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Why Digitalisation In The Admission Procedure Of Shallow Geothermal Systems Is More Than Just Avoiding Paper Waste

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ABSTRACT

According to German mining and water law and the Geological Data Act, every well, regardless of its purpose, has to be reported to the public authorities in advance. Lower Saxony, a federal state in Northwest Germany, has developed a web-based drilling-notification tool, which is available online since 2007. In 2012, this system was expanded to register also shallow geothermal projects (up to 400 m drilling depth) in order to accelerate and harmonise the permitting process of more than 50 local water authorities and avoid time losses by sending forms by post. Since then, not only the data of the drilling itself, such as location, depth and drilling method is collected and stored in a database but also data of the geothermal project such as the type of geothermal system (e.g. borehole heat exchanger, vertical heat exchanger) or the heat output of the installation.

Up to the beginning of 2025, detailed data from 19,000 of the known 26,600 shallow geothermal plants in Lower Saxony were stored in this database. Analysing this data allows to:

1. detect long term trends, e.g. of installed shallow geothermal capacities,
2. show regional differences of drilling activities,
3. supply regional institutions and stakeholders with data for the development of long-term renewable heat supply,
4. detect new technical developments due to daily actual data,
5. provide decision makers with sound information about the complete picture of the shallow geothermal development in the state of Lower Saxony.

In May 2025, the first report “Facts and figures on shallow geothermal energy in Lower Saxony 2024” was published. This report will be published annually and is based on the evaluation of the database for shallow geothermal plants. One of the main insights showed an increasing number of shallow geothermal plants from 2007 to 2022, while the number of new plants is decreasing in 2023 and 2024. The installed heating capacity shows the same trend but with a much smaller decrease. This demonstrates that less but bigger plants with a higher heating capacity were built in 2023 and 2024.

1 INTRODUCTION

In Germany, every well has to be announced in advance according to the Geological Data Act, mining law and water law, regardless of its purpose. The responsibilities for these different laws lie with different institutions: the geological survey is responsible for the Geological Data Act, the mining authority for the mining law and the water authorities for the water law.

The State Authority for Mining, Energy and Geology is the geological survey for Lower Saxony, a federal state in Northwest Germany, and the mining authority for Lower Saxony, Bremen, Hamburg and Schleswig-Holstein. There are 53 local water authorities in Lower Saxony. In the past, the different responsibilities for the drilling notification resulted in different and often insufficient data sets in various locations: sometimes the drilling companies reported the drilling only at one institution, or they provided different data for the same project. Additionally, some of the data was provided by paper while others were stored in a database. None of the authorities had a complete data set of all the drillings in their territory.

This paper will describe how Lower Saxony solved the problem of incomplete data, and the benefits of information obtained.

2 DATABASES

The key for the digitalisation process of data related to shallow geothermal project is the usage of databases that are filled via internet forms. The following paragraphs will provide insight in the online drilling-notification tool and the database for shallow geothermal plants.

2.1 Online Drilling-Notification

As mentioned above, every well has to be announced according to different laws. Lower Saxony developed an online drilling-notification in 2007 for the obligations under mining law and the predecessor of the Geological Data Act. Since the handling of the online tool was much more comfortable than the use of paper forms, the online tool was soon the common way to report a drilling operation.

The notifications required under water law were still sent to each water authority (53 in total in Lower Saxony) in an analogue way. Since almost 100% of the drillings were registered with the online application, the State Authority for Mining, Energy and Geology decided in 2012, in close collaboration with water authorities, to expand it to register also geothermal projects according to water law. Thus, the notifications under different special laws were combined in a single online tool for geothermal projects (Figure 1). This way, all relevant authorities received the same set of data and missing information was less likely, and the applicant saved time. By using a web-based front end, the input of data was accelerated and data quality was increased by providing drop down lists, value checks and coordinate gathering with click on the location maps.

