

Assessing geothermal potential by leveraging current infrastructure: A study for the Berlin–Brandenburg Area, Germany

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ABSTRACT

This study assesses the geothermal potential of the Berlin–Brandenburg region, with a particular focus on leveraging existing infrastructure, including legacy hydrocarbon wells and/or deep drilling boreholes, for sustainable heat and baseload electricity supply. Two representative areas, Groß Schönebeck site and Lusatia region, serve as examples of a regional strategy that combines technical and economic feasibility with existing regulatory frameworks. Findings highlight the potential of repurposing wells including district heating with multi-layer of reservoir development schemes for low- and medium-enthalpy geothermal applications and seasonal Underground Thermal Energy Storage (UTES). Drawing on the Groß Schönebeck case study, the value of reusing existing wells can be maximized by identifying multiple formations with different geothermal application pathways. The technical aspects should focus on the economic viability of using existing infrastructure to extend the productive life of hydrocarbon, mineral, and water wells, as well as geothermal wells. This would allow for the optimum utilization of formations, depending on their technical and economic suitability in relation to the geothermal utilization technology. In the other hand, the Lusatia case study reveals a successful approach to evaluating UTES potential by identification of geothermal resources (temperature and reservoir locations) combined with an understanding of regional heating demand and existing district heating infrastructure. Critically, the regional energy transition plan leverages government support for geothermal project investment, beginning with exploratory activities like 2D seismic surveys. This study, encompassing a larger regional area, addresses the significant investment costs and exploration risks inherent in geothermal development. While technical assessments and demonstrable demand establish economic viability at the micro-scale, broader implementation of geothermal projects, particularly those utilizing existing infrastructure, requires a robust regulatory framework and supportive local policies. These elements are essential catalysts for attracting investment, streamlining permitting processes, and mitigating initial financial risks, ultimately enabling the widespread adoption of geothermal energy.

1. INTRODUCTION

The energy transition in Germany is a broad shift towards renewable energy sources. It has been driven by laws such as the Climate Protection Act, which aims to achieve net-zero emissions by 2045, and the Renewable Energy Sources Act (EEG). The latter is driving the expansion of wind and solar energy within the country. Other recent key legislation includes the Building Energy Act (GEG), which stipulates that 65% of the energy used to heat newly built houses must come from renewable sources starting in 2024; the Energy Efficiency Act, which aims to drastically reduce energy consumption; the 2011 Amendment to the Atomic Energy Act, which aims to phase out nuclear power by 2023; and the Coal Exit Act (2020), which prescribes phasing out coal by 2030/2038. The ultimate goal is to achieve an 80% renewable energy supply by 2030, rising to 100% by 2050. These laws align with the European Union's broader climate strategy, including the EU Green Deal and the Fit for 55 packages, which aim to reduce emissions by 55% by 2030. This study, conducted within the TRANSGEO project (<https://www.interreg-central.eu/projects/transgeo/>), examines the geothermal potential of the Berlin–Brandenburg region. We focus on finding new uses for existing deep well infrastructure, including old hydrocarbon wells and boreholes, as well as the district heating network. Five geothermal technology applications providing sustainable heat and a steady supply of electricity shown in Figure 1: (1) Borehole Thermal Energy Storage (BTES), (2) Borehole Heat Exchanger (BHE), (3) Hydrothermal System (HE), (4) Aquifer Thermal Energy Storage (ATES), and (5) Enhanced Geothermal System (EGS). Two of these are particularly suitable for underground thermal energy storage (UTES): ATES and BTES. In Germany, the most widely used methods for extracting deep geothermal energy (at depths > 400 meters) are HE and BHE. On the contrary, EGS, BTES, and ATES are used far less frequently, mainly in research settings (BVEG, 2025). Two representative areas are used to inform a broader regional strategy for assessing geothermal potential: The Groß Schönebeck geothermal research platform and the Lusatia region, which historically depends on coal. This strategy is based on leveraging current infrastructure. The study identifies the potential for low- and medium-enthalpy geothermal applications, including district heating and seasonal thermal energy storage, by assessing a database of 2,974 well records from Brandenburg data repository and selecting promising wells for further evaluation of reuse. The study addresses key challenges related to well integrity, reservoir performance, and regulatory constraints. Our findings demonstrate the potential for scalable geothermal retrofitting in infrastructure-rich regions and contribute to a replicable, multidisciplinary framework supporting Germany's commitment to carbon neutrality.

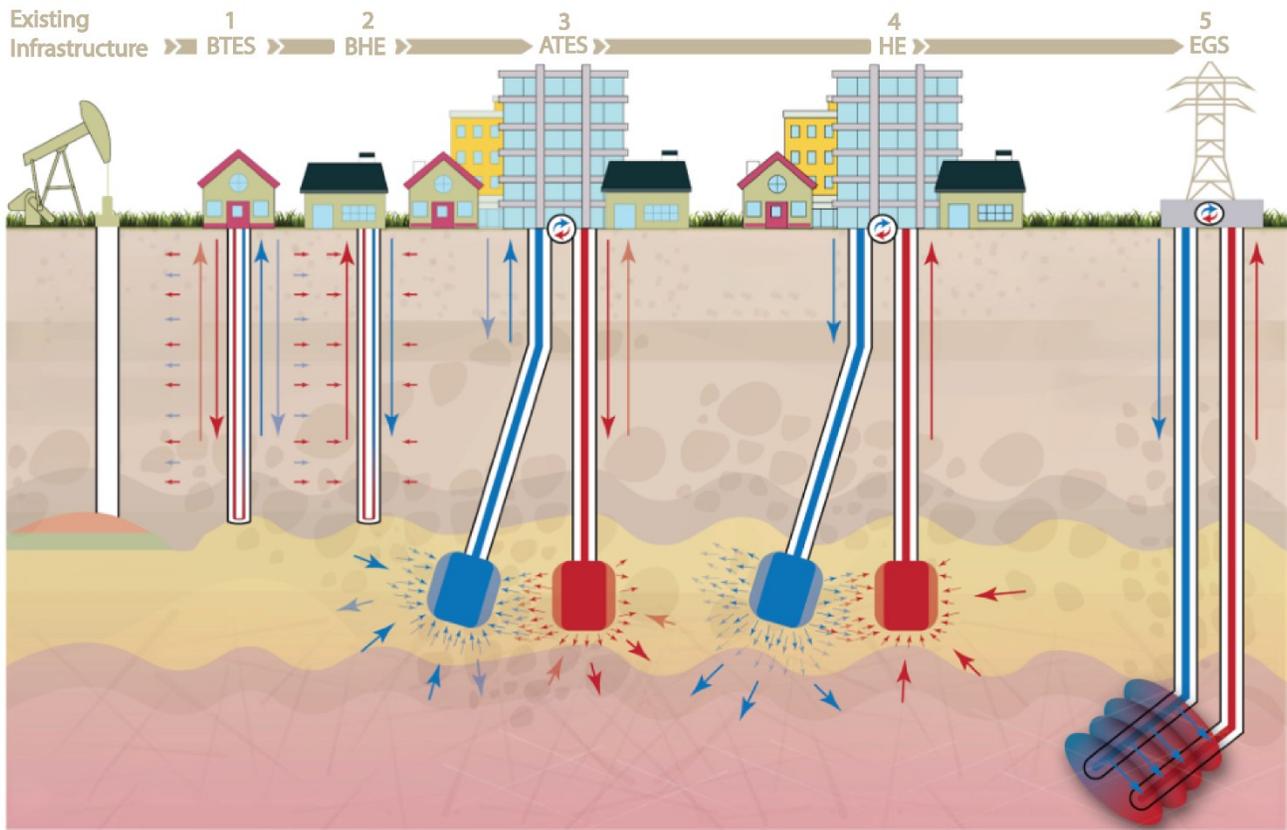


Figure 1: Five geothermal application technologies that can be used to leverage existing infrastructure for geothermal energy production (Modified from TRANSGEO Project, 2024 (<https://www.interreg-central.eu/projects/transgeo/>)).

