Feasibility Study: Geothermal Local Heating with Mine Water for the Development Area Richtericher-Dell in Aachen, Germany

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Abstract

This feasibility study explores the potential of utilizing geothermal energy from mine water for heating the Richtericher-Dell development area in Aachen, Germany. In light of the EU's goal for a net-zero greenhouse gas economy by 2050, and the significant contribution of heating and cooling to Germany's energy demand, this study proposes the implementation of a fifth generation district heating and cooling (5GDHC) network. The project aims to leverage mine water from a depth of 270 meters, employing an electrical submersible pump to circulate water through an energy center, while integrating a pit thermal energy storage system to enhance capacity during peak loads. The planned heating grid is designed to support approximately 850–900 residential units, with an anticipated annual consumption of 9.5 GWh. The study concludes that the proposed system can operate independently of fossil fuels, relying solely on sustainable energy sources and a power-to-heat backup system. This model serves as a blueprint for future heating grid expansions in the Aachen region, promoting the reutilization of mine water and the integration of decentralized energy systems.

Keywords: Coal mines, mine water, geothermal energy, fifth generation district heating and cooling (5GDHC) networks

Introduction

The EU aims to have a net-zero greenhouse gas (GHG) economy by 2050, with 55% reduction on 1990 levels by 2030. At present, heating and cooling represent over 50% of the final energy demand in Germany and are mainly supplied by fossil fuel derived energy (BMWK, 2022). The implementation of mine water in fifth generation district heating and cooling (5GDHC) networks is a possibility to counterbalance this effect.

The feasibility study for the planned development area Richtericher-Dell in Aachen, Germany aims at the supply of heating and cooling via mine water with the focus on the underground development of geothermal energy in conjunction with a 5GDHC network.

5GDHC refers to a modern approach to district energy systems that focuses on improving energy efficiency, integrating renewable energy sources, and reducing greenhouse gas emissions.

Relevance to Sustainable Energy:

- **Energy Efficiency:** 5GDHC systems utilize advanced technologies such as heat pumps and thermal energy storage to optimize energy use.
- **Renewable Integration:** They can incorporate a higher share of renewable energy sources, such as solar thermal and geothermal energy.
- **Decentralization:** Promotes local energy production and consumption, reducing transmission losses.
- **Flexibility:** Adaptable to varying energy demands and the integration of smart grid technologies.
- **Lower Emissions:** Contributes to climate goals by reducing reliance on fossil fuels.

In summary, 5GDHC networks play a

crucial role in transitioning to sustainable energy systems by enhancing efficiency and promoting the use of renewables, e.g. mine water.

Mine water utilization concepts

Utilizing the thermal potential of mine water from abandoned mines is generally possible with different technical systems. If the mine water is to be used as a heat source, either a closed or an open system can be employed.
In closed systems the mine water is indirectly utilized by borehole heat exchangers (BHE), which are installed in shafts (Fig. 1). These are usually tubular heat exchangers made of metal or plastic, in which a heat transfer medium is circulated (secondary circuit), which absorbs the heat, e.g. from the backfill column of a former shaft. It is also conceivable to tap into the existing water column via a tubular heat exchanger, which is fed through a degassing pipe that is e.g. still accessible.

The volume flow of the circulating heat transfer medium is generally the limiting factor for the indirect use of the geothermal energy present in the subsurface, due to an optimum extraction rate depending on the flow rate (VDI, 2019).

The direct thermal utilization of mine water in an open doublet system should be favored at an early stage, due to significantly higher thermal extraction rates. For this purpose, the available mine water potential in the subsurface must be estimated.

In an open system with direct utilization of the existing ambient heat in the subsurface, it must be ensured that the extraction and injection wells are not hydraulically connected to each other, as this can result in a "thermal short circuit", which can significantly reduce the performance of the mine water scheme. It is therefore highly recommended to position the wells in different levels of the mine layout.

Study area

Urban development plans for the Richtericher Dell area in Aachen, Germany (Fig. 2) led to the adoption of a master plan in 2005. A final partial or overall plan with a binding development scheme still has to be finalised by the City of Aachen.

However, residential development is still planned, supplemented by sites for daycare centers, a retirement home and retail. In consultation with the City of Aachen, it was highlighted that the energy requirements of the development scheme will be in line with the already provided data from 2005. For the feasibility study, it was therefore assumed that the future development is in accordance with the elements of the previous planning, which was utilized for the expected heat demand and the planning of the heating network.

