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Feasibility of Geothermal Energy Use in Lusatia, Brandenburg, Germany

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ABSTRACT

Lusatia, a region in south-eastern Brandenburg, Germany, is undergoing a significant energy transition following decades of lignite mining. In line with the regional energy transition plan, the Lusatia region is undergoing major structural changes following the political decision to phase out coal-fired power generation. A key aspect of transforming the district heating networks in this area is assessing the feasibility of using geothermal energy for thermal storage and heat extraction. This study evaluates the potential of geothermal energy, specifically Underground Thermal Energy Storage (UTES), to meet regional heating demands and support infrastructure development. The assessment leverages over 15,000 existing wells and demonstrates the promising potential of UTES. Aquifer Thermal Energy Storage (ATES) is identified as a particularly viable and prioritized option due to the confirmed presence of Lower-Middle Buntsandstein in the area between Cottbus and Guben. While Borehole Heat Exchangers (BHE) and Borehole Thermal Energy Storage (BTES) are technically feasible, their economic viability is currently limited to utilizing existing wells. There is future potential for Enhanced Geothermal Systems (EGS) to access temperatures in excess of 100°C. This study directly supports the local government's ongoing, comprehensive seismic campaigns, which are crucial for refining subsurface models, reducing geological uncertainty and reinforcing the regulatory framework to reduce investment risk and enable more accurate resource assessments. The study emphasizes the importance of a collaborative approach that integrates energy demand assessment, evaluation of geothermal potential, and the regulatory framework to facilitate a sustainable energy transition in Lusatia.

1. INTRODUCTION

Germany's coal phase-out, specified in the 2020 Coal Exit Act, is a landmark commitment to decarbonize its energy system and central to the energy transition. Although Germany has historically relied on coal, particularly lignite, in Central Germany, Lusatia and the Rhineland, it is now accelerating its transition to renewable energy sources in line with EU climate objectives. This shift is sparking innovative regional redevelopment, as evidenced by the conversion of former mines such as the Cottbus-Nord open-pit mine into the Cottbuser Ostsee artificial lake. Notwithstanding the intricacies of its legacy, encompassing almost 15,000 drilled wells and the ongoing operation of coal-fired power stations, the region is poised to emerge as a pioneering locale for post-coal energy pathways. In the contemporary context, the Lusatia region maintains its pivotal function in Germany's energy transition. The Jänschwalde power plant, which is operated by LEAG, has an installed capacity of 3,000 MW. The plant has historically produced up to 11.9 billion kWh of electricity. It is anticipated that the process of decommissioning will be fully completed by 2028, thereby marking the final phase of lignite's contribution to Germany's climate targets. This development follows earlier shutdowns and modernization efforts in the post-reunification era. As part of the EU-funded TRANSGEO project, a pre-feasibility study is underway to assess the integration of geothermal energy for district heating and thermal storage. The objective of this initiative is to repurpose existing geological knowledge and infrastructure, thereby positioning Lusatia as a model for a sustainable and renewable future.

1.1 Geographic location and regional market area of Lusatia

The Brandenburg part of the Lusatia region shown in **Figure 1**, centered on the city of Cottbus (population approximately 100,000), is a regional hub in eastern Germany, located 124 km southeast of Berlin. Accessible by regional train or car, the region is served by Berlin-Brandenburg (108 km) and Dresden (124 km) airports. The Lusatia region encompasses the city of Cottbus (area: 165.5 km^2, population: 95,123 in 2024) and the Spree-Neiße district (area: 1,657 km^2, population: 109,635 in 2024), with population densities of 574/km^2 and 66/km^2, respectively (Urbistat, 2025). Historically a major coal mining region, Lusatia hosts several large coal-fired power plants (LEAG, 2025), including Jänschwalde (3,000 MW), Schwarze Pumpe (1,600 MW) and Boxberg (2,575 MW). The concentration of these facilities has contributed to a highly developed electrical grid infrastructure, as illustrated in **Figure 2**, which shows the region's power plants connected to 310 kV high-voltage transmission lines (purple) and urban areas linked to the regional distribution network via 110 kV lines (yellow).