2. STUDY AREA BERLIN-BRANDENBURG

The Berlin state, located in the northeastern part of Germany (Figure 2), is a metropolitan area of national significance. As Germany's capital city and largest urban center, Berlin serves as the seat of the government and a major cultural and economic hub. The state of Brandenburg is located adjacent to the Berlin state and shares a profound historical connection with its historic capital, Potsdam. The region has a rich legacy as the former heartland of Prussia and the Margraviate of Brandenburg. Historically, the region's robust energy infrastructure was largely supplied by Lusatia, which served as a critical coal-fueled power generation hub for decades. However, Lusatia is now undergoing a significant transformation, pioneering a transition away from traditional mining towards sustainable energy solutions and economic diversification. This presents both challenges and opportunities for the sustainable energy future of the entire Berlin-Brandenburg metropolitan area.

To date, the area has been trying to adopt geothermal energy as an alternative source for seasonal aquifer thermal energy storage (ATES) at the Reichstag in Berlin (Kranz and Frick, 2013), Neubrandenburg (Holstenkamp et al., 2017; Würdemann et al., 2014), and a new ATES research project in Adlershof by Geospeicher Berlin project (GFZ, 2025). A recent project in Potsdam, Brandenburg developed by utility company Energie und Wasser Potsdam (EWP) involved integrating a hydrothermal doublet in the city's district heating network which is now supplying heat to 340 apartments (Cariaga, 2025a). Another recent project involved successful drilling to a depth of 983 meter for a geothermal heating project in Prenzlau, Brandenburg. Testing was conducted in December 2025, and Stadtwerke Prenzlau GmbH intends to utilize thermal water at 44°C, boosted to 80°C with heat pumps, to supply 60% of the town's district heating needs, providing a total capacity of 4.5 MW (Cariaga, 2025b). In the Lusatia area, meanwhile, the majority of new geothermal wells were drilled for geothermal exploration (Gt BuC 1/1998, 1350 m MD) and shallow Borehole Heat Exchangers (BHEs) at around 100 meters. Highlighted by recent successful project in Potsdam and Prenzlau, geothermal energy has been gaining acceptance by local community and supported by the federal government under the Federal Funding Program for Efficient Heating Networks (*Bundesförderung für effiziente Wärmenetze / BEW*).

A study by Herpich (2024), based on the GENeSYS-MOD model, demonstrates that Berlin could achieve independence from fossil energy imports by 2050 through a transition to 100% renewable heat supply. Achieving this ambitious goal requires a rapid expansion of the city's renewable heat potential, with geothermal energy playing a crucial role. However, the inherent uncertainties associated with identifying viable geothermal resources present a significant risk to project success and investor confidence, a challenge that has historically hindered geothermal initiatives. To mitigate this exploration risk and potentially accelerate project development, leveraging existing infrastructure, such as well repurposing, offers a promising pathway, reducing reliance on high-risk subsurface exploration and enabling a more efficient assessment of geothermal potential.

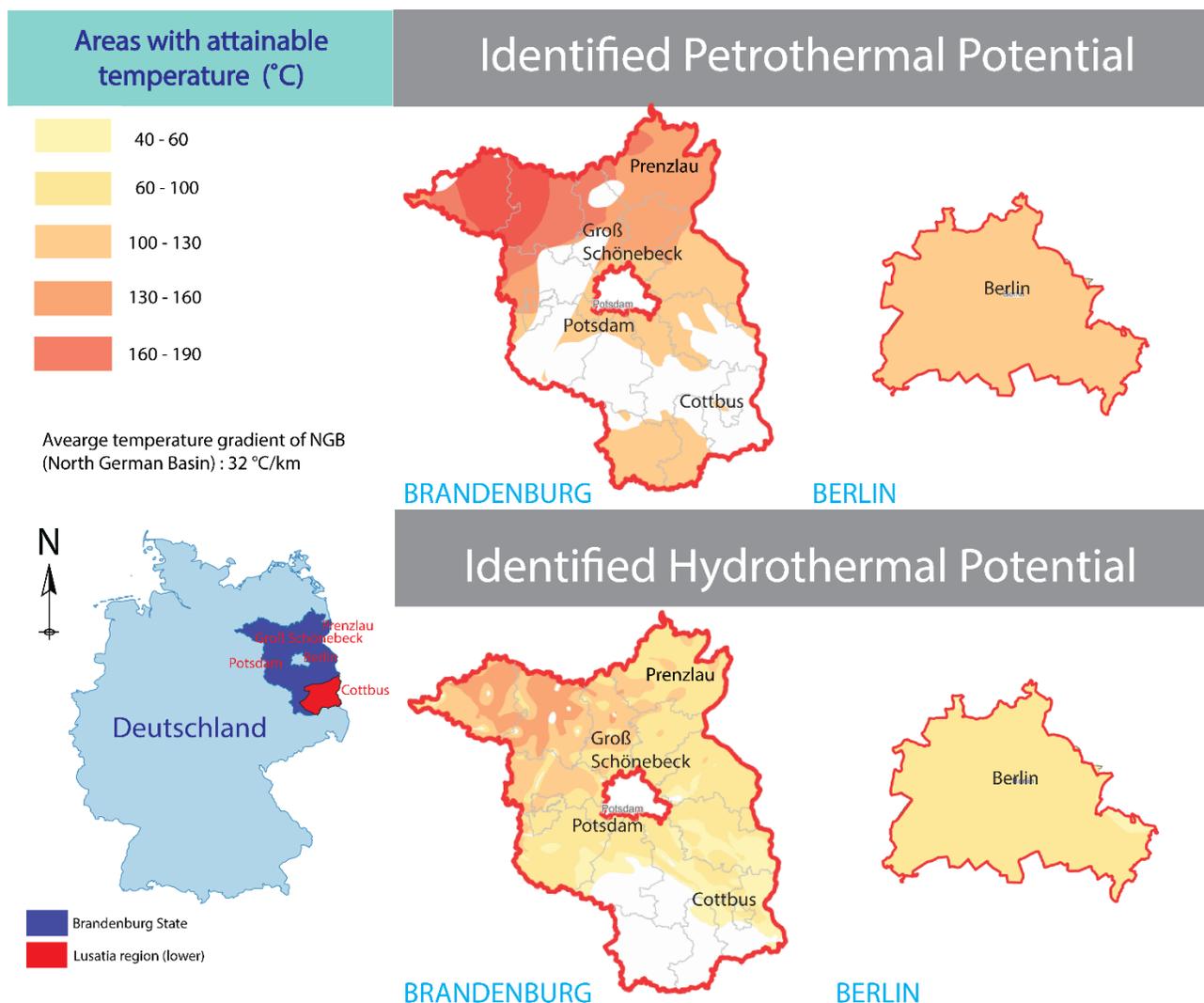


Figure 2: Location of Berlin-Brandenburg states and major cities discussed in this study (Modified from GEOTIS: <https://www.geotis.de/geotisapp/geotis.php>) (Accessed 01.01.2026).

Extensive exploration for raw materials during the era of the German Democratic Republic resulted in a dense network of approximately 2,974 deep boreholes with the depths greater than 400 m. While these boreholes were originally drilled for copper, iron and hydrocarbons, they now offer significant potential for low-enthalpy geothermal energy extraction. Before German reunification, all wells were state-owned. The majority of deep wells remain in state hands today. For instance, the state of Brandenburg owns all copper and iron exploration wells, as well as some oil and gas wells. However, this does not mean that these wells are accessible (most have been abandoned and the land has been revitalized). After 1990, some deep wells (especially oil and gas) were transferred to the private sector. Today, Neptune Energy is the largest private-sector operator of hydrocarbon wells in the area. Oil and gas production, however, ceased completely in Brandenburg a few years ago. Only two sites remain in Mecklenburg-Western Pomerania: Lütow and Mesekenhagen (BVEG Jahresbericht, 2024).