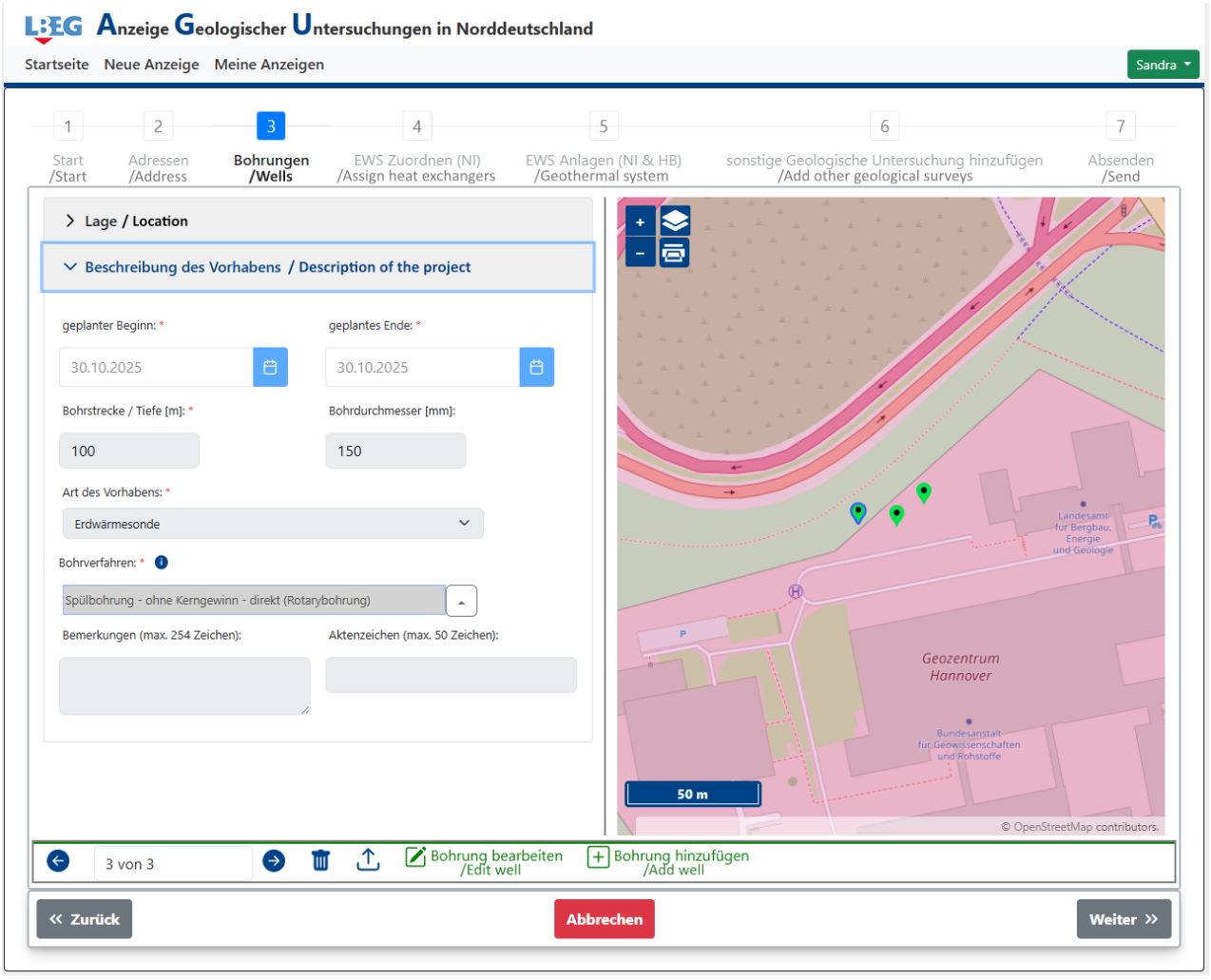


Figure 1. Screenshot of the online drilling-notification as it is used to announce a geothermal project (recent applicant view).

So now, not only the data of the drilling itself such as location, depth and drilling method is collected, but also data about the geothermal project that are relevant for the license under water law. This includes the following data:

- type of geothermal system (borehole heat exchanger, horizontal heat exchanger, open well systems, exploration well, thermally activated foundation pile),
- depth of project (e.g. well depth),
- planned beginning of project,
- total number of installed subsurface components (e.g. total number of borehole heat exchangers),
- heat output of the installation (output of the heat pump),
- cooling output of the installation (in case of cooling),
- seasonal performance factor,
- full load hours,
- type of heat pump,
- further information on the geothermal system, e.g. borehole heat exchanger: Total meters of borehole heat exchangers, type of borehole heat exchanger (e.g. single U-type), type of heat carrier fluid, type of grouting material.

2.2 Database for Shallow Geothermal Plants

The input data about the geothermal installation from the online drilling-notification is stored in the data base for shallow geothermal plants. The data base is hosted by the State Authority for Mining, Energy and Geology, while every water authority has an online access for their area of responsibility to edit the data in case of any changes. As of January 2025, data from 19,000 of the known 26,600 installations in Lower Saxony were stored in this database. The missing data belongs to geothermal plants that were installed before the extended drilling notification went online in 2012. Hopefully, with time the older plants will be added as well.

Figure 2 shows the application as it is used by the water authorities. As an overview, the known geothermal wells are shown on a map, together with a list of all the wells and plants below. On the right side, there are three sections: well data, plant data and permit data. As shown, the plant data is divided into different fields containing data about the type of plant, the heating system, the location and details about the borehole heat exchanger. The data about wells and plants were feed in by the applicant and can be changed by the authorities in the permitting process. The permit data has to be added by the local water authority.