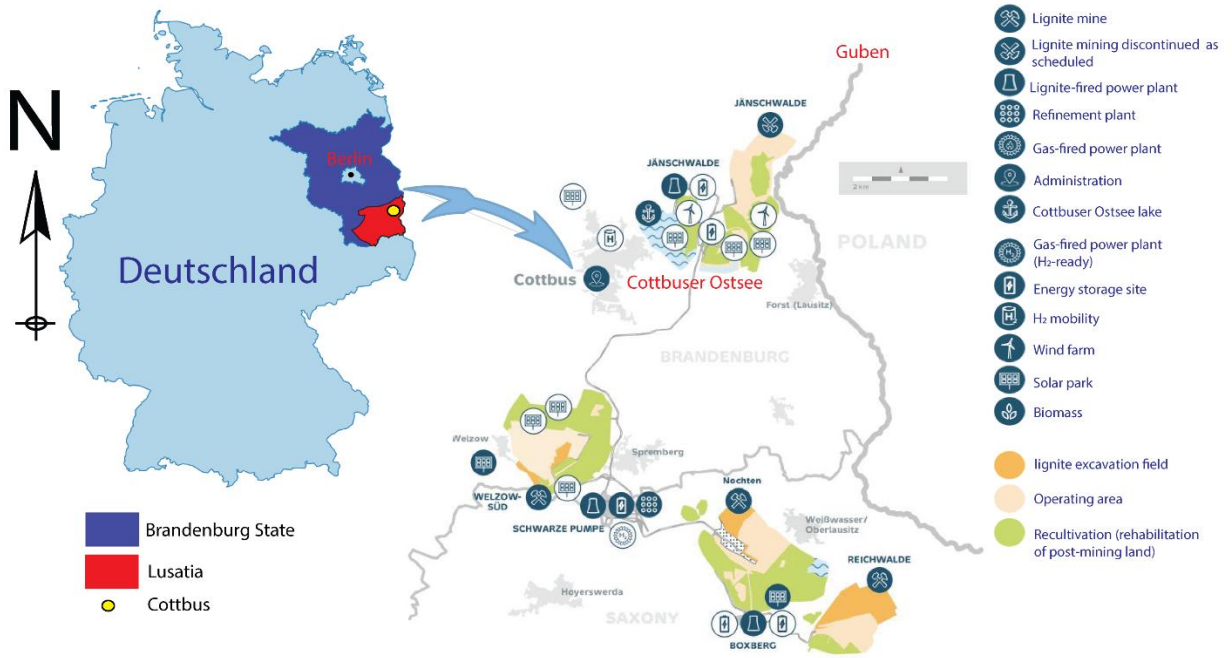


Figure 1: Location of the Lusatia region and LEAG's coal mining areas. Source: LEAG ESG Report 2024 (Accessed September 2025).

The region is also developing renewable energy sources, including solar and wind power. Floating solar panels (29 MW capacity) and onshore wind turbines are located in and around the Cottbuser Ostsee lake area, with additional installations concentrated in the northern areas around Lübbenau-Spreewald and the southwestern areas west of Spremberg. Existing district heating infrastructure, originally developed during the German Democratic Republic (GDR) era utilizing locally sourced lignite, is now crucial for phasing out coal and achieving decarbonization goals. These systems, characterized by a strong tradition of municipal ownership and increasingly diversified with private and cooperative entities, offer a practical pathway for integrating renewable energy sources (Konstantin, 2018). Cottbus city exemplifies this potential with a well-developed 175 km district heating network, supplying over 33,000 apartments, and covering 57% of the city's housing as of 2012 (Bhansen, 2020). While networks vary, ranging from integrated municipal grids serving entire cities to localized sub-grids adapting to geographic constraints (e.g., Guben city's 19 km network), they collectively represent a significant asset for sustainable heat provision (Bhansen, 2020). The region's existing infrastructure offers a cost-effective and efficient platform for incorporating renewable heat sources such as geothermal energy, solar thermal systems, biomass, and industrial waste heat. This aligns with the objectives of the EU's Renewable Energy Directive (RED III) and the EU Strategy for Energy System Integration, promoting a circular economy and reducing reliance on fossil fuels. Leveraging established networks and local governance models, Lusatia can demonstrate a successful transition from coal dependence to a sustainable, integrated energy system, offering valuable lessons for other regions undergoing similar transformations. Further research and investment are crucial to maximize the potential of this existing infrastructure and accelerate the clean energy transition in Lusatia and beyond.



Figure 2: Renewable energy power plants and existing energy infrastructure in the vicinity of Cottbus and Guben cities. The line in index map indicating the area shown in the pictures. Source of the map: https://www.openstreetmap.org/. (Accessed October 2025).

1.2 Description of research area and its historical drilling activity

Over decades, Lusatia was also explored for other resources such as hydrocarbons, copper and uranium as shown in **Figure 3**. Today Lusatia stands at a turning point. The region is actively embracing the energy transition, with early steps already taken to implement geothermal technology particularly through shallow Borehole Heat Exchanger (BHE) systems in Lusatia region.

