GIS based analysis of heat demand and subsurface potential of abandoned mine infrastructure in the Ruhr region WVTF & IMWA 2024

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Abstract

The Ruhr region, located in western Germany, is one of the largest metropolitan areas in Europe and has a long history of coal mining. Due to the need for an energy and heat transition away from fossil fuels towards renewable energies, the thermal reuse of existing mining infrastructures and the associated mine water offer a great potential that needs to be exploited. By combining surface heat demand with underground potential for heat supply and storage, the development of possible concepts for sustainable heat supply using mine water is optimized and streamlined.

The GIS-based analysis of the heat demand of the local supply area can be used to determine the spatial expansion phases of a district heating network as well as areas that are particularly lucrative from an economic point of view. By digitizing underground mines from existing mine layouts, a better understanding for the underground structures can be gained and it is also possible to find the best access points to the mine gallery by means of drilling and to create the basis for modelling.

The investigation of the heat demand for every single building shows the total heat demand within the supply area but also areas with higher or lower demand. This enables a precise design of networks and the associated concepts (cold local heating, central large-scale heat pump). With the help of the digitized underground mining infrastructures, it is possible to useful embed the mine water as a heat source in the heating network. In addition to the possibility of intersecting heat demand and potential, digitization also offers many further advantages, such as the basis for modelling and for 3D well path planning.

With almost 5.1 million inhabitants and 4400 km² the Ruhr region, Europe's fourth largest metropolitan area, offers a lot of potential for the use of mine water in local heat supply networks. The aim of the work is to design a workflow that can be used to plan and implement mine water-based district heating networks in the Ruhr area and to shape the heat transition.

Keywords: WVTF & IMWA2024, GIS, digitization, district, heat, network, geothermal, potential, Rhine Ruhr Region, Germany

Introduction

The Rhine Ruhr Region, located in western Germany, is Europe's fourth largest metropolitan area with almost 5.1 million inhabitants and an area of 4400 km². The area has a long, rich mining history and especially the last 150 years have been embossed by industrial mining. Therefore, the underground of the Rhein Ruhr Region contains lots of old mining infrastructure, from which most areas are abandoned and filled with mine water. This geothermally heated mine water can provide a big support to the transition of heat supply towards renewable heat sources. In order to make this possible, a workflow was created that can be used to optimise the development of mine water projects.

Digitization of underground mine layout

One of the first steps in starting a geothermal mine water project, after clearing legal issues, is the investigation of the historical background of the mine. Including the inspection of mine layouts, shafts and dam locations (Hahn 2023). This is done to get a good overview over the underground infrastructure of the mine.

The information is provided either by the local mining company's or the district government for mining. Most relevant are the mine layouts and cross sections of the mine. The cross sections are used to get an overview over the number, position and orientation of the different mine levels. In most cases the mine layouts are provided in an already georeferenced format as.tiff or.pdf files, which can then be imported into a geographic information system, exemplary QGIS. After gaining a brief overview of the mine layout, the digitization process is started. For this purpose, a new shapefile with the geometry type LineString for each level of the mine is created. In the next step all drifts and crosscuts are traced in the shapefile, so that a digital two-dimensional copy of the mine layout emerges. For later calculations the drifts and crosscuts are marked with different IDs in the attribute table to distinguish them from each other. In the next step all available depth points are extracted from the mine layouts and traced in a point shapefile. Those points are used to create an interpolated mine level surface, which than can be projected onto the previously created two-dimensional shapefile, to create the base of a three-dimensional model. The three-dimensional visualisation of the underground structures of the mine gives a much better understanding of the mine layout (Fig. 1). This process is repeated for all available mine levels, and also the shafts, so that in the end the data can be used for further work, like well path planning and THCM-modelling (thermo-hydraulic-chemical-mechanical). In this modelling process other properties, besides the geometry, are also considered. For example, hydraulic properties of the mine like residual cavities, technical barriers or heat distribution underground.