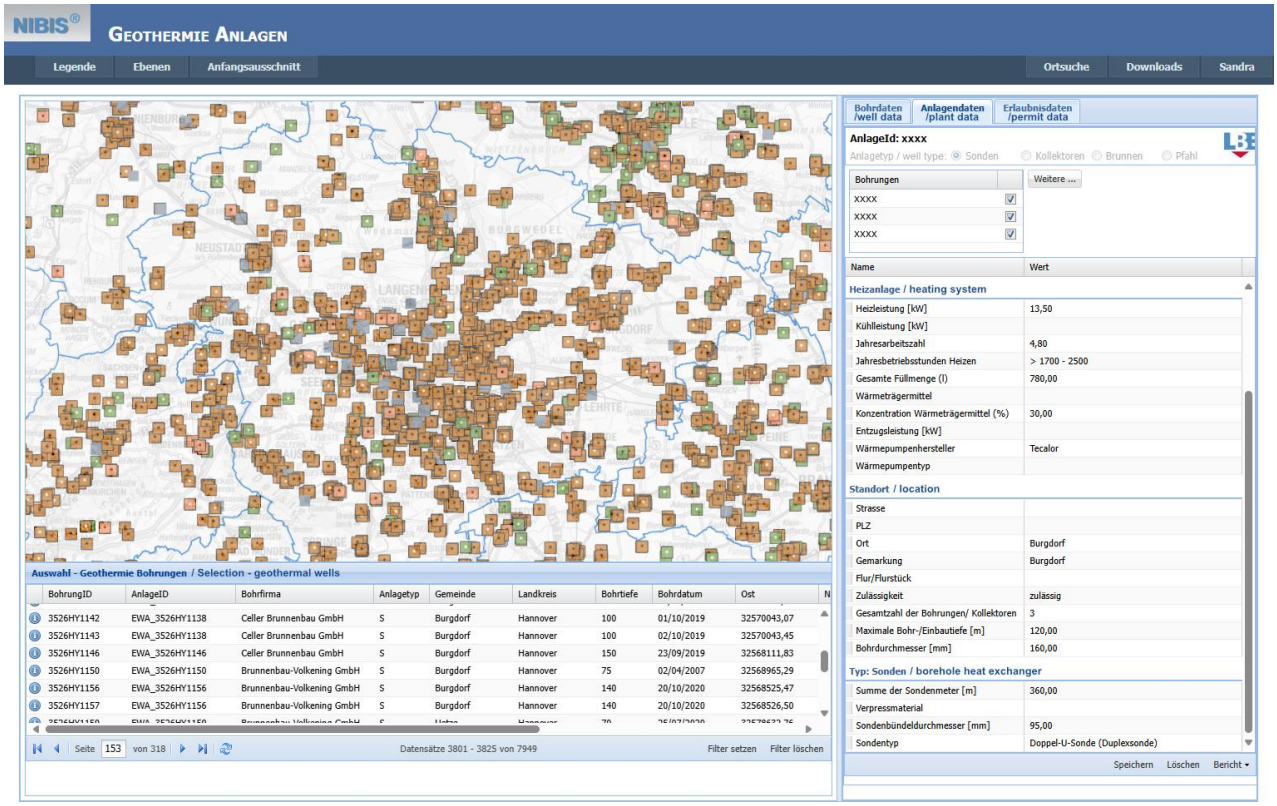


Figure 2. Screenshot of the online application of the database for shallow geothermal plants (authority view).

The database provides certain preconfigured statistics and download options for easier evaluation, for example for the federal state and its administrative districts. Figure 3 shows an example of one of the different statistics available from the database for one administrative district in Lower Saxony. Here, the new geothermal installations broken down to the type of system are plotted for each year. In this case, the local authority can see the development of the geothermal installations per year. It is evident that borehole heat exchangers have a dominant market share and open well systems are rarely used.