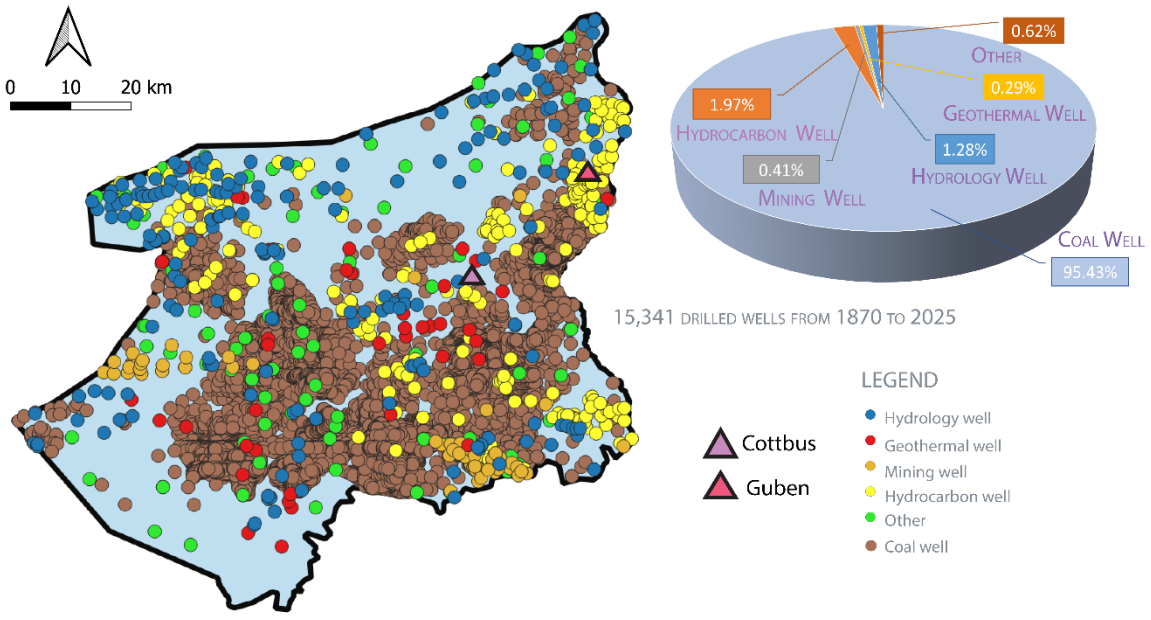


Figure 3: Overview of the legacy of drilling campaign from coal, hydrocarbon, and mineral explorations in the region. Source: well database "GeoDaB" of LBGR Brandenburg. (Accessed January 2025).

Extensive geological and drilling data provides a robust basis for assessing the geothermal potential. However, the majority of legacy wells, which were originally drilled for coal, hydrocarbons and mining, have been formally

abandoned in compliance with German mining regulations. These decommissioning procedures are mandated by the German Federal Mining Act (BBergG §§55 and 63) and are guided by the DIN 4022 and VDI 4640-2 standards. They require the wells to be plugged and sealed in order to prevent fluid migration, ground water contamination and maintain structural integrity. This effectively precludes their repurposing for geothermal applications. Consequently, Cottbus and Guben were selected for detailed evaluation due to factors such as local heating demand, existing grid infrastructure, revitalization initiatives, and the presence of deep hydrocarbon wells. These locations offer potential for base-load heating and thermal energy storage solutions such as Aquifer Thermal Energy Storage (ATES), Borehole Thermal Energy Storage (BTES) and/or Borehole Heat Exchangers (BHE).

2. SUBSURFACE CHARACTERISTICS OF LUSATIA

A 3D model of the Southeastern part of the North East German Basin (NEGB) was utilized to facilitate an understanding of the geology of the Lusatia area, with this model being built upon four decades (Scheck and Bayer, 1999) of exploration data (1950 -1990), including approximately 24,500 km of seismic data. While the initial exploratory phase concentrated on the analysis of Mesozoic and Zechstein structures employing analogue methodologies, subsequent digital surveys placed greater emphasis on underground storage and geothermal potential. The highest data density is observed over the Zechstein and Rotliegend formations. The updated model (Jahnke et al., 2024) represents an enhancement of the earlier TUNB-project (BGR, LAGB, LBEG, LBGR, LLUR, LUNG, 2021) model, incorporating refraction seismics utilized for lignite exploration, and harmonizing discrepancies through borehole connections and interpolation. Despite the limitations imposed by access restrictions and a decline in data collection after 1990, the model's primary strength lies in the consistent data acquisition facilitated by a single contractor, VEB Geophysik Leipzig. Data from western Berlin and post-1990 surveys (Fürstenwalde, Berlin/Spandau, Lübben) were excluded from the latest 3D Brandenburg model. In addition to drilling exploration and seismic, comprehensive gravimetric and magnetic data exists for Brandenburg, though with varying resolutions (Jahnke et al., 2024).