The data, shown in Fig. 1 was gathered as part of the Richtericher Dell-project and processed further in a master thesis (Laufhütte 2023). The project aims to use the thermal underground heat of the abandoned

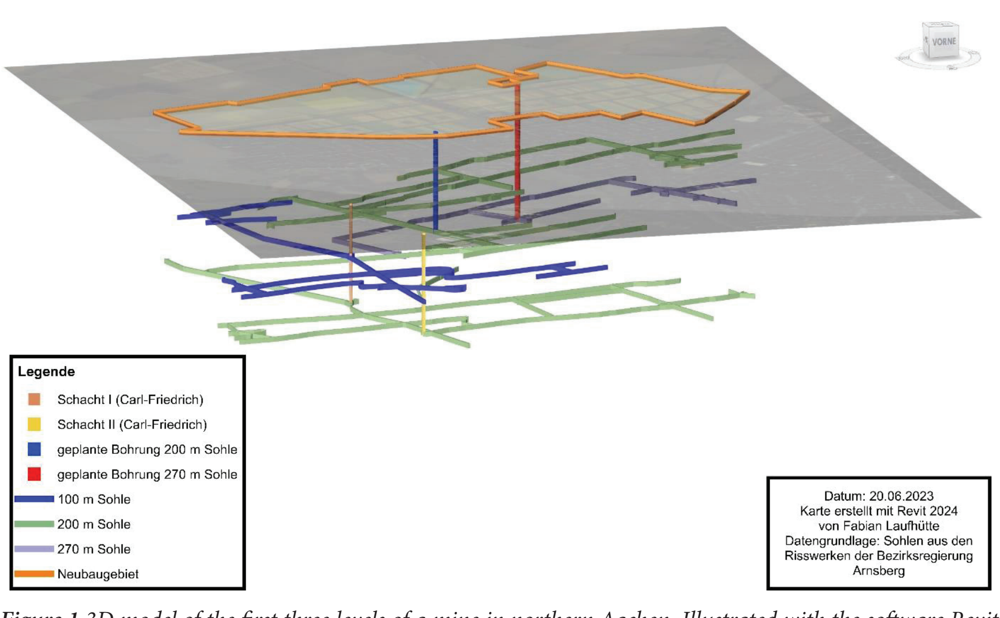

Figure 1 3D model of the first three levels of a mine in northern Aachen. Illustrated with the software Revit 2024 (Laufhütte 2023) mine water to provide heat for a local district heat network.

Determination of the potential heat demand

The heat demand of the districts located in the area of the underground mining infrastructure can be determined slightly differently depending on the data available. The best way, with the highest accuracy and reliability depends on the data provided by the local energy supplier. If the supplier can provide the gas consumption of the last three to five years, the demand of a district can be calculated most accurately. A python script, utilizing the pandas and geopandas libraries, is used to merge buildings from OpenStreetMap with the gas consumption data from the local gas supplier and generate a shapefile that contains the georeferenced gas consumption per house. If this data is not provided or available, the geoinformation centre as part of the State Office for Information and Technology North Rhine-Westphalia provides a so-called space heating demand model. For this model data like building type, annual mean temperature and year of construction are compiled to calculate an area-specific heat demand. This is than combined with the specific building data like height and floor space to calculate an absolute heat-demand per building (opengeodata.nrw 2023). In a still ongoing project with municipal utilities of Kamen, Bergkamen and Bönen (short GSW) the data provided by the State Office for Information and Technology North Rhine-Westphalia was compared to the provided gas consumption data. First results show, that especially with normal residential buildings the model is close to the actual measured consumption. However, for large industrial and warehouse type buildings the difference between model and real data gets bigger. Overall a difference of plus minus 10–15% is realistic.