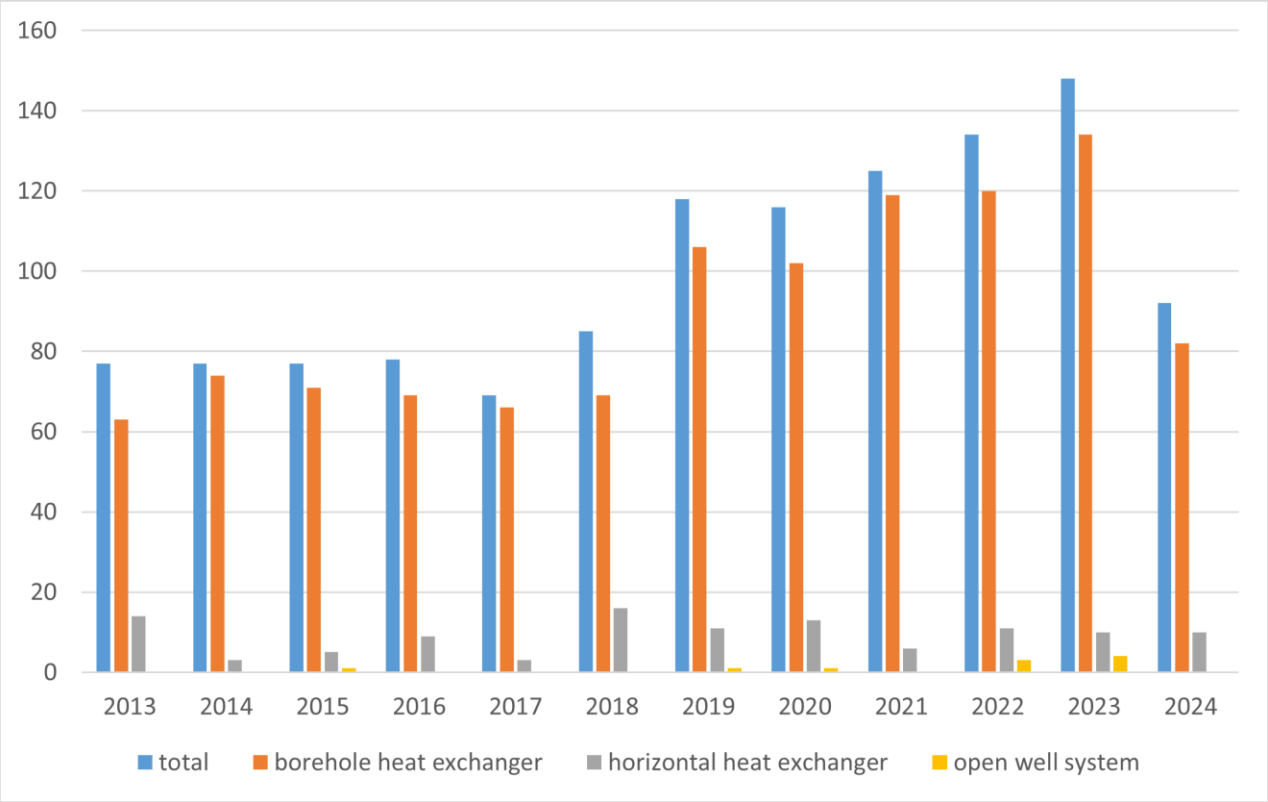


Figure 3. Number of new geothermal installations per year and type of heat pump system for one administrative district in Lower Saxony.

It is not only possible to see the development of the market for shallow geothermal systems in Lower Saxony but also to detect trends in installation configuration. Furthermore, the data base allows an overview on the materials used (heat carrier fluid and grouting material) and the possibility to select installations with specific properties. This can be useful, for example, if problems with certain materials or products arise in the future. In this case, it is possible to quickly analyse where these were used.

3 FACTS AND FIGURES ABOUT SHALLOW GEOTHERMAL ENERGY IN LOWER SAXONY

In the facts and figures on shallow geothermal energy in Lower Saxony, the State Authority for Mining, Energy and Geology annually takes stock of the current state of market development in the field of geothermal energy production from depths of less than 400 metres. Different heat source systems (borehole heat exchanger, vertical heat exchanger, open well systems, energy piles) as well as their spatial and temporal development are discussed. The aim is to provide a statistical overview of the activities in the field of shallow geothermal energy in Lower Saxony. The total number of installations in the data base at 01.01.2025 is approx. 26,600, of which approx. 650 are considered as large-scale installations with heating capacities > 30 kW_{th}.

3.1 Spatial Development of Installations in Lower Saxony

Figure 4 shows the spatial distribution of all shallow geothermal systems stored in the database for shallow geothermal plants in Lower Saxony (26,600 in total), with about 650 geothermal systems with a heating capacity > 30 kWth being highlighted. Geothermal systems are widespread throughout the country. Clusters of geothermal systems occur around the bigger cities like Hanover, Oldenburg, Osnabrueck, Goettingen and regions bordering the city states of Hamburg and Bremen. A low density of plants is evident in the rural and less populated areas of the Harz Mountains (northeast of Goettingen), the Lueneburg Heath (south of Lueneburg), the Wendland (east of Lueneburg) and the Solling (northwest of Goettingen).

Large geothermal systems are defined as systems with a system output > 30 kW_{th}. These systems are usually built to heat or cool commercial or public buildings. Accumulations of these large plants can be found in particular around the cities and conurbations. In addition, large geothermal plants are increasingly widespread in the western districts of Lower Saxony.