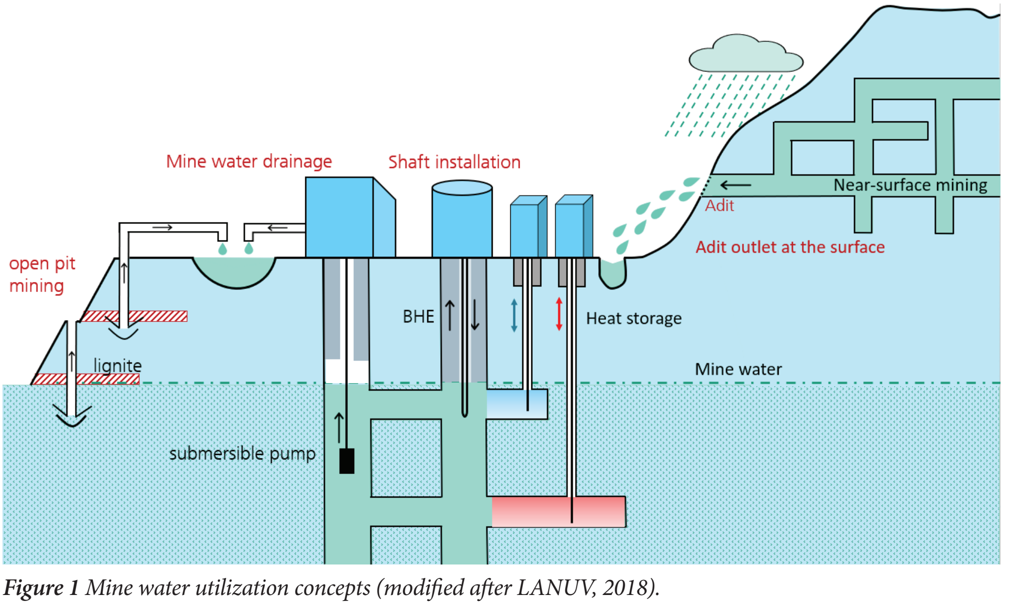

Figure 1 *Mine water utilization concepts (modified after LANUV, 2018).*

The following cartographic representation (Fig. 3) shows the Richtericher Dell master plan with the foreseen housing scheme. For the feasibility study, the master plan was the basis for the planned heating network and the spatial integration of the mine water utilization concept. The layout of the planned heating and possible cooling network was set in the streets of the master plan (dashed in different shades of blue).

The heating scheme of the newly built houses can be freely selected and adapted to the conditions of supply from a low temperature heating source. Surface heating systems are assumed for the heating distribution within the housing units, so that only a low flow temperature (max. 35 °C) will be required.

The planned heating grid within the Richtericher-Dell development allocates an area of 37 ha with approx. 850–900 new residential units. A maximum grid capacity of approx. 4.2 MW with a simultaneity of 83% was based on the net energy balance of the foreseen buildings (with an anticipated annual consumption of approx. 9.5 GWh). As an innovation, it should be emphasized that the influence of an additional pit thermal energy storage (with a constructible surface that can be reused as a parking lot in the vicinity of the energy center) was specifically investigated and evaluated within the feasibility study. This could significantly support the anticipated 40 °C grid temperature during peak loads by providing an additional hydraulically separated temperature circuit for more than 24 hours at a time. In combination with the pit thermal energy storage system, the output of the anticipated mine water system and heat pumps could be reduced by approximately 50%.

The integration of mine water into the Richtericher Dell development scheme is an integral part of the 5GDHC network and could be achieved by pumping mine water from the deeper 270 m level using an electrical submersible pump, feeding it to an energy center and then discharging the cooled mine water into the 200 m level (Fig. 1).

The actual heat or cooling medium for supplying the new development area circulates in a secondary circuit from the energy center to the consumer points and

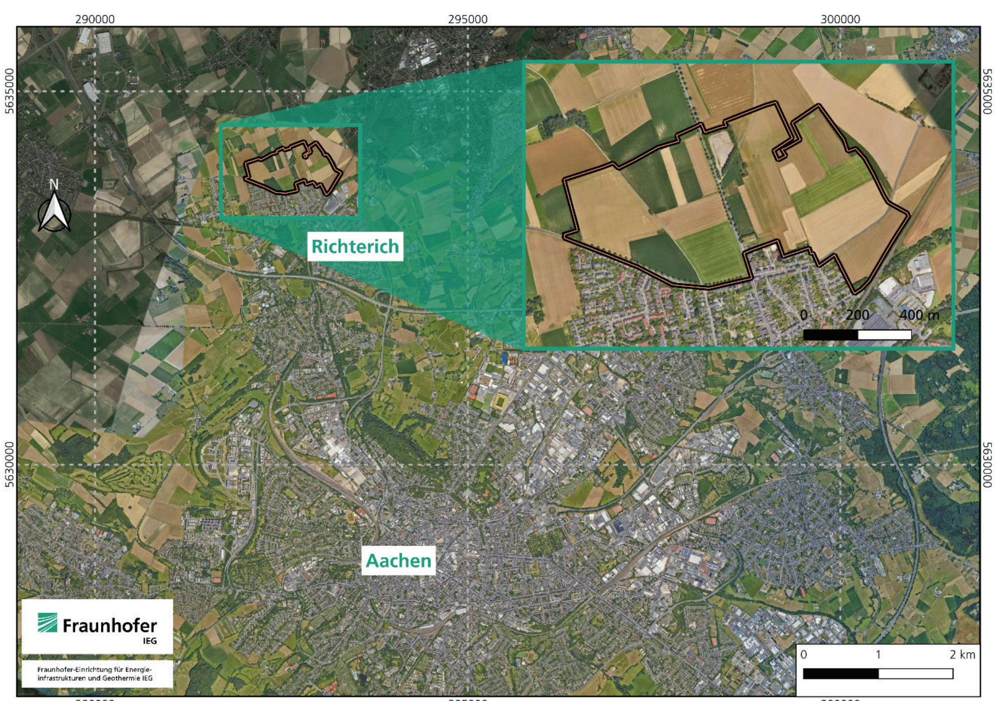

Figure 2 Geographical location of the planned Richtericher Dell development area in Aachen, Germany.