3. METHODOLOGY

3.1 Well assessment using TRANSGEO IT tool

The well assessment was evaluated for five technologies, with borehole and reservoir parameters consolidated through the report on the transnational repurpose potential in Central Europe within the TRANSGEO project (Hölzel et al., 2025). As described in the TRANSGEO IT Tool (<https://transgeo.eu/>) description deliverable (Fedor et al., 2025), the catalogue reviews and assesses the conditions that may influence the geothermal reuse of currently active or idle wells from the existing and abandoned wells, and defines the related concepts and their feasibility. Feasibility encompasses market, technological and geological conditions, as well as associated risks in these areas. The most significant technical aspects for the well assessment that were considered for the evaluation of the suitability existing wells and reservoirs for reuse with different geothermal technologies are described in Table 1. The well database provided by the TRANSGEO project covers the North German Basin (NGB), which belongs to Central Europe (Hölzel et al., 2025). It is accessible via the IT tool. The NGB area, defined in this study, is divided into three sections: Mecklenburg-Western Pomerania (Mecklenburg-Vorpommern), Brandenburg, and Saxony-Anhalt (Sachsen-Anhalt), which were all states of East Germany. The Mecklenburg-Western Pomerania

database contains information on 630 wells. Meanwhile, the Brandenburg database contains information on 1,127 wells, and the Saxony-Anhalt database contains information on 1,385 wells. No well-test results were integrated in this database. During the handling of data for neighboring states, some wells from Mecklenburg-Western Pomerania were found in the Brandenburg database (GeoDaB of LBGR Brandenburg), and vice versa with a total of 3,107 wells for which data was collected. In this study, the well assessment is scrutinized specifically for Berlin-Brandenburg area.

Table 1: Wellbore and reservoir characteristics were developed for the purposes of well assessment. Please note that the criteria for each technology were established based on a literature review conducted as part of the TRANSGEO project (Hofmann et al., 2025; Fedor et al., 2025).

Technology	EGS	HE	DBHE	BTES	ATES
Application	Electricity/Heating			Storage	
Wellbore Parameters					
Well status	Active (Production), Shut-in (Idle), Partially sealed, P&A (Abandoned)		Active (Production), Shut-in (Idle), Partially sealed		Active (Production), Shut-in (Idle), Partially sealed
Downhole temperature	90°C	35°C	20°C	100 °C	any
Depth	>1000 m	> 400 m			
Reservoir Parameters					
Porosity	< 10%	> 30%	any	any	> 30%
Permeability	< 10E-14 m ²	> 10E-12 m ²	0 - <10E-14 m ²	0 - <10E-14 m ²	< 10E-14 m ²
Water flow rate (reservoir fluid)	< 10 l/s	> 10 l/s	Not important	Not important	> 100 (>50) l/s
Productivity Index	< 10 l/s/MPa	> 10 l/s/MPa	Not important	Not important	>10 l/s/MPa
Minimum casing diameter (inch)	>=7				
Impermeable layers/formation	Not important	Not important	Not important	Not important	Important
Reservoir thickness	Not important	>10 m	Not important	Not important	> 10 m

3.2 Well assessment based on the economically viable geothermal reservoir and repurposing technology

Following the GDR state mapping drilling program (1953–1967), core samples were extracted from across Brandenburg, particularly from the Triassic and Jurassic periods. These samples are held at the Wünsdorf core repository of the Brandenburg State Office for Mining, Geology and Raw Materials, and provide valuable insights into aquifer differentiation. They also offer a detailed stratigraphic classification of the Triassic and Jurassic periods, during which time massive amounts of sediment were deposited. Göthel (2006) and Feldrappe (2008) have described the characteristics of aquifers in the Berlin-Brandenburg region in chronological order. Notably, boreholes drilled in Brandenburg and Berlin between 1985 and 2001 for the exploration of thermal water and geothermal energy provided important new bio-stratigraphic data (Göthel, 2006). As described by Feldrappe et al. (2007), the following criteria were used for classification as a geothermal aquifer (cf. Wormbs et al., 1992). The temperature should be between 40°C and 100°C or higher, which can be expected at a depth interval of about 1000-3000 m. An assumed minimum production rate of 14 l/s requires an aquifer thickness of at least 10 – 15 m and an effective porosity of more than 20%, preferably 25%. The permeability of the rock should exceed the minimum value of 0.25-05 Darcy.

According to Göthel (2006), economically viable aquifers suitable for geothermal energy production within the suprasalinar region, the layers of rock above the Zechstein salt deposits, are primarily found in porous formations. These formations are capable of holding and transmitting fluids like hot water (Table 4). This classification of potential geothermal reservoirs was established through a detailed biostratigraphic analysis of data obtained from wells Gt Nn 2/87 and Kb Su 1/63. Currently, permeable Lower Muschelkalk aquifers and fractured Muschelkalk above salt structures are considered to have limited economic potential. However, they may become viable resources in the future due to technological advancements or changing energy demands. Conversely, Upper Muschelkalk karst aquifers found in the Upper Rhine Graben and Malm formations of southern Germany, while economically significant in those regions, are lithologically distinct and therefore not considered relevant to the geothermal potential of Brandenburg. Building upon this foundational understanding, Feldrappe et al. (2007 & 2008) identified the most significant horizons suitable for geothermal storage provided in Table 2.

The Rotliegend formation, which is a potential petrothermal system that spreads throughout the North German Basin, is one of the most targeted reservoirs for hydrocarbon exploration. The Rotliegend formation itself consists of quartz-dominated sandy deposits that represent one of the geothermal reservoir targets (Norden et al., 2023) and the Elbe base sandstone (EBS) (Bauer et al., 2020). The Elbe base sandstone (EBS) is a well-pronounced, porous sandstone found at the bottom of the Elbe subgroup. It is distributed in the marginal areas of the northeastern German Basin (Gast et al., 1998; McCann, 1998). In the E GrSk 3/90 well, the EBS is encountered between 4060 m and 4100 m depth where it shows low, only weakly varying Gamma ray values and decreased P-wave velocity in the sonic log. Open

hole logs show that the EBS is characterized by low gamma ray values and a high quartz content. Additionally, reduced P-wave velocities, as determined by sonic logging, suggest an increase in porosity (Trautwein & Huenges, 2005). These two observations explain the general interest in the EBS as a geothermal target. In Groß Schönebeck, it hosts water at a temperature of around 150 °C, with an initial Productivity Index (PI) of 0.97 m³/h/MPa, and a permeability of no higher than 5 mD (Huenges, 2002).

Table 2: Economically viable aquifers suitable for geothermal energy production in Berlin-Brandenburg.

Göthel (2006)	Feldrappe et al., (2007 & 2008)
<ul style="list-style-type: none"> • Middle Buntsandstein (Volpriehausen and Detfurth formations) • Upper Keuper (Contorta sandstone) • Lias (Pilsdonot, Lotharing, Hettang and Domer sandstones) • Dogger (Aalen sandstone) • Lower Cretaceous (Neocom sandstones) • Paleogene: Rocks from the Paleogene period also exhibit potential as geothermal reservoirs, contributing to the overall resource base. 	<ul style="list-style-type: none"> • Middle Buntsandstein sandstones • Schilfsandstein (Stuttgart Formation/Middle Keuper) • Rhaetian/Lias aquifer complex (Upper Keuper to Lower Jurassic) • Aalenian sandstone (Middle Jurassic) • Lower Cretaceous sandstones (Wealden, Valanginian and Hauterivian) • Minor geothermal aquifers such as: Hauptlettenkohle sandstone (Lower Keuper), Toarcian sandstones (Lower Jurassic), Bathonian and Bajocian sandstones (Middle Jurassic), Upper Cretaceous sandstones and coral oolite (Upper Jurassic), and the Pelitröt sandstone of the Upper Buntsandstein.

The second formation with high thermal conductivity and petrothermal potential is the Zechstein formation. In hydrocarbon systems, salt acts as an impermeable sealant, meaning idle wells often intersect long salt zones (Grunau, 1981; Jin et al., 2006; Liu et al., 2017). Due to extensive salt tectonics in the NGB, the thick Zechstein salt layer is deformed into salt pillows, salt domes, and salt diapirs. As described by Fromme et al. (2010), vertical salt structures with high thermal conductivity efficiently discharge heat from depths to shallow formations by conduction, thereby leading to positive thermal anomalies above the salt structures. This effect is also known as the 'chimney effect' and is based on high thermal conductivity of salt (Jensen, 1983; Fromme et al., 2010; Noack et al., 2010; Kaiser et al., 2011; Balling et al., 2013; Sippel et al., 2013; Koltzer et al., 2024). Consequently, the increased temperature potential within and above these structures can be exploited using closed-loop systems. These features characterise the deep subsurface of the North East German Basin (NEGB) (Fromme et al., 2010) and render idle hydrocarbon wells promising candidates for geothermal conversion with closed-loop systems (Koltzer et al., 2024; Christi et al., 2026).