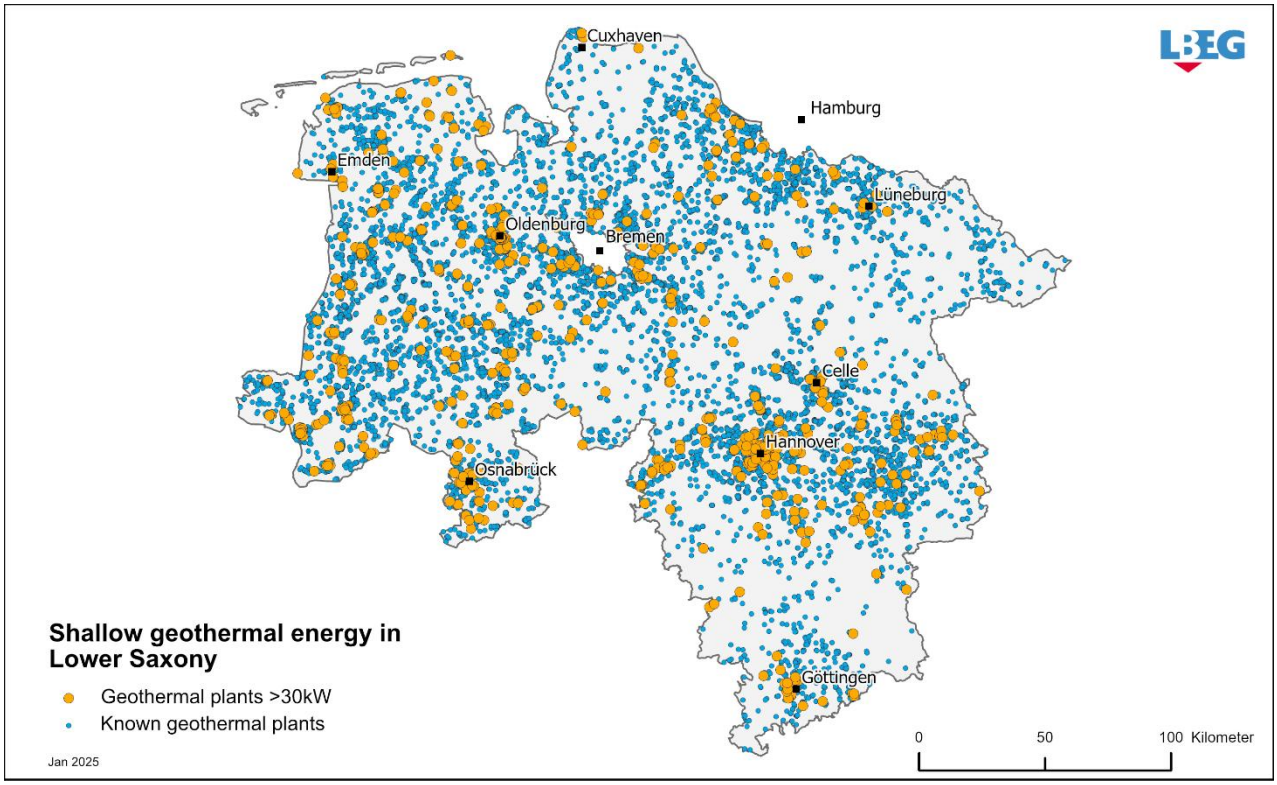


Figure 4. Distribution of geothermal plants with heat pumps in Lower Saxony (Situation as at January 2025).

3.2 Temporal Development of Installations in Lower Saxony

The market development of geothermal heat pumps in Lower Saxony is reflected in the number of reported borehole heat exchangers per year (Figure 5). The evaluation shows that the number of borehole heat exchangers has increased from a stagnating low level of approx. 1,000–2,000 heat exchangers per year between 2007 and 2016 to approx. 6,000 heat exchangers in 2022. Since 2022, the number of annually installed borehole heat exchangers in Lower Saxony has been declining. On the other hand, however, the metres drilled must be considered. Figure 5 shows that although, compared to 2022, fewer borehole heat exchangers were drilled in 2023 and 2024, they have on average longer total length. In 2024, approximately 530 kilometres were drilled for shallow geothermal wells.

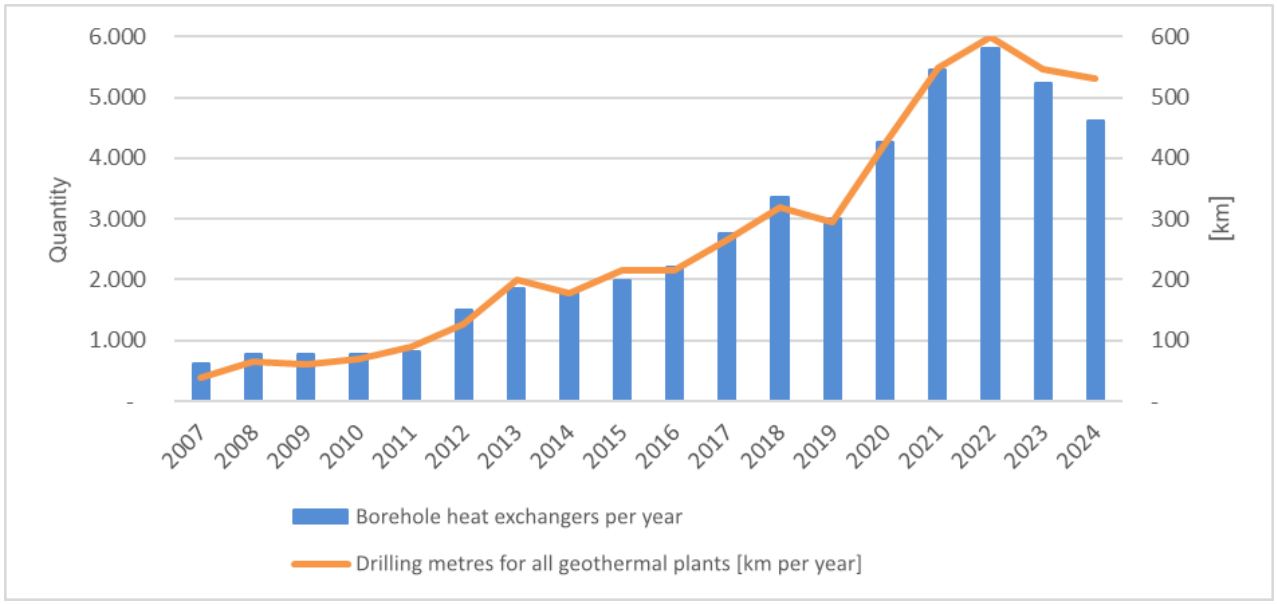


Figure 5. Announced borehole heat exchangers and drilling metres for all geothermal plants in Lower Saxony.

The number of borehole heat exchangers is not identical to the number of geothermal plants, as several heat exchangers often belong to one system. Figure 6 shows the plants built in Lower Saxony between 2018 and 2024. The number has more than doubled from approx. 1,200 plants in 2018 to approx. 2,500 plants in 2022. After that, the number fell again to around 1,500 plants in 2024. Looking at the growth in plant capacity per year, it increases from approx. 12 MW in 2018 to approx. 27.8 MW in 2022. In 2023 and 2024, the plant output declines but not as much as the number of plants (Figure 6). According to the report, fewer but larger plants were built in 2023 and 2024 than in previous years. An evaluation of the performance classes that were added in the period of 2018 to 2024 can be found in chapter 3.3.