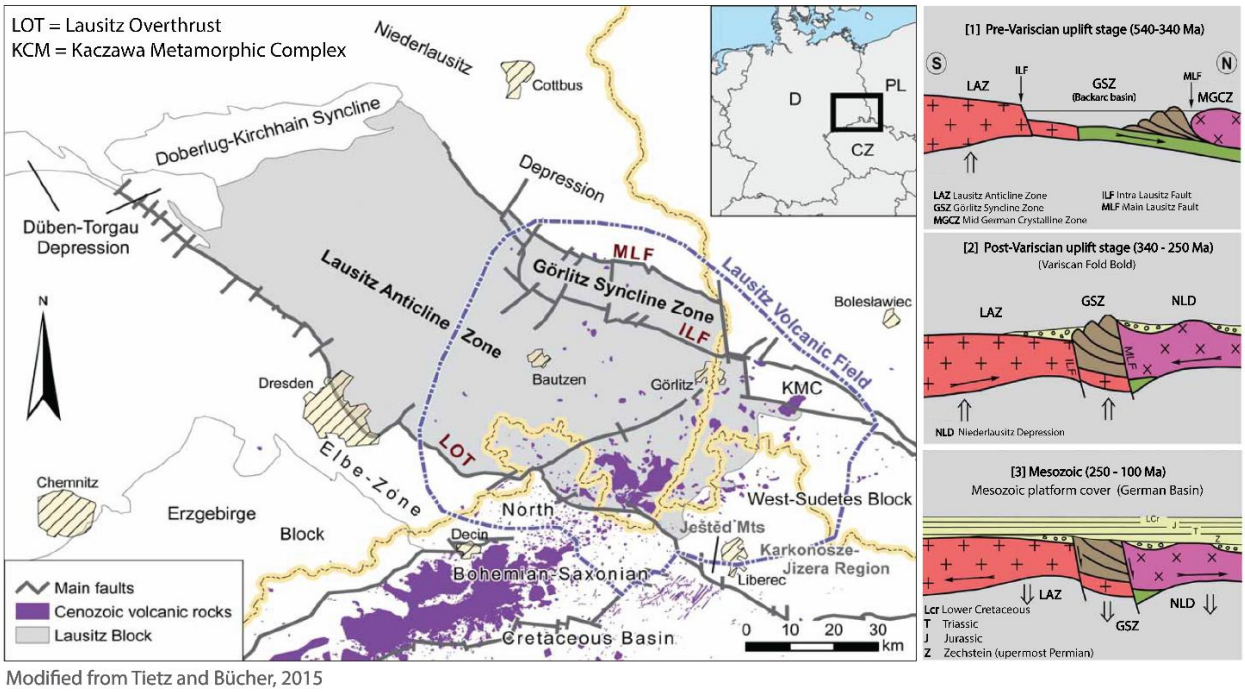
2.1 Geology and tectonic setting of the interest area

The states of Berlin and Brandenburg are located within the North German Basin, specifically in its easternmost and south-easternmost parts (**Figure 4**). The Northeast German Basin (NEGB) is a sub-basin of the Southern Permian Basin (Ziegler, 1990). The NEGB is underlain by Variscan-deformed crust to the south and Caledonian-deformed crust to the north (Scheck and Bayer, 1999). The Lusatia Anticline Zone constituted a segment of the Avalonian–Cadomian orogen belt. This was situated at the north-western margin of Proto-Gondwana (Göthel, 2001) during the period from 540 to 340 million years ago (Ma). During this tectonic period, characterised by the pre-Variscan uplift stage, the Lusatia area comprised three primary geotectonic units. The Lusatia Anticline Zone is located in the south of the region, while the basin and the Niederlausitz Depression are situated in the north. The Görlitz Syncline Zone is delineated by the Intra-Lusatian Fault, with the Main Lusatian Fault marking its northern border. As Tietz and Büchner (2015) describe, the Niederlausitz Depression and the Duben-Torgau Depression accumulate Variscan main molasse debris from the largely eroded fold belt zone, connected with bimodal volcanism during the Lower Permian (Rotliegend). The thickness of the sediments in the basins surrounding the Lusatian Block ranges from 100 to 400 metres (Nowel, 1979). The Mesozoic peneplain stage, which lasted from 250 to 100 million years ago, was marked by the break-up of Pangea and subsequent extension. This was a significant geological period (Tietz and Büchner, 2015). Following this event, the basement of the Lusatian Block was levelled and covered by Triassic, Jurassic, and Lower Cretaceous sediment sequences (Voigt, 2009; Hofmann et al., 2013), during the extension stage of the consolidated Variscan lithosphere (Stackebrandt & Franzke, 1989; Stackebrandt et al., 1994). This stage can only be inferred from the study of reworked detritus in younger sediment deposits in marginal basins, since the Mesozoic sediment cover has been completely eroded from the Lusatian Block (Voigt, 2009), particularly in southern Brandenburg. Furthermore, the north-western continuation of the Lusatian Block in the Prignitz rampart indicates a relatively mild tectonic environment. Voigt (2009) posits an inversion and partial preservation of this Mesozoic sediment cover.

2.2 Characteristics of potential aquifers in Lusatia

Extensive geological investigation, including core samples from 1953-1967 (now stored at the LBGR) and borehole data from thermal water/geothermal exploration (1985-2001), forms the basis for understanding aquifer characteristics in the Berlin-Brandenburg region. These investigations, alongside studies of underground storage facilities, have identified key aquifer formations. Göthel (2006, 2016) identified economically significant aquifers within porous formations including the Middle Buntsandstein (Volpriehausen & Detfurth), Upper Keuper (Contorta), Lias (Psilonoten, Lotharing, Domer), Dogger (Aalen), Lower Cretaceous (Neocom), and Paleogene.

While the Lower Muschelkalk holds potential, the Upper Muschelkalk and Malm are mostly irrelevant to Brandenburg.



Modified from Tietz and Bücher, 2015

Figure 4: Tectonic setting of Lusatia area (Modified after Tietz and Bücher, 2015).

