both wells underwent pumping tests to characterize hydraulic behavior, thermal conditions, achievable flow rates, and overall operational suitability.

2 GEOLOGICAL AND MINING CONTEXT

The Dannenbaum coal mine is located in Bochum, within the Ruhr Valley, a region with a long mining history. The mine is situated in the Upper Carboniferous sedimentary rocks of the Ruhr Basin, consisting of an alternating sequence of sandstones, siltstones, claystones, and hard coal seams (Figure 1). The sedimentary succession is extensively folded and faulted due to Variscan tectonics (Drozdzewski 1993). While the primary matrix permeability of the host rocks is generally low, mining-induced voids and fracture systems create significant secondary permeability, forming an extensive artificial geothermal reservoir. The regional geothermal gradient within the Carboniferous strata averages approximately 3.62 K/100 m (36 °C/km), with local variations between 2.66 and 6.11 K/100 m due to tectonic folding structures (Leonhardt 1983).

Initially developed as a drift mine, Dannenbaum evolved into a multi-level underground system extending several kilometers. In the 1950s, Dannenbaum was interconnected with the neighbouring mines Prinz Regent and Friedlicher Nachbar through cross-level galleries, forming a subsurface network exceeding 10 km laterally. Following closure in 1958, the workings gradually flooded, forming a hydraulically active mine-water reservoir (Bussmann et al. 2021).

The mine extended over eight levels and reached a depth of around 800 meters below ground level.

Historical records indicate gallery cross-sections of 2 to 3 m, though local collapse, deformation, or sediment infill may have altered the geometry. Of particular geothermal interest are the 4th and 8th levels: the shallower 4th level provides cooler water for cooling, while the deeper 8th level offers higher temperatures for heating. This vertical separation supports flexible operation of a 5GDHC system.

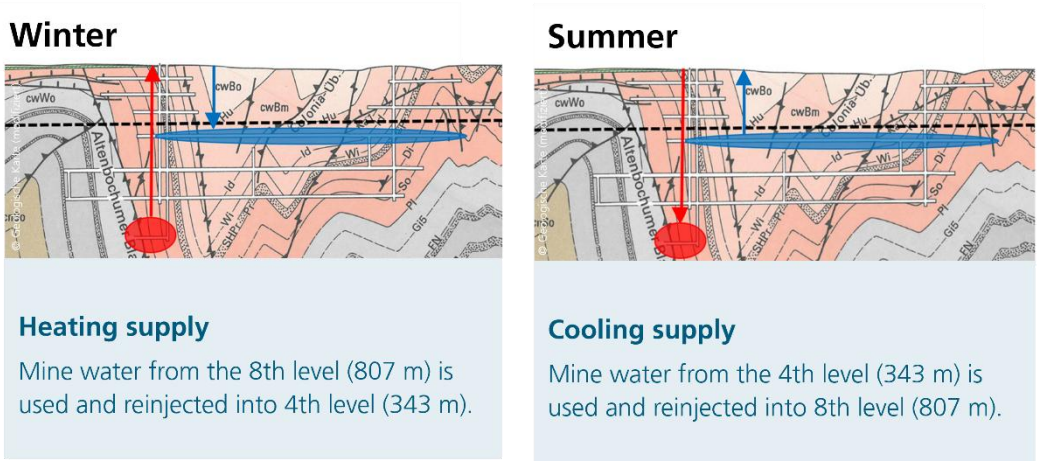


Figure 1. Side view of the Dannenbaum mine showing geological layers and the concept for seasonal operation: heating in winter and cooling in summer. Geological base map, modified from Stehn (1988).

3 DRILLING AND PUMPING TEST

Directional boreholes GT1 and GT2 were drilled from a single site. GT2 targeted the 4th level and reached 343 m (MD), while GT1 targeted the 8th level and reached 864 m (MD). Entry into the mine galleries was indicated by a sudden drop in water level and a sharp decrease in weight on bit, consistent with historical mine plans. The main challenge was precise drilling over a short distance. Potential mine gas was considered, but none was detected. Both wells were completed to support hydraulic testing.

In early 2023, an electric submersible centrifugal pump was installed at ~300 m depth to cover a wide range of flow rates and ensure operational flexibility. Step-rate pumping tests were performed with continuous monitoring of pressure, temperature, and flow in both wells. Limited on-site storage required circulation mode, transferring water between wells. Water samples were collected during stable phases to verify operational suitability.