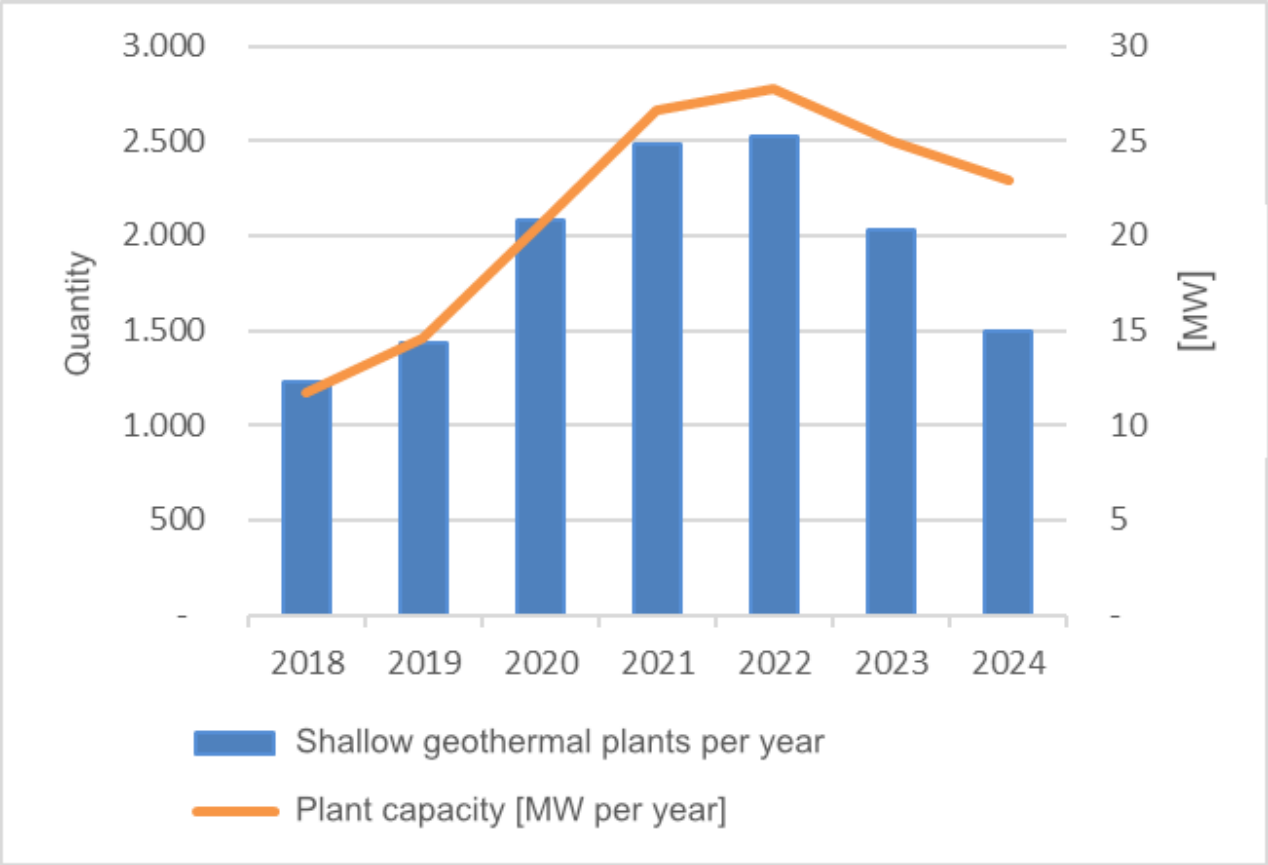


Figure 6. Shallow geothermal plants and plant capacity in Lower Saxony between 2018 and 2024.

Since 2018, the share of borehole heat exchanger systems has consistently accounted for over 90% of all installed geothermal systems. If we take a closer look at the year 2024 (Figure 7), more than 91.5% of all the approximately 1,500 installed systems were borehole heat exchangers – this corresponds to 1,371 borehole heat exchangers systems with approx. 23,000 kW_{th} heating capacity. The share of horizontal heat exchanger systems in 2024 was approx. 8%, i.e. 120 systems with approx. 2,000 kW_{th} heating capacity. Geothermal systems with energy piles and geothermal well systems were implemented in less than 1% of all installations built in 2024. Four wells with a heating capacity of approx. 40 kW_{th} and one geothermal system with energy piles with 8 kW_{th} were built. The median value of the installed heating capacity per system in 2024 was 9 kW_{th}.