This study evaluated the feasibility of accessing economically viable geothermal reservoirs through deep wells. Interpretation of seismic data identified reflectors corresponding to a specific formation horizon, which was consistent with the results of the drilling. Data on penetrated aquifers are from "Geothermische Ressourcenberichte" Diener et al. (1988, 1990, 1990a, 1990b, 1991, 1992). For the Lower Cretaceous, the base of the "Deutsches Wealden," "Hauterive," and "Barreme" formations were used; for the Aalen formation, the base of the Aalen formation; for the Rhaetian-Lias formation, the base of the Lias formation and the base of the Rhaetian formation in the northwesternmost part of Brandenburg; for the Schilfsandstein formation, the base of the Schilfsandstein formation; and for the Middle Buntsandstein formation, the base of the Dethfurt formation. These were used to determine the depth of penetration. For the deeper Zechstein formation, the X1 reflector was used as the marker for the top of the Zechstein, and the Rotliegend formation or "Oberrotliegend II" (R6 reflector), was used from the B3D model (Jahnke et al., 2024). However, all oil and gas wells reach the Staßfurt formation (carbonate) within the Zechstein formation.

4. RESULTS

4.1 Well assessment results using TRANSGEO IT Tool

According to the regional assessment employing the TRANSGEO IT tool (Hölzel et al., 2025) for the expansive North German Basin area in eastern Germany (Table 3), the predominance of existing wells drilled after 1990 are deemed suitable for DBHE, HE, and BTES. EGS and ATES technologies are subsequent in this assessment, with a total of 210 existing wells evaluated for their potential to be repurposed. Conversely, the wells classified as uncertain in terms of category reside within the ATES and HE suitability limits, while DBHE, BTES, and EGS exhibit comparatively minimal performance. The substantial potential for the repurposing of oil and gas wells is primarily attributable to the fact that the majority of oil and gas wells have reached the Zechstein formation. By reaching the Zechstein, these wells are suitable to be repurposed as DBHE (Koltzer et al., 2024; Christi et al., 2026) or BTES. Additionally, wells that have reached the Rotliegend reservoir can be repurposed as an EGS injection well (Christi et al., 2025e). In addition, the presence of several potential hydrothermal reservoirs for HE and ATES has been identified. The necessity of deepening the wells or sidetracking them is contingent upon the depths of reservoirs penetrated by the wells. This will facilitate access to the potential hydrothermal reservoir, which has substantial permeability and flow rates, as described in Table 1. Conversely, there is a possibility that the access to the reservoir is partially sealed (partially sealed well), in which case it will be necessary to reopen the well. These factors contribute to the categorization of the wells as "uncertain" in terms of technology implementation. In light of the broad nature of the initial results, a more thorough approach was employed to delineate the area encompassing the Berlin-Brandenburg states. This entailed the consideration of the economically viable formations to be explored in the existing wells in addition to one single technology option.

Table 3: Numbers of reusable wells for the 5 geothermal methods in the Central Europe part of the North German Basin based on all available wells (drilled after 1990) in the TRANSGEO database (Hölzel et al., 2025).

North German Basin	EGS	HE	DBHE	BTES	ATES
Suitable	22 (0.5%)	52 (2.4%)	72 (1.7%)	50 (1.7%)	14 (0.7%)
Uncertain	9 (2.9%)	32 (0.4%)	12 (0.1%)	4 (1.1%)	87 (0.3%)
Not suitable	2873 (96.6%)	2890 (97.2%)	2920 (98.2%)	2890 (97.2%)	2943 (99.0%)

4.2 Well assessment results based on the economically viable geothermal reservoir and repurposing technology

The assessment of wells drilled after 1990, was conducted to narrow down the number of potential wells to the ones that encounter at least two or more geothermal reservoirs in Berlin-Brandenburg states. As illustrated in Figure 3, the findings disclose the nature of the well (hydrocarbon, geothermal, or other), its depth, and the formations penetrated by the well. A total of 24 wells satisfied the necessary criteria for inclusion in this assessment. As demonstrated in Figure 4, the location of the wells is illustrated in relation to the wells indicated in Figure 3. The potential for the utilization of the wells in the near term is indicated by white bullets, while those that are excluded are denoted by red bullets. The wells excluded from this analysis are those that are currently in use. The majority of these are geothermal wells used for thermal spas (Gt Nn S 1/2006, Gt Nn S 2/2006, Gt Wlk 1/1996, Gt Tp 1/1995, Gt BuC 1/1998) or for research purposes (E GrSk 3/1990 and Gt GrSk 4/2005). The remaining wells exhibit either a single potential formation (E Bres 2/1991) or are located at a depth of less than 300 meters. It has been determined that a depth of 300 meters is at which the geothermal reservoir's temperature is not conducive to economic geothermal potential (Hy Gzi 1/1996, Cu Sp 136/2009, Cu Sp 131/2009).

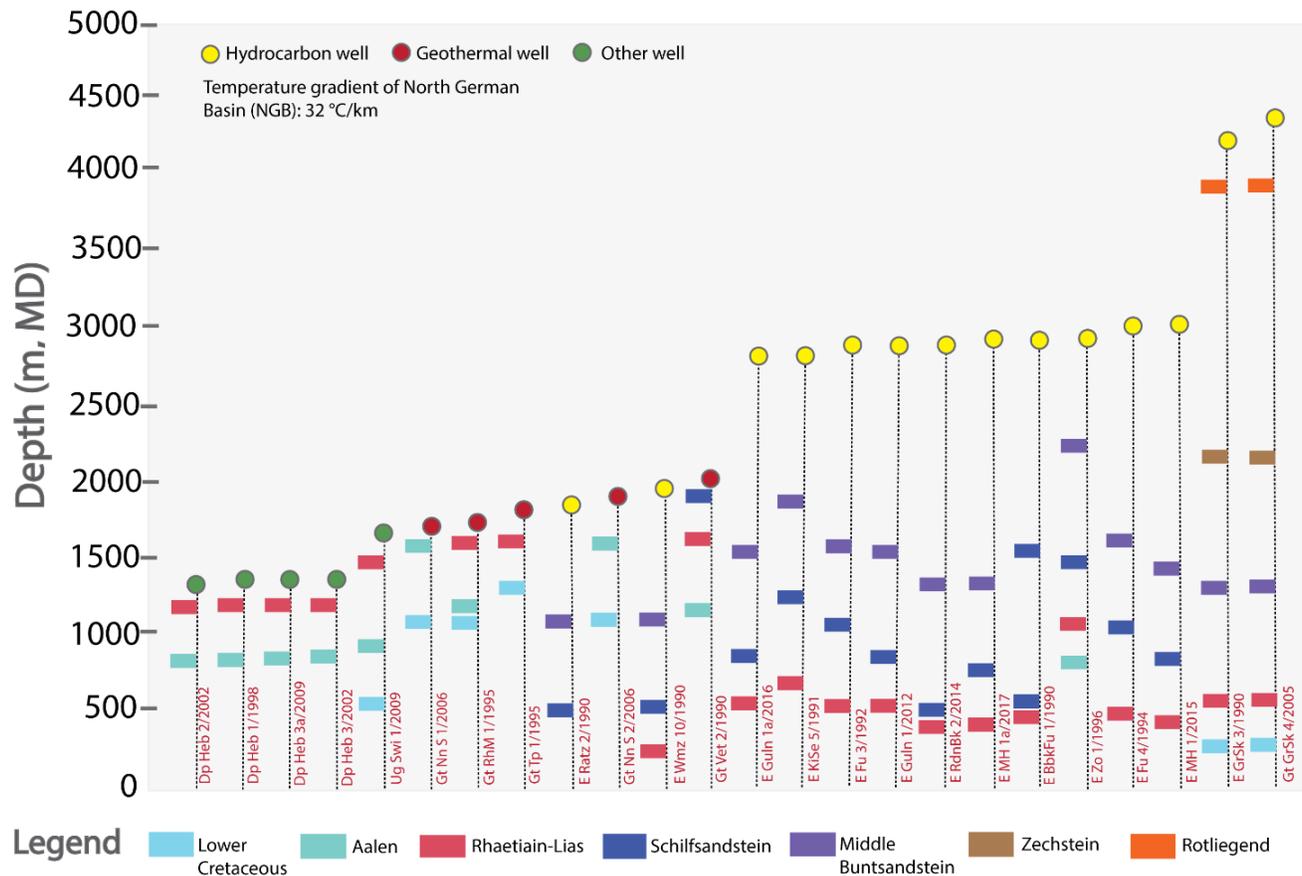


Figure 3: The existing wells, their types and depths, as well as the depth of each potential geothermal reservoir associated with each well. Source: well database “GeoDaB” of LBGR Brandenburg.