The most viable aquifers are concentrated in the northern and central regions, primarily within Lower to Middle Jurassic sandstones (Polyplocus, Domaro, Carix, Lotharing, Arieten, Hettang, Contorta). Conversely, Lower Triassic Detfurth and Volpriehausen formations dominate the south. Other locally distributed aquifers include Wealden, Callovian and Solling. Feldrappe (2008) highlights the Middle Buntsandstein, Schilfsandstein, Rhaetian/Lias complex, Aalenian sandstone and Lower Cretaceous sandstones as significant geothermal storage horizons. In lower Lusatia, the Middle Buntsandstein (**Figure 5C**) is the most significant aquifer, extending widely across the area at depths of 200-1400 m b.s.l. (and up to 1800 m b.s.l. centrally). This widespread distribution suggests its presence near Cottbus and Guben. The Schilfsandstein (**Figure 5B**) and Rhaetian/Lias (**Figure 5C**) complex are more localized to northern Lusatia (depths of 200-800 and 200-600 m b.s.l. respectively) and have poor aquifer properties explaining the limited data available. Evaluating these aquifers relies on lithology, porosity, and permeability, with well correlation and seismic data being crucial for understanding depth and distribution. Zechstein and Gipskeuper formations can act as barriers. Frick et al. (2022) demonstrate that Jurassic reservoirs offer versatile potential for both heat extraction and storage, while the Middle Buntsandstein is limited in storage capacity, offering localized extraction potential.

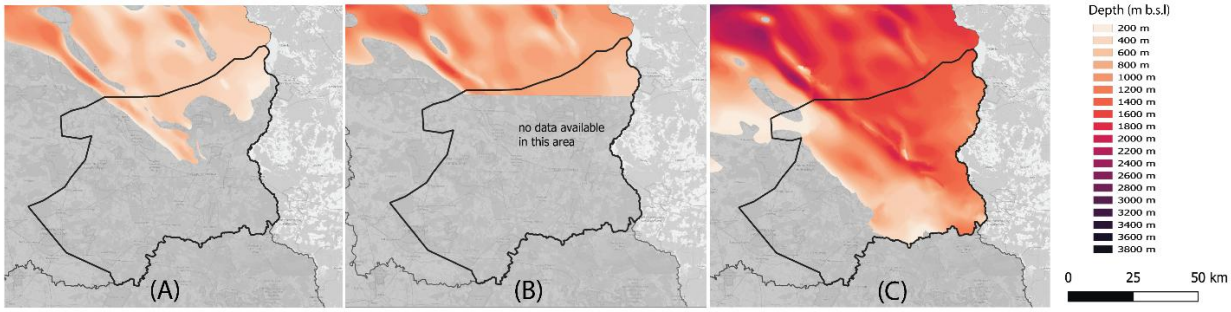


Figure 5: Distribution and depth of the (A) Rhaetian/Lias; (B) Schilfsandstein; (C) Middle Buntsandstein (Modified after Diener et al., 1988-1992).

Figure 6 illustrates the correlation identified in Göthel's (2016) study, indicating that the most economically viable aquifers are concentrated in the northern and central regions of the Berlin-Brandenburg area. The aquifers in the Lusatia region date back to the Jurassic and Triassic periods. These widely distributed aquifers are of Lower to Middle Jurassic age and comprise Polyplocus, Damaro (L2), Carix, Lotharing (L3), Arieten (L3), Hettang (L4),

and Contorta (T6) sandstones, which are mostly found in the northern part of the Brandenburg area. Conversely, the Lower Triassic Detfurth (S3) and Volpriehausen (S4) sandstones are mainly found in the south of the Brandenburg region. Other potential storage aquifers, such as the Lower Cretaceous, Callovian, Cornbrash Equivalent, Oberbajoc-Lower Bathonian, Thorsense/Dispansum (L1) and Polymorphites (L3') sandstones (all Jurassic), are only locally distributed and absent from the southern part of the Lusatia study area. Similarly, some aquifers, such as the Solling (S2), Hardegsen (S3) and Bernburg sandstones (S4). They are distributed locally in the southern part of the Brandenburg area, but they are not suitable for aquifers.