The provided and georeferenced data is than imported in the GIS project (Fig. 2) to get an overview over the buildings to be

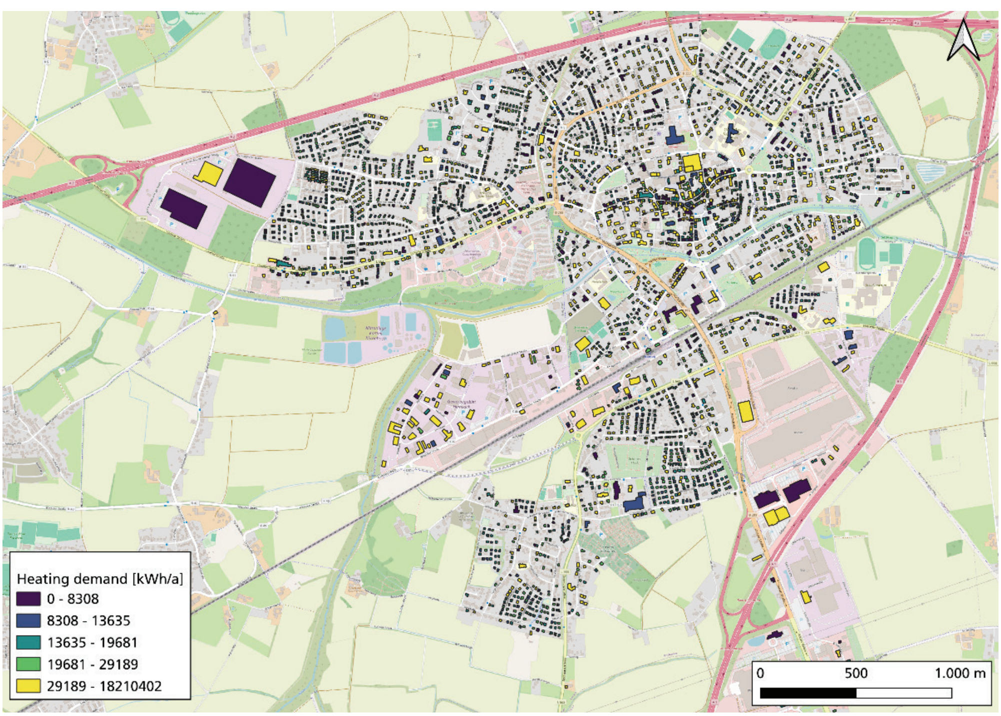

Figure 2 Heating demand of the buildings in the supply area of Kamen. Gas consumption data provided by the GSW

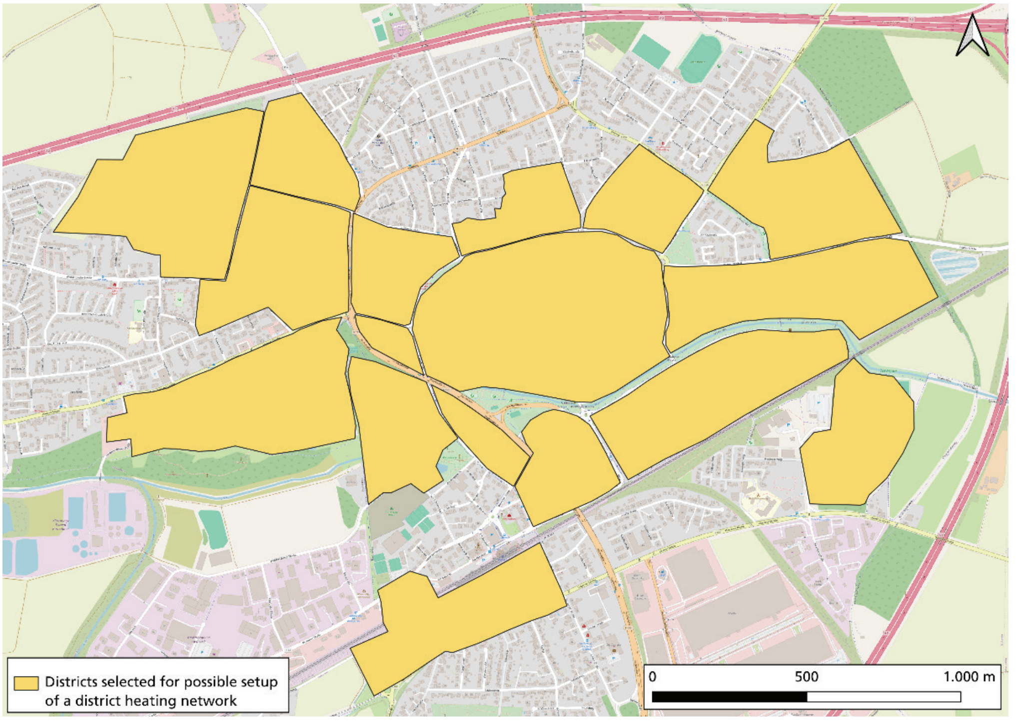

Figure 3 The shown districts have been created in close co-operation with the local municipal utilities, to setup a district heating network to provide heat from an abandoned coalmine