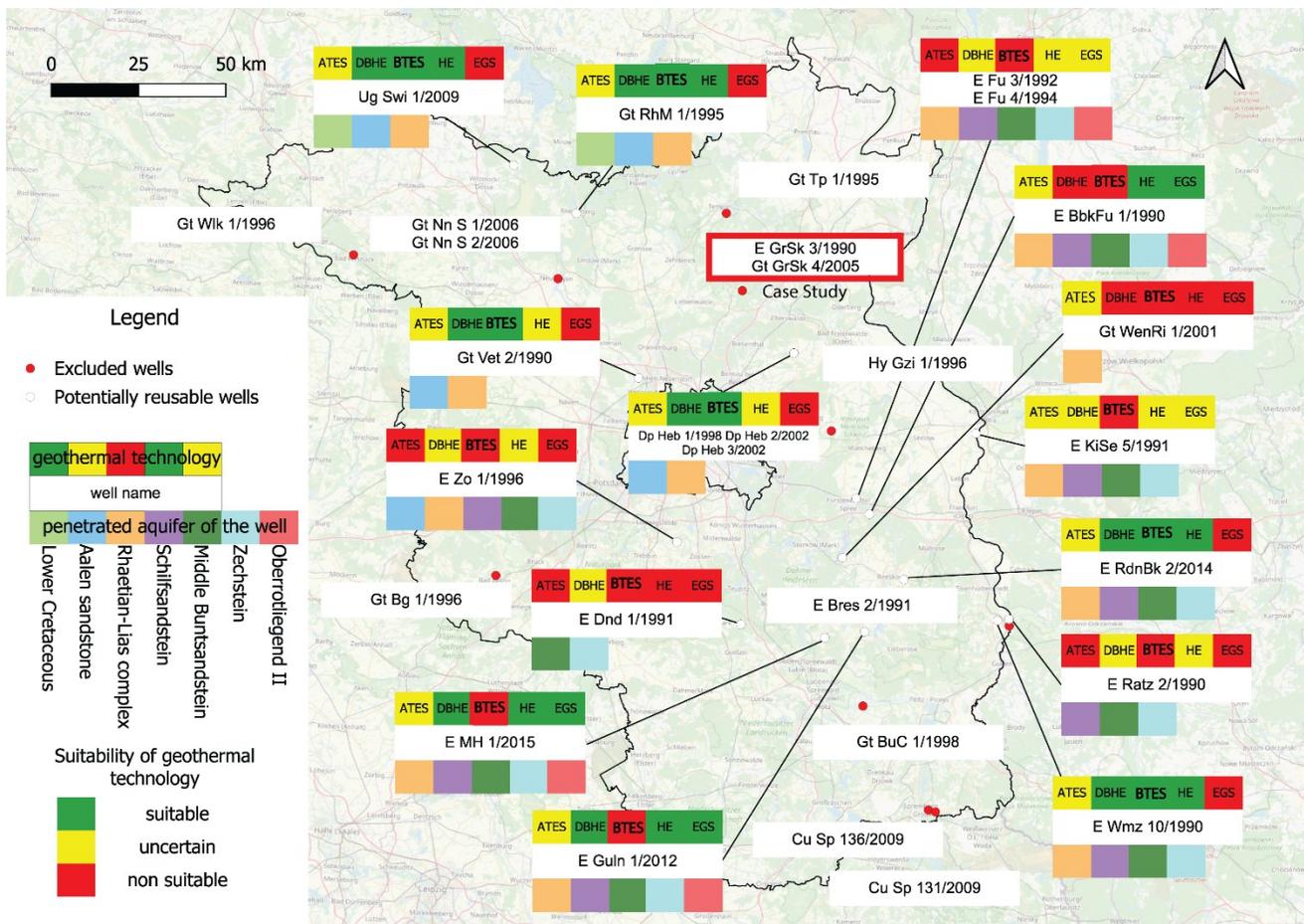


Figure 4: The location of wells is indicative of the near-term potentially reusable wells, the associated economically viable geothermal reservoir, and the suitable geothermal technology assessed in this study. Source: well database “GeoDaB” of LBGR Brandenburg and TRANS GEO IT tool.

5. GEOTHERMAL RESOURCE EVALUATION STRATEGY BY LEVERAGING EXISTING INFRASTRUCTURE

5.1 Geothermal resource evaluation based on sub-surface characteristics

The geothermal resource evaluation strategy was based on knowledge directly transferred from the Groß Schönebeck geothermal research platform. As detailed in the Groß Schönebeck feasibility study (Christi et al., 2025a, 2025b), multiple retrofitting pathways were established for different geothermal reservoir types (Figure 5). The site's first deep well, E GrSk 3/90, was originally drilled in 1990 for gas exploration, targeting the Rotliegend reservoir. Despite the lack of hydrocarbons, the well had a bottom-hole temperature of 149 °C at 4,240 m MD, establishing Groß Schönebeck as a promising deep geothermal test site in north-eastern Germany. Subsequently, a geothermal well was drilled as a well doublet, designated Gt GrSk 4/05 (A2). The study was developed using reservoir models for two main technological approaches: Enhanced Geothermal Systems (EGS) and Deep Borehole Heat Exchange (DBHE) systems. A third option involves utilising the existing deep wells for exploration and monitoring to support medium-depth hydrothermal resource development.

For the EGS-based approach, which was studied by Christi et al. (2025e) as the first pathway, the study proposes converting the Gt GrSk 4/05 (A2) well into an injection well. This would involve sidetracking the 13.375" casing at a depth of 2,116–2,200 meter. This approach is supported by recent accessibility tests and the available surface area, which minimizes the need for civil engineering works. However, the presence of corrosion in the casing and liner necessitates the verification of its mechanical integrity and the development of a completion strategy with respect to the clogging issue, thereby avoiding the use of carbon steel. While EGS remains a high-potential option for accessing the Rotliegend formation with sufficient thermal energy and temperature output for electricity generation, there is still uncertainty regarding fracture sustainability, the efficiency of multi-fracture stimulation, scaling and clogging risks, and long-term thermal performance. To date, no successful EGS demonstration has been carried out in the Rotliegend formation, except for an early matrix-dominated concept in Groß Schönebeck. Due to these unresolved technical uncertainties, a reliable economic assessment cannot yet be provided and further research and demonstrations are necessary. The current evaluation concluded that EGS development is still in the process of maturing the technology to enable commercial-scale development. Reducing drilling costs and achieving a suitable completion that can withstand the high salinity of the Rotliegend reservoir fluid, which is characterized by temperatures of 150 °C and

salinities of 280 g/l (Lehmann, 1974a, b; Naumann, 2000), is key. This would enable access to these resources at a depth of 4 km, with the horizontal well extending far enough to create a multi-stage fracture system.