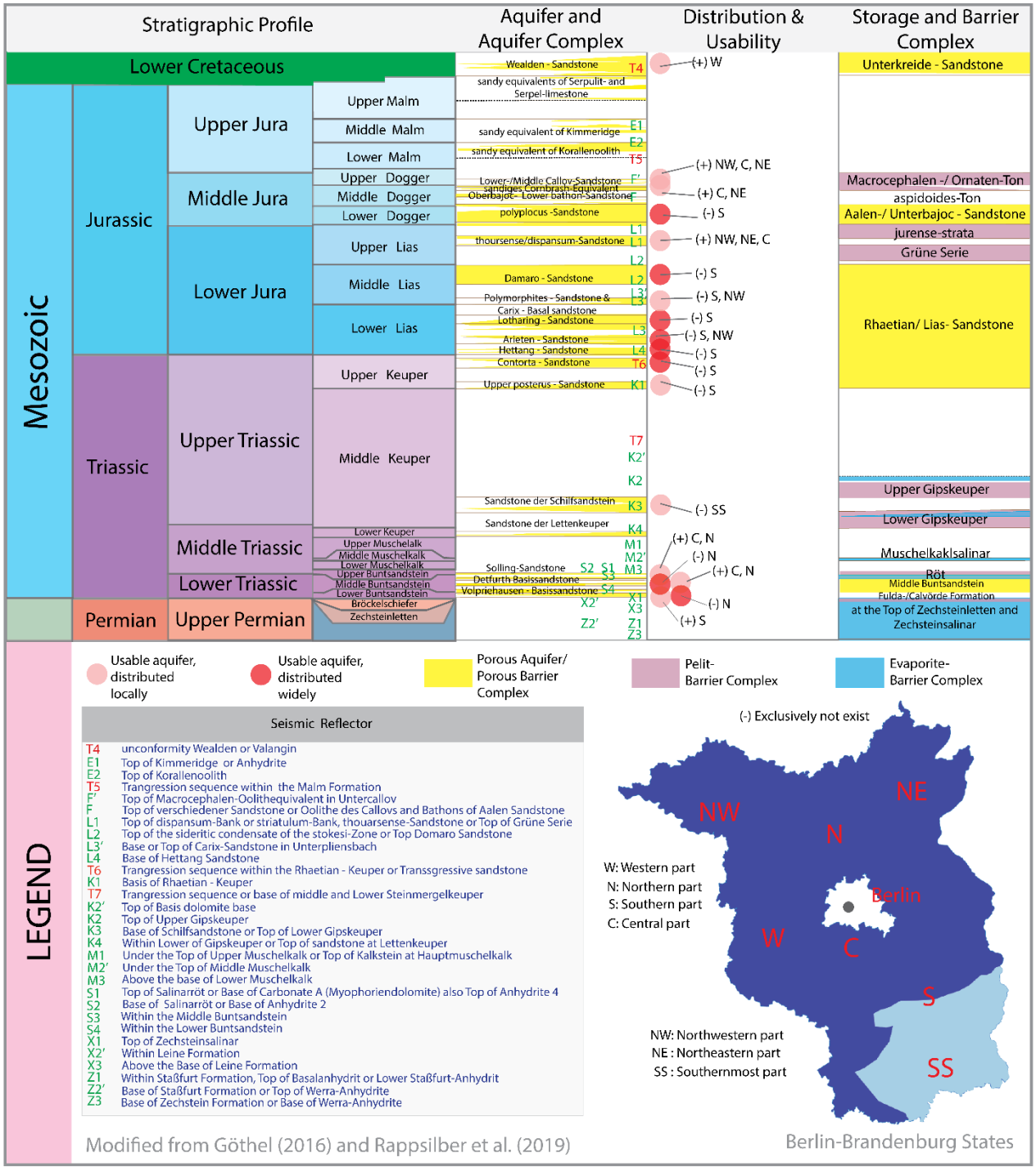


Figure 6: Correlation of reflection seismic horizon with aquifers, storage and barrier complex in Brandenburg area.

2.3 Temperature distribution

For this analysis, temperature distribution data were obtained from the GEOTIS (Geothermal Information System) database (Agemar, 2022; Agemar et al., 2012). Comprising approximately 11,000 wells and over 700 ground-level datasets, the database was used to develop a three-dimensional estimate of the subsurface temperature distribution in Germany. **Figure 7** shows the Lusatia region in particular. Based on the correlation of temperature data from thousands of boreholes, temperatures in excess of 110°C can be reached at depths of more than 3,000 metres below sea level. Temperatures ranging from 110°C to 80°C are found at depths between 2,200 m and 3,000 m b.s.l., while temperatures ranging from 80°C to 40°C are found at depths between 2,000 m and 1,200 m b.s.l. Temperatures range from 40°C to 10°C between 2,200 m and 1,200 m b.s.l. Consistent with the presence of the previously mentioned potential aquifer, the expected temperature ranges from 20 to 40 °C at depths of 200–800 m b.s.l., where the Schilfsandstein and the Rhaetian/Lias complex are more locally distributed in the northern part of the Lusatian region. However, for the Buntsandstein aquifer, the reservoir temperature could be expected to range from 40 to 80°C. For all these temperature ranges, the North German Basin has an average temperature gradient of 32°C/km (Agemar, 2020 & 2022).