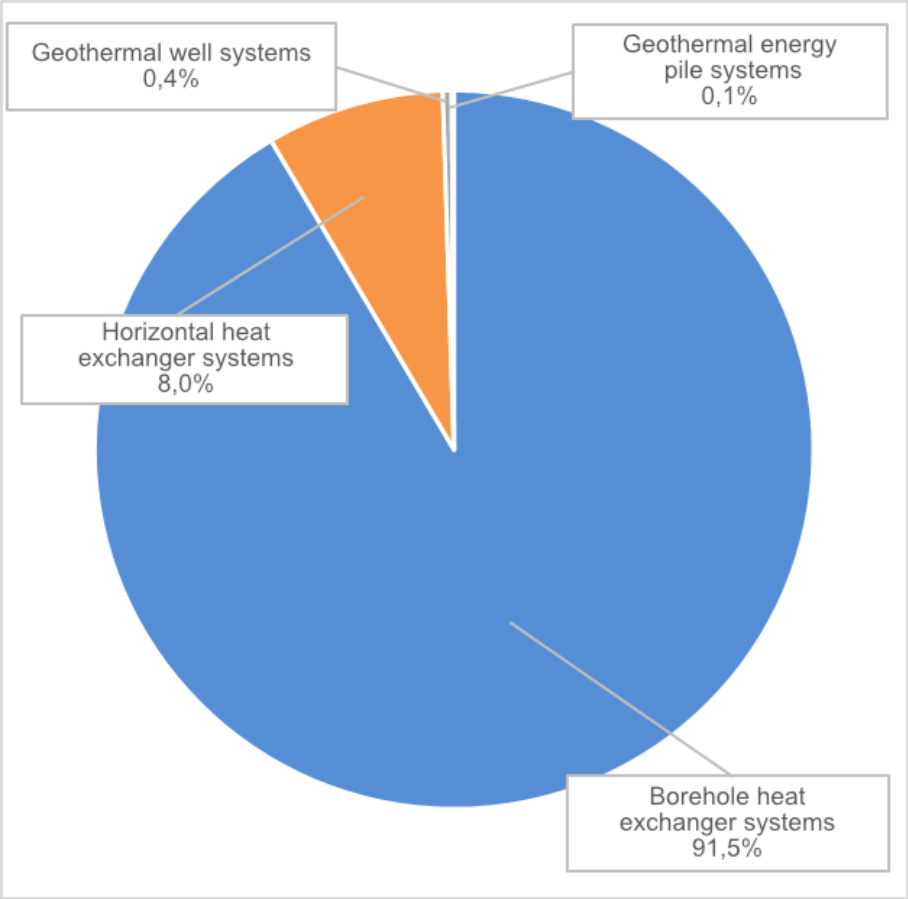


Figure 7. Types of shallow geothermal systems in Lower Saxony in 2024.

3.3 Performance Development of Installations in Lower Saxony

According to the German standard VDI 4640, large geothermal plants are defined as plants with a total heating capacity of > 30 kW_{th}. In order to record the distinction from small geothermal plants more precisely, the Guideline for Geothermal Energy Use in Lower Saxony (Jensen et al. 2022) specifies that this also includes plants that perform an annual heating work of more than 72,000 kWh/a. Systems in this performance class are usually used for heating or cooling public or commercial buildings.

Figure 8 shows the frequency distribution of the power classes (heating capacity of the heat pump) of all geothermal plants installed in Lower Saxony between 2018 and 2024. This shows that most geothermal systems installed in Lower Saxony have a planned output in the range between > 4 kW_{th} and 15 kW_{th}. Plants with a heating capacity of less than 4 kW_{th} or greater than 15 kW_{th} have been built significantly less. Although large geothermal plants with a heating capacity > 30 kW_{th} are relatively rarely built (about 3 % of all plants), they account for a considerable proportion of the annual installed heating capacity (about 20 % between 2018-2023 and 40 % in 2024). So even if the number of plants in this class is small the impact on the renewable heating capacity is significant. The average value of the installed heating capacity of the large-scale plants has risen continuously from 53.1 kW_{th} to 162.7 kW_{th} over the last five years.

Smaller commercial geothermal systems (30–100 kW_{th}) are usually installed in apartment buildings and educational buildings such as daycare centres. Medium-sized systems (100–200 kW_{th}) are often used in office and administrative buildings, factory buildings or warehouses, while large commercial systems (> 200 kW_{th}) are built for the air conditioning of treatment buildings (hospitals) and larger administrative building complexes or for local heating networks.