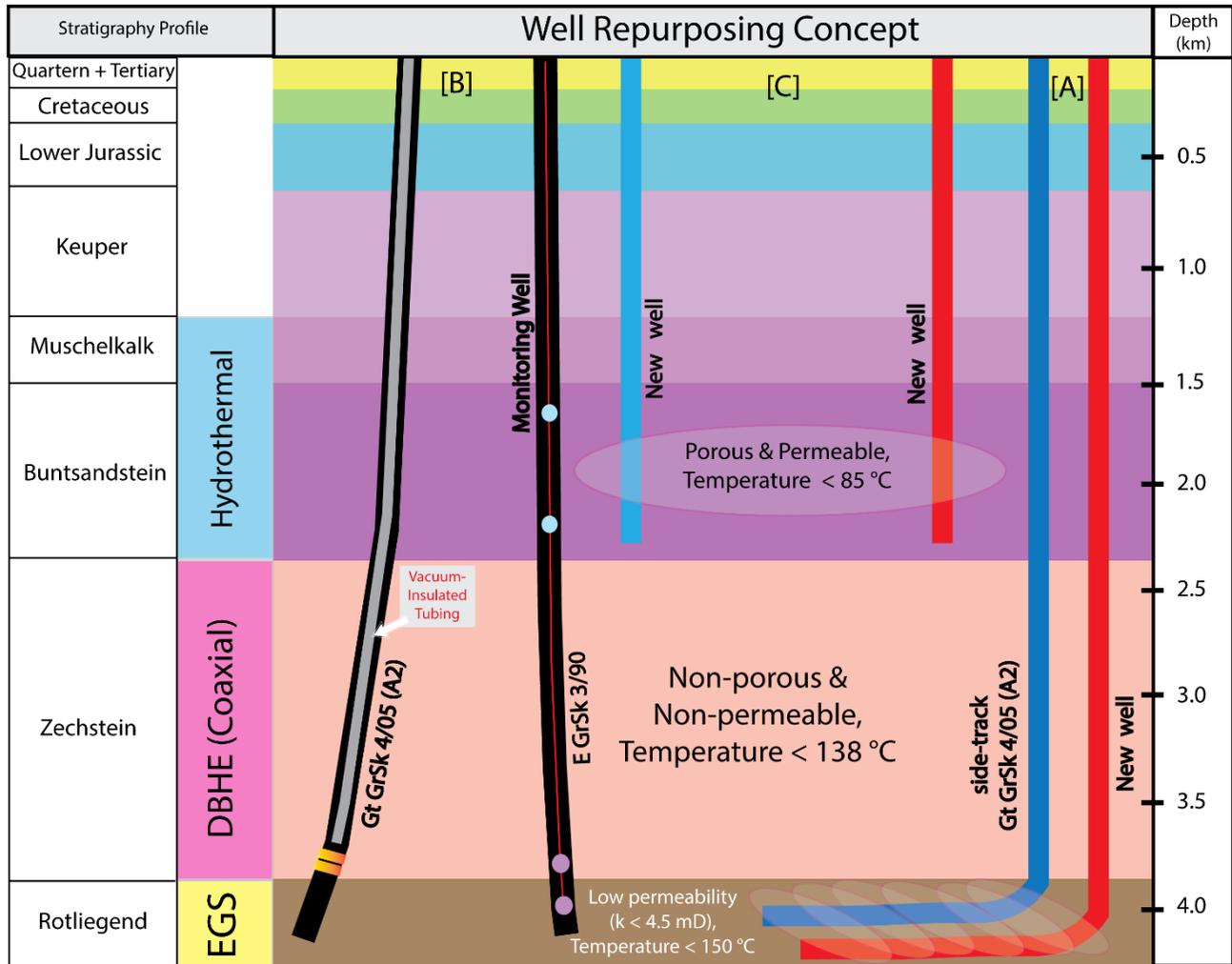


Figure 5: Potential well repurposing concepts at the Groß Schönebeck site. [A] Repurposing the Gt GrSk 4/05 (A2) well as an EGS injection well; [B] Repurposing an existing well to serve as a coaxial DBHE system; [C] Repurposing an existing well for use as a monitoring well for medium-depth hydrothermal resource development (Christi et al., 2025a).

A second pathway is the DBHE concept studied by Christi et al. (2026, 2025d), which offers a nearer-term deployment option with lower exploration risk. The site demonstrates a high level of suitability for closed-loop heat extraction, attributable to two key factors. Firstly, the bottom-hole temperature of 137°C at a depth of 3,800 m MD. Secondly, the 1.5-kilometer-thick Zechstein formation. Simulations show that, by using vacuum-insulated tubing with a thermal conductivity of less than 0.06 W/m/K and inlet temperatures between 10 and 25 °C, outlet temperatures of 49 – 67 °C can be produced over 30 years. This would yield 500 – 750 kW of thermal power at flow rates up to ~26 m³/h. Further evaluation of insulation performance, the thermal conductivity of formation materials and long-term well integrity is required to ensure reliability and cost-effectiveness. This approach is particularly attractive where district heating demand is established or where nearby consumers exist. The third pathway involves repurposing the existing deep wells as monitoring infrastructure (Christi et al., 2025a, 2025b). This would enable seismic and pressure monitoring, as well as fiber-optic-based reservoir surveillance. This significantly reduces exploration risk and increases investor confidence. Exploration costs can be reduced by drilling a new exploratory well to develop a hydrothermal system that targets the Muschelkalk and Buntsandstein formations around the local salt structure.

Drawing on the Groß Schönebeck case study, the value of reusing existing wells can be maximized by identifying multiple formation layers with different geothermal application pathways. The technical aspects should focus on the economic factor of using existing infrastructure to extend the productive life of hydrocarbon, mineral and water wells, as well as geothermal wells. This would allow for the full utilization of layers, depending on their technical and economic suitability in relation to the five geothermal utilization technologies. A cost-benefit analysis would then be worthwhile for a well with multiple geothermal application possibilities. This would take into account the investment costs involved, the complexity of the required workover, and the need for exploration and operational permits, as well as legal liability with regard to ownership of infrastructure assets.

5.2 Geothermal resource evaluation based on surface characteristics

The case study is based on the study conducted in the lower Lusatia region (Christi et al., 2025c). The Brandenburg part of Lusatia, centred on the city of Cottbus with a population of approximately 100,000 (Figure 1), is a regional hub in eastern Germany. It is located 124 km southeast of Berlin. The region is actively embracing the energy transition, having already taken early steps to implement geothermal technology, particularly through shallow Borehole Heat Exchanger (BHE) systems. In line with the regional energy transition plan, the Lusatia region is undergoing major structural changes as a result of the political decision to phase out coal-fired power generation. The region is also developing renewable energy sources, including solar and wind power. Floating solar panels with a capacity of 29 MW and onshore wind turbines have been installed in and around the Cottbuser Ostsee lake area. The existing district heating infrastructure around the city of Cottbus, originally developed during the German Democratic Republic (GDR) era using locally sourced lignite, is crucial for phasing out coal and achieving decarbonisation goals. Characterised by a strong tradition of municipal ownership and an increasing presence of private and cooperative entities, these systems offer a practical pathway for integrating renewable energy sources (Konstantin, 2018). Throughout the decades, Lusatia has undergone exploration for a variety of additional resources, including hydrocarbons, copper, and uranium. In this particular instance, these resources (Figure 6) were utilised to facilitate geothermal resource identification within the region manifested in regional temperature distribution information (Agemar, 2022; Agemar et al., 2012).

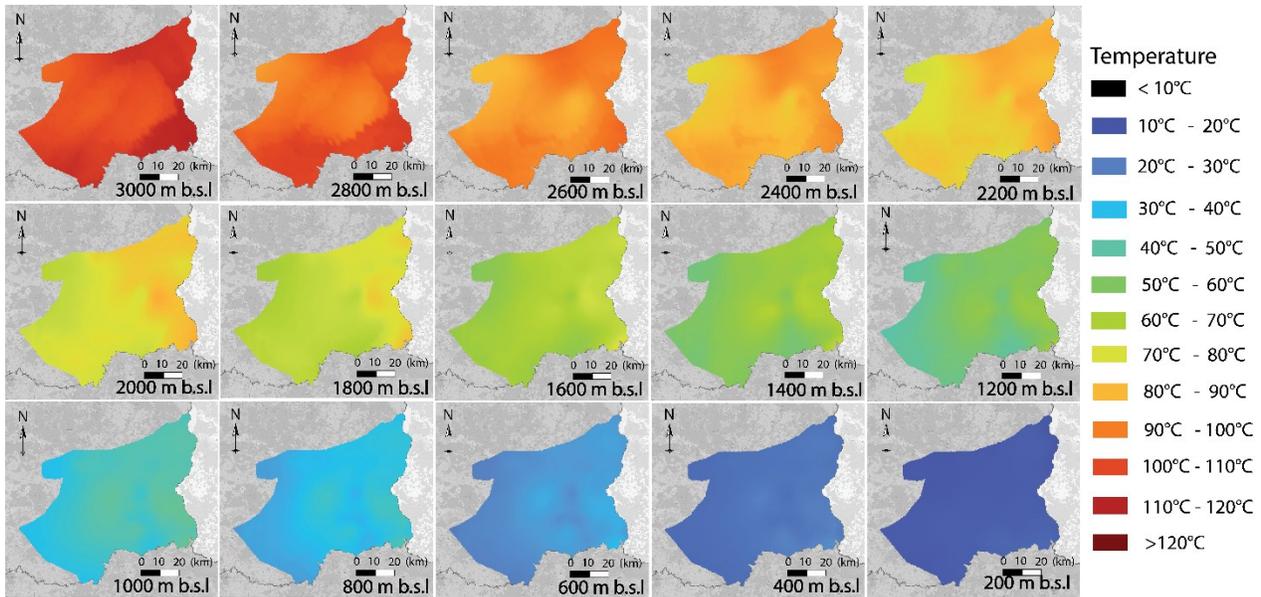


Figure 6: Temperature distribution in Lusatian region. (Christi et al., 2025c. Modified from GEOTIS: <https://www.geotis.de/geotisapp/geotis.php>). (Accessed December 2024).