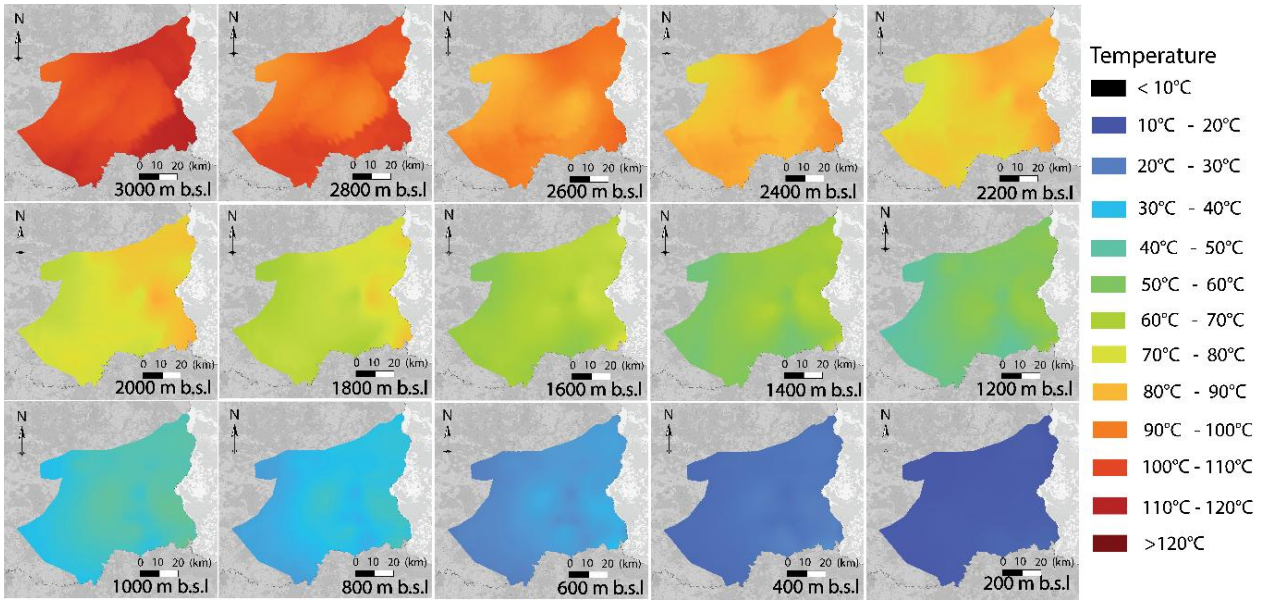


Figure 7: Temperature distribution in Lusatian region. (Modified from GEOTIS: https://www.geotis.de/geotisapp/geotis.php). (Accessed December 2024).

3. POTENTIAL SITE FOR UNDERGROUND THERMAL ENERGY STORAGE IN THE LUSATIA REGION

The identification of a potential site for Underground Thermal Energy Storage (UTES) in the Lusatian region was predicated on a convergence of geological, infrastructural and strategic factors as shown in **Figure 8.** It is crucial to note that the site's selection is strategically advantageous due to its close proximity to two significant heat sources: the Jänschwalde power plant site and the Heating Power Plant Cottbus (HKW GmbH site). These heat sources represent substantial potential for the integration of UTES, in addition to other heat source opportunities located in close proximity. This proximity minimizes thermal losses during heat transfer, reducing overall system costs and enhancing efficiency. Furthermore, the presence of an established district heating network in the city of Cottbus (HKW GmbH site), provides a readily available thermal distribution infrastructure, obviating the need for extensive and costly pipeline development. Initial assessments indicate this network has sufficient capacity to accommodate the anticipated thermal output from the proposed storage facility. Currently the district heating network at the city of Cottbus has an input temperature to the system of around 130°C, and the return temperature is 60°C.

Comprehensive analogue well data are used to support this infrastructural advantage. These exhibit both substantial depth penetration and complete stratigraphic profiles. This data from well 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 Rhaetian/Lias sandstone and Middle and Lower Buntsandstein, at depths conducive to efficient UTES operation. Analysis of these formations suggests favorable permeability and porosity (15 – 20 %) characteristics, which are critical for achieving high storage capacity and recovery rates. 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 current feasibility study also supports the 2D seismic survey in Lower Lusatia focusing for geothermal application conducted by the State Office for Mining, Geology, and Raw Material of Brandenburg (LBGR). The selection of Cottbus and Guben areas, as shown in **Figure 8,** aligns with regional energy strategy and existing infrastructure and was already identified by local mining authorities, to reduce investment risk and inform future energy planning. This will involve examining the subsurface from a geothermal perspective. The results will provide local authorities, industry and project developers with a better basis for planning, thereby reducing investment risk. **Table 1** summarizes the current identification on the potential reservoir that is suitable for ATES and BHE or BTES.

Potential area	ATES			BHE/BTES			Reference Well
	Potential reservoir	Depth (m.b.s.l)/ Thickness	Temperature (℃)	Potential reservoir	Depth (m.b.s.l)/ Thickness	Temperature (℃)	
Limberg-Guben area	Lower to Middle-Buntsandstein	800 – 2100 / 600	40 - 80	Zechtein - Rotliegend (basement) at Guben part	2000 – 3000 (> 3000)	> 90	E Tau 101/65 E Lka 6/79
Tauer-Laubsdorf area	Lower to Middle-Buntsandstein	1200 – 2000/ 650	40 - 80	Zechtein - Rotliegend (basement) at Laubsdorf area	1800 – 3000 (> 3000)	> 90	E Tau 101/65 E Lka 6/79
Drebkau-Forst area	Lower to Middle-Buntsandstein	750 – 2000/ 500	50 - 90	Zechstein-Rotliegend (basement) at Drebkau area	1200 – 3000 (>3000)	> 90	E Tau 101/65
Guben area	Lower to Middle-Buntsandstein	600 – 2000/ 600	30 – 80	Zechstein-Rotliegend (basement)	1400 – 3000 (> 3000)	> 70	E Gu 12h/64

Table 1: Depth, temperature, and average thickness of the most promising aquifers for ATES and BHE or BTES.