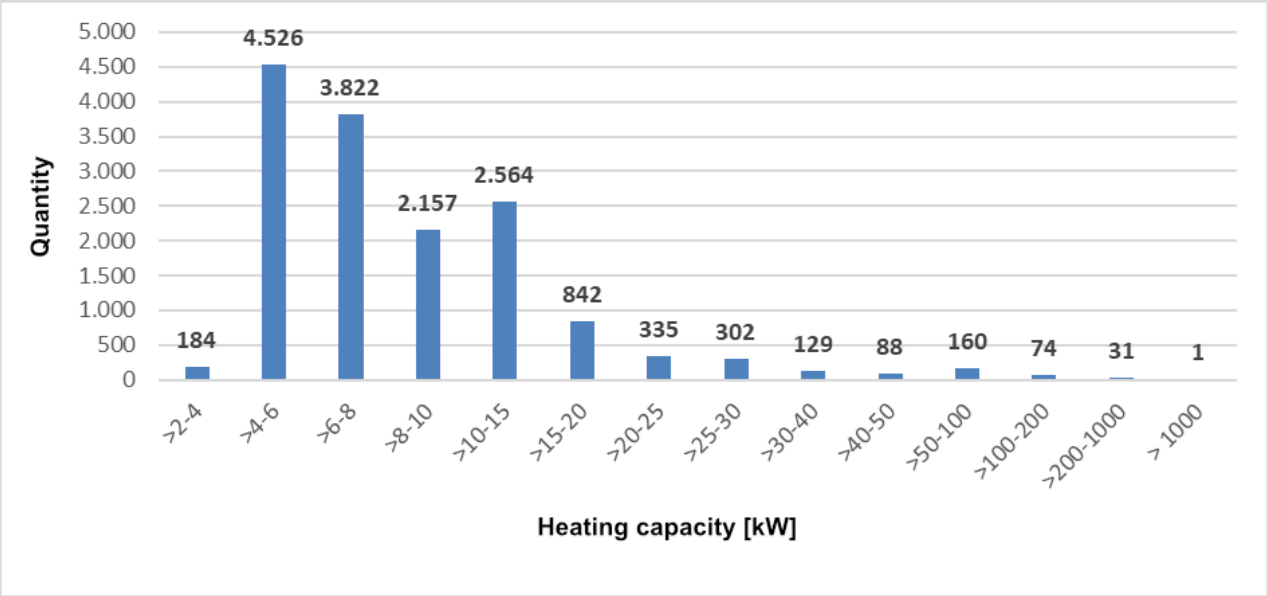


Figure 8. Frequency distribution of the power classes in Lower Saxony (2018-2024).

Figure 9 shows the development of installed geothermal systems with a heating capacity > 30 kW_{th} over the last few years. A clearly growing trend is emerging here.

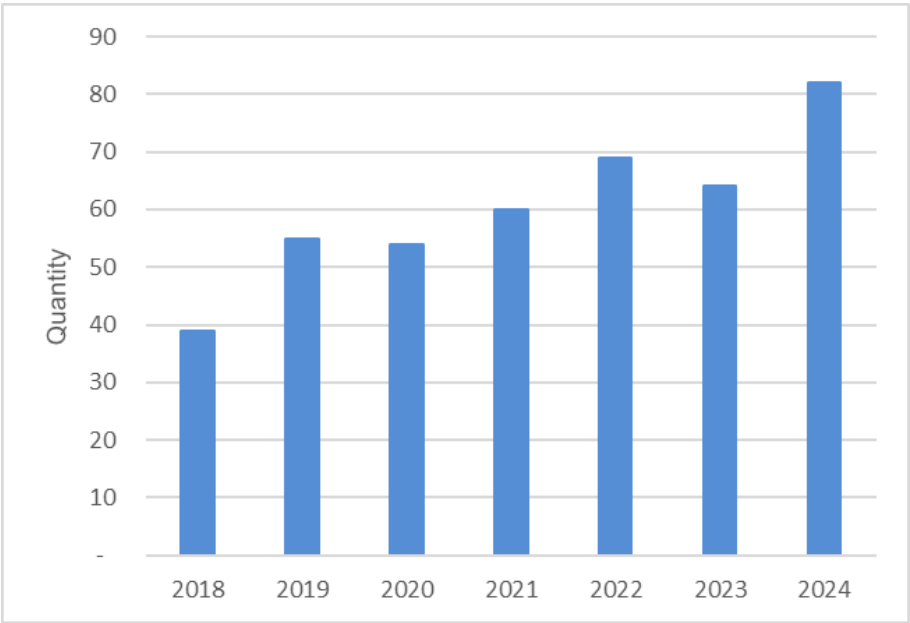


Figure 9. Development of installed geothermal systems with a heating capacity > 30 kW_{th} in Lower Saxony (2018-2024).

4 CONCLUSIONS

Reliable, comprehensive, digital data is essential in today's modern society. The example of the approval process for shallow geothermal energy shows how Internet-based forms and networking between different stakeholders can create added value for everyone involved. The digital application process in Lower Saxony has led to three main benefits:

1. Faster, easier and harmonised process for the applicants
2. Simplified processes for approval authorities thanks to standardised, complete applications
3. Availability of detailed data on geothermal energy use for policymakers, the public, and technical experts

The evaluation of the available data shows that the construction of geothermal plants has declined sharply in the last two years, after many years of steady growth. In typical new buildings in the single-family home sector, the use of ground-coupled heat pump systems is declining significantly. However, the data also clearly show that the systems built in recent years cover a higher heating capacity on average. Increasingly larger plants are driving the growth of renewable energy supply with geothermal energy. Geothermal systems for commercial purposes or public buildings were installed more frequently in the last years, and they were also significantly larger than previously. This is due to the growing influence of cold local heating networks as well as the change in commercial heating, which is increasingly using alternatives, such as near-surface geothermal energy, instead of the typical gas-powered combined heat and power plants. Due to limitations in space and noise protection in urban areas, shallow geothermal energy is one of the rare solutions that meet the requirements for a renewable energy source on the industrial demand. It supplies large amounts of energy, has low space requirement and is available all throughout the year and nearly everywhere. The evaluation options offered by the database presented here enable these developments to be identified at an early stage. This gives decision-makers in politics and business the opportunity to support and accelerate the market growth of shallow geothermal energy supply.

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