The study conducted by Christi et al. (2025c) examined the demand perspective and the significant, rapid transition of energy supply from coal to renewable energy due to coal phase-out planning. The motivation for this study was the necessity for thermal storage with a minimum capacity of 150 MW_{th} thermal energy for the city of Cottbus. This is particularly pressing given the absence of deep, high-temperature, and high-permeability geothermal reservoirs in the area. The identification of a potential site for UTES in the Lusatia region was predicated on a convergence of geological, infrastructural, and strategic factors of renewable energy integration with solar and wind power as the major renewable energy source supply at the moment. It is imperative to acknowledge that the site's selection is strategically advantageous due to its close proximity to the Jänschwalde power plant site and the Heating Power Plant Cottbus (HKW GmbH site). These locations, as shown in Figure 7, represent a substantial heat source, a crucial element for the effective integration of UTES. Furthermore, the presence of an operational district heating network in the city of Cottbus (HKW GmbH site) provides a pre-existing heat distribution infrastructure, thus obviating the necessity for extensive and costly pipeline development. Supporting this infrastructural advantage is comprehensive analogue well data, exhibiting both substantial depth penetration and complete stratigraphic profiles. Data from wells E Bres 3/89, E Gu 12H/64, E Tau 101/65, and E Lka 6/79 confirm the presence of economically viable aquifer formations, specifically the Middle Buntsandstein, Volpriehausen, and Detfurth formations, at depths conducive to the efficient operation of UTES. At this juncture, optimization efforts are focused on minimizing the distance between the Jänschwalde power plant and key supply points within the district heating network, this distance represents a pivotal parameter in determining the optimal location for the storage facility, balancing heat transfer efficiency with network integration costs. The proposed location is situated within the LEAG master plan area, ensuring alignment with regional energy strategy and facilitating potential synergies with existing energy infrastructure.

The Brandenburg Ministry of Economic Affairs has commissioned the Landesamt für Bergbau, Geologie und Rohstoffe (LBGR) to conduct an initial 2D seismic survey of lower Lusatia, as announced by the LBGR. This will involve examining the subsurface from a geothermal perspective. Seismic survey is a methodology that has been proven to reduce uncertainty, particularly when selecting locations for further drilling based on the suitability of the geothermal application. As illustrated in Figure 7, the seismic survey's location corresponds to the potential UTES location in the region, as determined by the presence of surface infrastructure. However, there is a necessity to reduce the uncertainty surrounding the basement depth (Zechstein and Rotliegend formations) in the area. Additionally, there is a need to consider specific potential minor formations for underground storage, such as the Volpriehausen and Detfurth formations,

which are located within the Middle Buntsandstein formation. The present feasibility study endorses the area earmarked for the seismic survey, which corresponds to the area under investigation for geothermal energy use between Cottbus and Guben. The results of the seismic survey are pivotal in comprehending the subsurface geology and mitigating investment risks for a novel drilling strategy in the area. These results appear to justify progressing to the subsequent stage, which is to quantify the potential of the geothermal resources and determine the initial investment required to develop geothermal energy in the region. The Lusatia case study demonstrates that a multidisciplinary approach, supported by proactive policy, is essential for establishing geothermal energy as a reliable alternative. The local government's initiative to mitigate exploration risk is indicative of a strong commitment to advancing the energy transition.

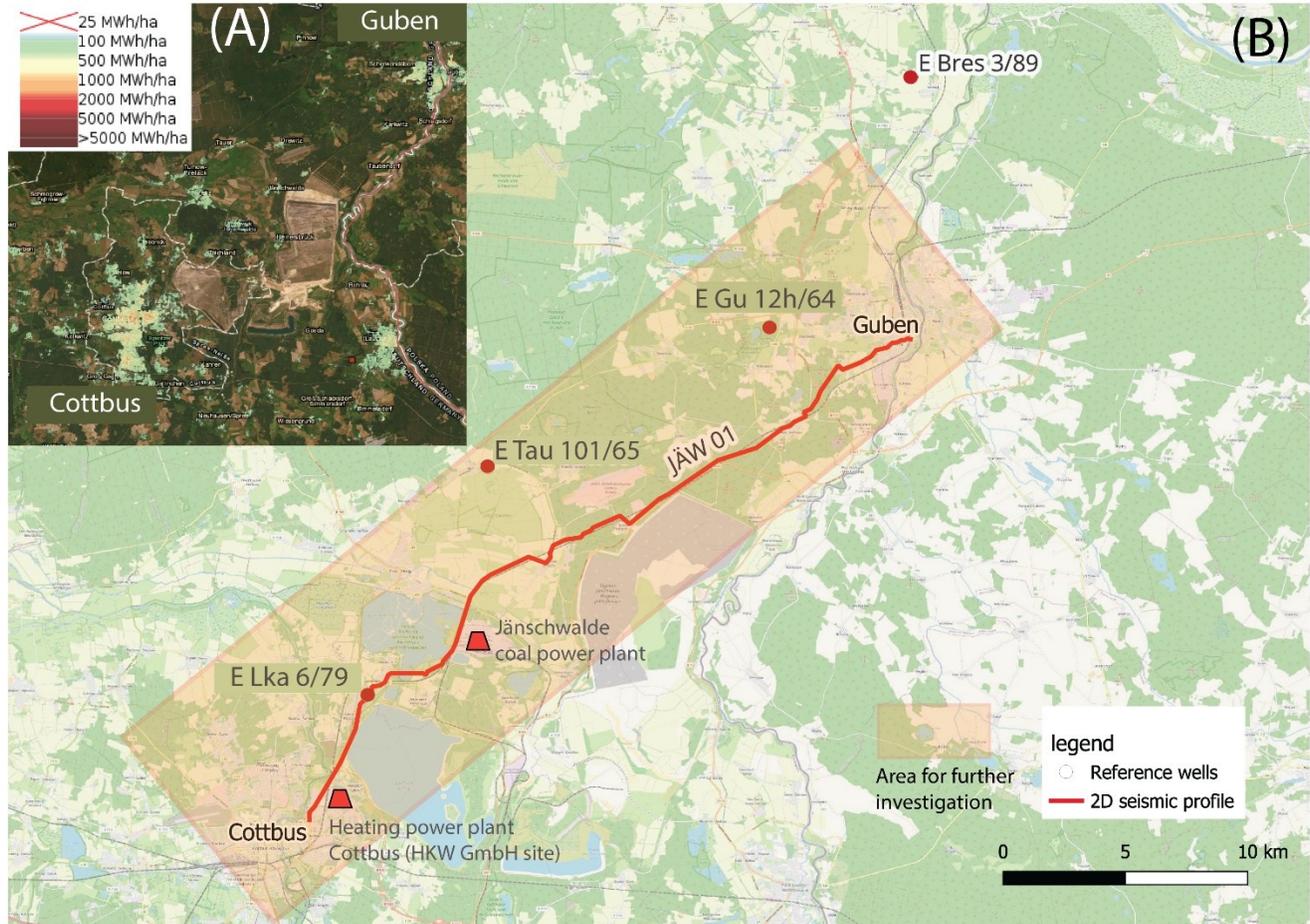


Figure 7: Potential area for UTES around Cottbus and Guben. (A) Heat demand map (modified from Hotmaps: <https://citiwatts.eu/map>). (B) Area for further investigation of UTES feasibility, delineated along a 2D seismic survey line (Modified from Christi et al., 2025c).