A successful ATES system relies on a complex interplay of geological, hydraulic and chemical factors. This requires a careful assessment of porosity, permeability and water chemistry. Optimizing well spacing, mitigating potential issues such as clogging and corrosion, is crucial for maximizing storage efficiency and ensuring the system's longevity, given that there is no such thing as an ideal aquifer. Both BHE and BTES require a thermally conductive formation effective well insulation designs for efficient heat transfer, however BTES requires a larger network of boreholes and careful assessment of reservoir homogeneity to ensure even thermal distribution and optimize storage capacity.

4. CONCLUSION

The Lusatian region has the potential for geothermal energy production, particularly Underground Thermal Energy Storage (UTES), which could support the transition to renewable energy. Current exploration activities, including a 2D seismic campaign, aim to identify the location, depth and volume of potential geothermal and storage reservoirs evaluation and drilling purposes for ATES applications. BHE and BTES are feasible options for utilizing existing wells, but no suitable wells have been identified since most wells have been plugged and abandoned. In the long term, Enhanced Geothermal Systems (EGS) could access higher temperatures in basement rock, pending technological advancements.

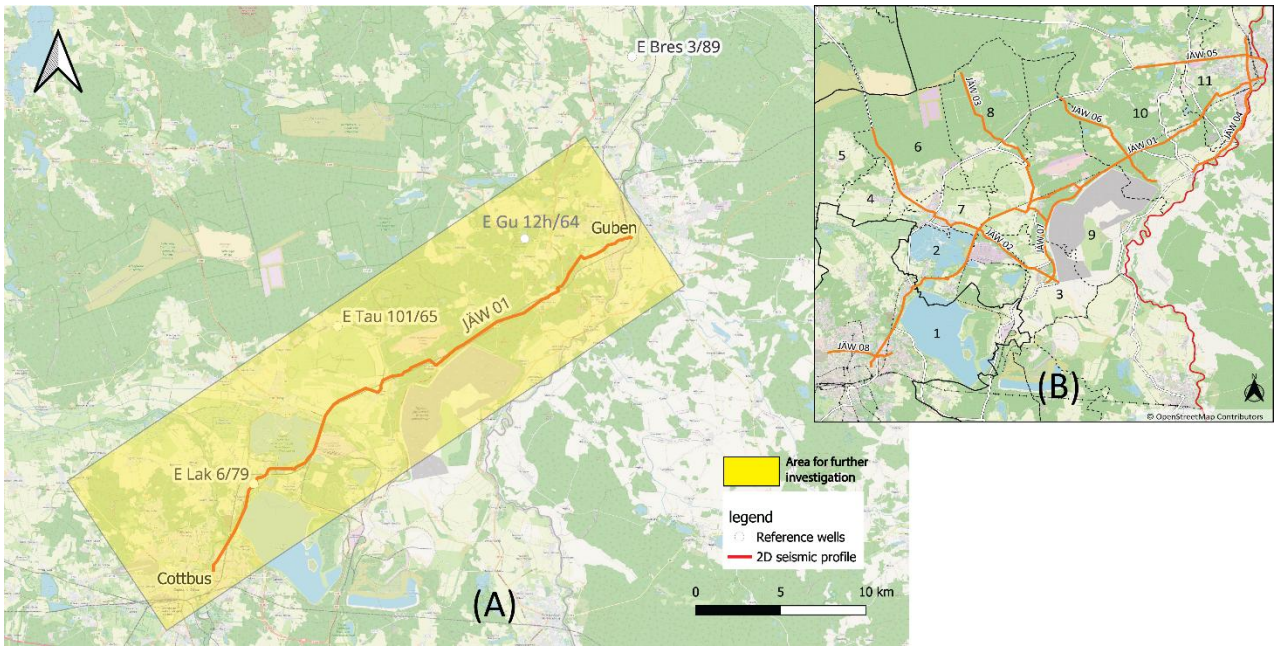


Figure 8: (A) Potential area for thermal storage application between Cottbus and Guben cities; (B) Location of 2D seismic campaign conducted on October 2025. (1) Cottbus; (2) Teichland; (3) Heinersbrück; (4) Drehnow; (5) Dachhausen; (6) Turnow – Preilack; (7) Peitz; (8) Tauer; (9) Jänschwalde; (10) Schenkendöbern; (11) Guben. Source: https://lbgr.brandenburg.de/lbgr/de/aktuell/2d-seismische-kampagne/. Accessed October 2025.

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