considered. Depending on the size of the area to be analysed either a frame is drawn over the whole relevant area and all buildings and their heat demand are summarised to get the total heat demand or multiple much smaller frames are drawn over specific districts separated for example divided by railways, main streets or other barriers (Fig. 3).

The heat demand of the districts is than summed up per district and divided by the area of each district to get the heat demand per area expressed in [kWh/(m² × a)] also called heat demand density. This value helps with the decision-making, to select the districts of the supply regions, where a development of the DHN would be most economical. Districts with values over 70 kWh/(m² × a) are highly economical, values between 30 and 70 also are mostly worth it, a district with values below 30 should initially be considered subordinate (Bleidießel 2023) (Fig 4).

The city of Kamen is in the eastern part of the Ruhr Region and used to show how gas-demand data, provided in an excel sheet, can be transformed into a two-dimensional map in short, comprehensible steps. In Fig. 4 it is clearly shown, that the 4 yellow depicted districts in the middle of the city have the highest demand of heat per area and are therefore the most interesting for the construction of a heating network. The areas depicted in purple have comparatively lower heat demand but are still over the value of 30 kWh/(m² × a) and thus still can be developed economically.

Combining heat demand and underground infrastructure

With the district specific heat demand and the total heat demand of the supply area on the one hand and the underground mine infrastructure on the other hand, the data now can be blended together. With the mine infrastructure, laying under the buildings that need heating the foundation for further concept planning has been laid. For the example of Kamen, shown in Figs. 2–4, the

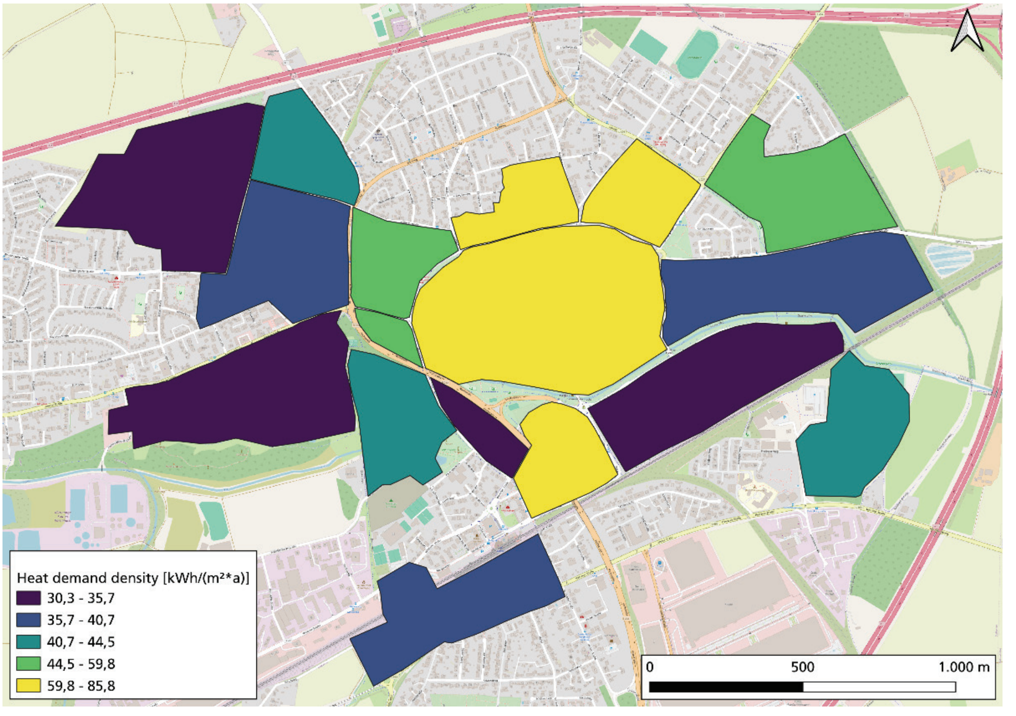

Figure 4 The heat demand density, calculated from the total heat demand of all buildings inside a district and the area of the district

digitization of the underground structure is still in progress, therefore, to illustrate the process an exemplary first mine level with drifts and crosscuts is presented (Fig. 5).