6. REGULATORY FRAMEWORK SUPPORTING GEOTHERMAL UTILIZATION BY LEVERAGING EXISTING INFRASTRUCTURE

6.1 General procedure for geothermal exploration and development

Germany's mining law (BBergG) classifies geothermal heat as a mineable raw material. Critically, heat and brine are currently considered as discrete resources, this would necessitate permits for both exploration and extraction. Should one company obtain a permit/license to explore or exploit geothermal heat, it is possible that another company could extract brine (or lithium from brine) in the same area. This would necessitate permits for both exploration and extraction. Consequently, before commencing any activity, operators must obtain the necessary permits and licenses from the responsible mining authority. While the BBergG is a federal law, individual German states interpret and apply its regulations with slight variations. In summary, the following steps are required to ensure the successful approval of a geothermal project:

- (1) Exploration and licensing: prior to drilling, companies are required to obtain exploration licenses and conduct environmental impact assessments.
- (2) Approval procedures: projects often require multiple permits, including those related to water use, environmental protection, and land use (individual case decision).
- (3) Public participation: local communities and stakeholders are typically involved in the approval process.

6.2 Well reuse and regulatory framework

6.2.1 Regulatory framework for well reuse and abandonment

In the case of drilling projects, the land where surface facilities are placed is usually leased. Generally, the well is owned by the developer company. Some wells are transferred to state property. When monitoring (mining authority) ends, the drilling site goes back to the original owner of the land. The wells can be transferred between companies, allowing for reuse by the original or a new owner for different purposes. Typically, contracts are established to achieve a well-owner change, and a critical issue is the financial reserve that is usually kept at the authority in order to undertake the abandonment in a proper way. But, if the well is no longer used for its intended original purpose, a new permit is needed. In theory, the process of repurposing existing hydrocarbon (oil and gas) wells for geothermal heat or brine extraction is generally considered simpler than the procedures required for their complete abandonment. Regulations govern well decommissioning and future subsurface use, defined specifically by the Bundesberggesetz (BBergG – Federal Mining Act). Backfilling procedures are outlined in more detail in the BVOT_NI_2022, also known as the Mining Ordinance for Deep Drillings, Subsurface Storage, and for the Extraction of Natural Resources by Drilling in the State of Lower Saxony (Deep Drilling Ordinance – BVOT), which was enacted on 17 May 2022. In most other states, the BVOT from Lower Saxony state is also applied.

A key consideration within the BVOT (Table 5) is the potential for future mineral extraction after a well has been abandoned (BVOT § 11). Beyond ensuring resource preservation, the regulations also address physical security of idle wellbores (BVOT § 31). In the context of well integrity, it is essential to conduct a thorough inspection following use, any significant alterations, and every six years. This is particularly crucial for the identification of potential leakage.

Table 5: Mining Ordinance for Deep Drillings, Subsurface Storage, and for the Extraction of Natural Resources by Drilling in the State of Lower Saxony (Deep Drilling Ordinance – BVOT) relevant to well reuse and abandonment.

Regulation	Requirement	Relevance for well reuse
BVOT § 11 (1)	Wellbores that are no longer needed must be backfilled immediately in such a way that ground surface collapses are avoided and the subsurface's potential for future use, such as the extraction of mineral resources and water, or subsurface storage, is not impaired.	This suggests that, even during the decommissioning process, authorities prioritize maintaining the potential for future resource utilization. The process of well plugging must be executed in a manner that ensures the possibility of future access, if such access is deemed necessary. Merely plugging the well is insufficient; the procedure must be carried out in a way that allows for the possibility of future access.
BVOT § 11 (2)	Oil and natural gas reservoirs, storage horizons and usable aquifers must be sealed. In areas of usable salt deposits, precautions must be taken to prevent water entering the deposit.	This stipulation is designed to safeguard valuable resources during the decommissioning process. The sealing of these formations is crucial for preventing contamination or depletion, thereby preserving their viability for future utilization. It is imperative to safeguard salt deposits from the infiltration of water, as they are frequently utilized for underground storage or as a mineral source.
BVOT § 31	Regarding securing idle wellbores, they must be closed and secured against unauthorized access	This highlights the importance of preventing access to abandoned wells in order to mitigate potential environmental risks and safety hazards. This security measure also helps maintain the integrity of the subsurface for any future activities.

Considering the legal feasibility and regulatory framework, wells that remain active or open but have reached the end of their original production lifecycle should be prioritized for repurposing evaluation. Early consideration should also be given to exploratory wells that did not meet their original objectives. This prioritization reflects both economic and environmental benefits, maximizing the value of existing infrastructure and minimizing the need for new drilling.

6.2.2 Well Data Access & Legal Framework in states of Berlin-Brandenburg

By law, the data related to any mining activity including wells has to be handed in to the State Geological Surveys. Depending on the type, the data are either restricted or free for other to use. Master data is publicly available (data that assign the content of the geological investigations in terms of person, place, time and general content). The second data type is raw data (comprises technical/geological “measured” data, as for example borehole measurements and bore logs that are not “interpreted”). They can be purchased from the company or provided by the State Offices or, under certain circumstances, data can be free to use. The categorization of data into the 3 groups is made by the State Offices. There is a differentiation between private and State drillings. The interpretation data is not available (only if the owner agrees), but technical measured data is free after 10 years (industry), 5 years (other private drillings) or always (state, research, etc.) Most of the raw data is company owned but also stored at the Geological Surveys of each State Office.

7. CONCLUSION

The Berlin-Brandenburg region offers a significant opportunity to accelerate the transition to a sustainable energy supply. A comprehensive resource assessment, coupled with existing energy demand and infrastructure, indicates a viable pathway for leveraging existing assets, prioritizing current open or active wells and connections to district heating networks. While repurposing abandoned wells is possible, it requires selective and intensive evaluation. The concept of well reuse is bolstered by active support from local government initiatives focused on the energy transition. Geothermal energy is particularly well-positioned as a key of energy source allowing the region to reduce reliance on fossil fuels by leveraging existing district heating infrastructure and boreholes.

The current regulatory framework supports this transition by permitting the repurposing of existing infrastructure. This is reflected in regulations governing well plugging and abandonment, which explicitly require sealing procedures tailored to potential future use, whether for mineral extraction or subsurface storage. Moreover, access to legacy data from existing boreholes is facilitated by the local mining authority, streamlining the assessment process. A preliminary evaluation has been conducted, and it has been determined that further analysis is warranted for the wells identified as potentially suitable. This subsequent analysis will encompass a comprehensive evaluation of the technical procedures specific to the site, a thorough assessment of well integrity, and a detailed economic analysis.

8. RECOMMENDATION

Recommendations for optimized well reuse and leveraging infrastructure for geothermal energy production:

- (1) Prioritizing active and open wells as the ideal infrastructure for repurposing concept.
- (2) Long-Term Well Integrity: If a facility is to remain in use for an extended period, maintaining a high standard of well integrity is paramount. This requires diligent monitoring and maintenance to guarantee the safety and success of the entire well repurposing project. Taking proactive and frequent measures to ensure well integrity will minimize risks and safeguard investments.
- (3) Proactive Cost-Benefit and Resource Assessment: A comprehensive cost-benefit analysis of both plugging and abandoning wells and reusing them, alongside a thorough resource potential evaluation, should be established earlier in the process. This would have enabled the standardization of minimum requirements for well decommissioning (temporary), ensuring a balance between cost and future accessibility. Current regulations should be further refined to allow for greater flexibility, factoring in the projected cost of reopening a well and preliminary reports on potential alternative uses.
- (4) Dual-Application Feasibility: When evaluating wells for potential reuse, a minimum requirement should be to identify at least two feasible applications. This ensures a buffer against unforeseen challenges with one application and broadens the potential return on investment.
- (5) District heating and grid proximity prioritization: In the evaluation of permits and assessment of resource potential, priority should be given to areas where district heating (mainly) or electricity grids are already established. The strategic positioning of geothermal facilities in proximity to existing district heating and grid infrastructure has the potential to markedly reduce heat distribution expenses while optimizing the utilization of the renewable energy generated.

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