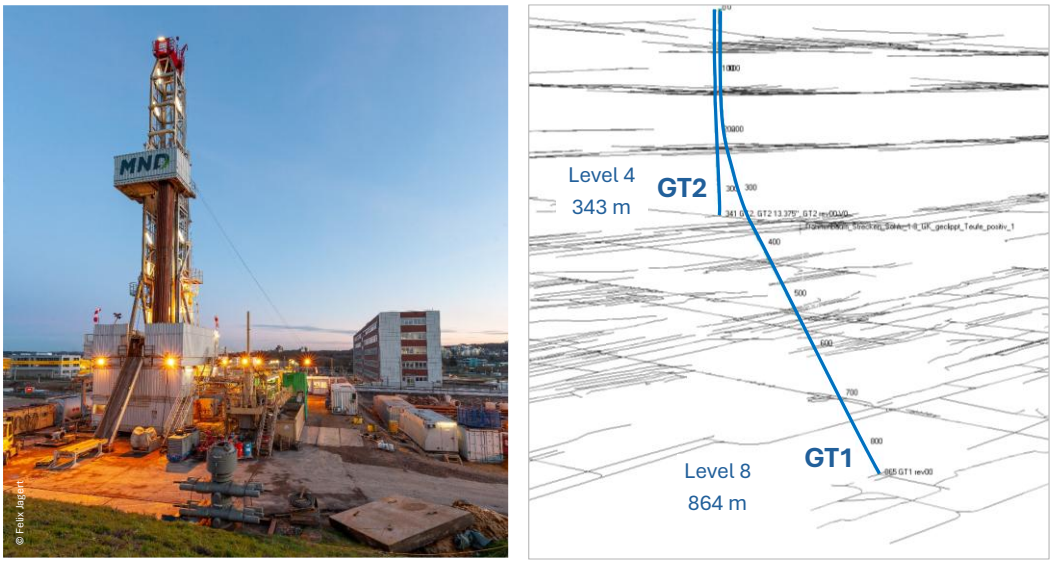


Figure 2. Drilling operation at the Mark 51°7 site (left) and 3D visualization of mine galleries including GT1 and GT2 drilling paths (right).

4 RESULTS

Pumping tests confirmed hydraulic access to both the 4th and 8th levels. Flow rates up to 160 m^3/h were achieved with minimal drawdown, demonstrating high productivity and storage capacity. The deeper 8th level

(GT1) exhibited superior hydraulic performance compared to the shallower 4th level (GT2), requiring lower differential pressure to maintain the same flow rate.

Water temperatures were slightly below expectations, with the 4th level stabilizing at 15 to 20 °C and the 8th level at approximately 27 °C, at the lower end of the regional geothermal gradient. Despite this, the temperature contrast supports efficient seasonal operation: the 4th level is suitable for cooling, and the 8th level provides heat for winter applications. Both wells remained stable throughout testing, and the system accommodated varying flow rates with minimal pressure loss. Overall, the results confirm that the mine-water reservoir can reliably support the planned geothermal operations.

5 DISCUSSION

Drilling and pumping results indicate favorable conditions for geothermal utilization. High productivity, large accessible void volumes, and stable temperatures support flow rates suitable for a 5GDHC system with relatively low pumping effort. The temperature difference between the 4th and 8th levels enables efficient seasonal heating and cooling.

Differences in hydraulic behavior highlight the need for detailed subsurface characterization. Even if historical records suggest similar gallery geometries, actual performance may vary due to collapse, sedimentation, or connectivity differences. The deeper 8th level (GT1) showed lower pumping resistance than the shallower 4th level (GT2), indicating better hydraulic connectivity and efficiency. These insights improve understanding of flooded-mine hydrogeology and support development of similar systems in other former coal mining regions.

6 CONCLUSIONS AND OUTLOOK

Drilling and pumping tests confirm the Dannenbaum mine is suitable for geothermal mine-water utilization. Both wells intercepted their target levels, achieving stable hydraulic performance and flow rates up to 160 m^3/h. Measured temperatures support integration into a 5GDHC system.

These results provide a foundation for planning and constructing the geothermal facility, with commissioning expected to begin in spring 2026. Future work will focus on long-term hydraulic and thermal modeling and operational optimization. This project demonstrates the potential of repurposing abandoned coal mines as sustainable, low-carbon energy sources for urban regions.

Acknowledgements

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