After blending subsurface mine data and surface heat demand data, the GIS project can now be used to start developing a plan to use geothermal heat from the mine for the different districts. The network planner for the district heating network can use the high heat demand districts as a starting point and also can use the data for all houses to plan widths and routes of the heating grid. For the integration of the geothermal heat the best drilling targets in the mine can be determined and merged with the district heating grid, to find the best place for the heat pump and net integration. Also, future extensions of the district heating net can be sketched out and new drill targets marked.

Conclusion

With the heat transition, away from fossil fuels and towards renewable energies the planning process of the transformation, extension and construction of district heating networks becomes more important but also partially more difficult. With the presented steps, the estimation of geothermal potential of abandoned mines and mine water becomes more concrete and enables further work with underground mine data. Furthermore, the blending of subsurface and surface data provides the opportunity for a better integration of the potential of mine thermal energy into the district heating sector.

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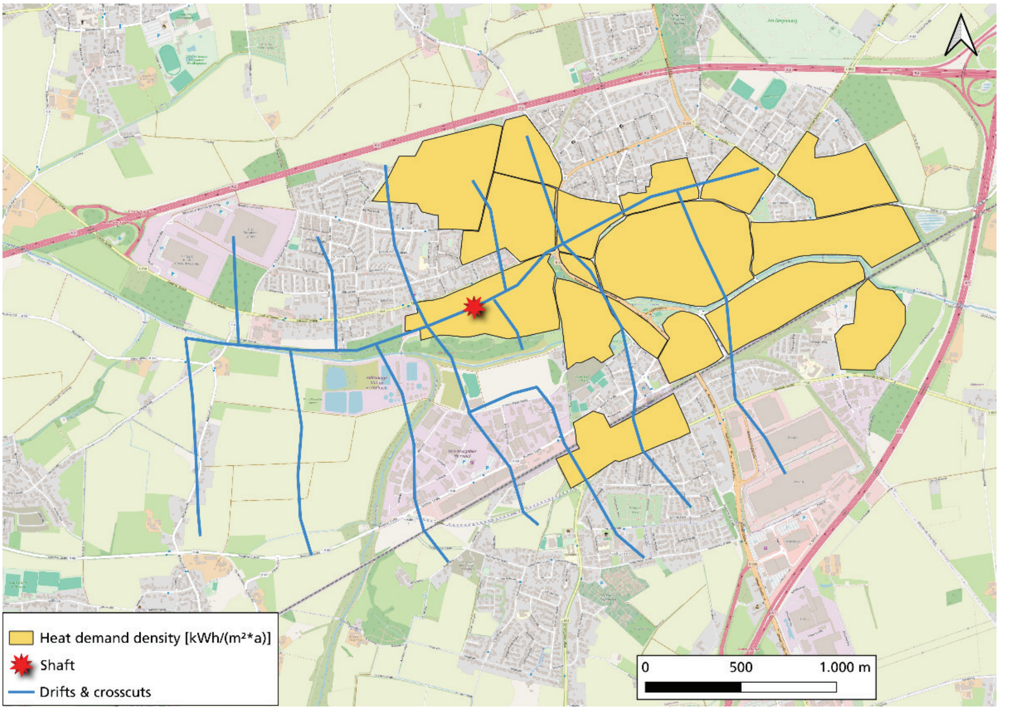

Figure 5 *The relevant districts of Kamen combined with exemplary created drifts & crosscuts of the first mine level. The shaft of the abandoned mine is precisely localised, the digitization of underground infrastructure is still a work in progress and therefore only presented as an example*

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