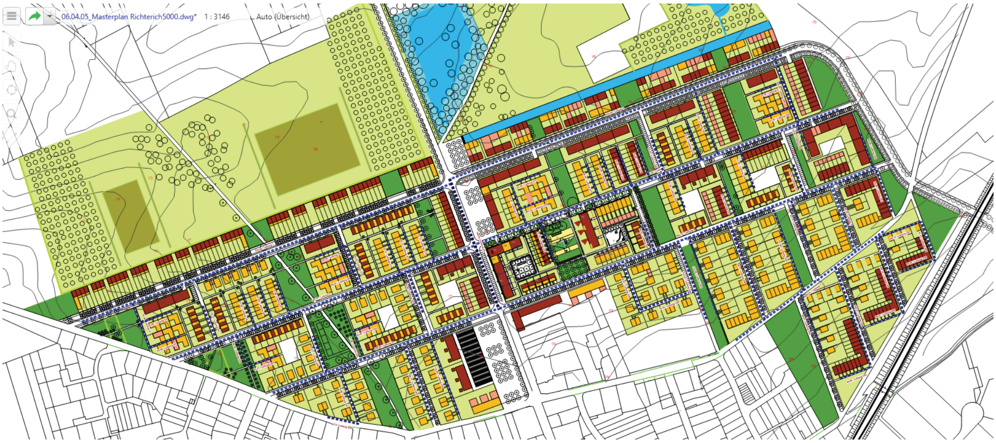

Figure 3 *Urban development draft of the Richtericher Dell development scheme (from 2005).*

after thermal use in the return flowline back to the energy center.

In an open doublet system, both wells would be equipped with an electrical submersible pump including a line for pumping or re-injection, so that the investment costs are minimized.

The same principle could be considered reversibly in the summer months for a possible cooling supply, so that cooler mine water is pumped from the 200 m level, fed to the energy center and then reintroduced into the 270 m level by absorbing the surplus heat from the cooling network.

In order to characterize the geohydraulic productivity of the mine workings, the old mining situation at the site was examined. Based on the mine layouts provided, including information on the coal production rates of the mines, the existing potential was assessed to be favorable.

After analyzing the geological and hydrogeological framework conditions, together with the planned above-ground development, including the grid design for the heating and cooling supply, two conceivable well locations were derived based on the mine layouts.

Conclusions

The feasibility study for geothermal local heating using mine water in the Richtericher-Dell development area demonstrates a viable pathway toward sustainable energy solutions. By implementing a 5GDHC network, this project effectively utilizes geothermal resources to meet the heating demands of approximately 850–900 residential units, with an anticipated annual consumption of 9.5 GWh. The innovative integration of a pit thermal energy storage system significantly enhances the network's capacity to manage peak loads, reducing reliance on fossil fuels.

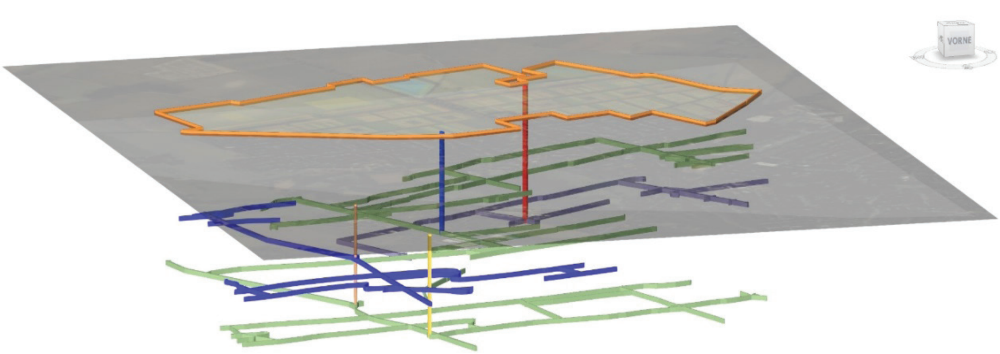

Figure 4 *3D representation of the 100 m, 200 m and 270 m level.*

Moreover, the dual functionality of the proposed system allows for cooling in warmer months by reversing the flow of mine water, thus optimizing the use of available geothermal energy year-round. The findings indicate that the existing geohydraulic conditions are favorable for the successful implementation of this concept, reinforcing the potential for similar projects in the Aachen region.

Overall, this study serves as a blueprint for future heating grid expansions, advocating for the reutilization of mine water and the establishment of decentralized energy systems. The integration of sustainable practices within urban development aligns with the EU's climate goals, contributing to a more resilient and low-carbon energy future.

Acknowledgements

This feasibility study was supported by the BAFA funding scheme Wärmenetze 4.0.

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