

Repurposing Flooded Underground Mines for Seasonal Heat Storage: Insights from the EU project PUSH-IT

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Abstract

Flooded underground mines are increasingly recognised as geothermal resources for seasonal heat storage. In the EU funded project PUSH IT, a large-scale Mine Thermal Energy Storage (MTES) pilot site will be installed, repurposing a section of the former “Mansfeld” colliery below the Technical Centre of the Ruhr University Bochum, Germany. An isolated, estimated 10,000 m³ mine void and four 120 m boreholes will enable injection of industrial surplus heat. Initial drilling, hydro-geochemical analyses, and modelling confirm suitable conditions for heat injection and recovery. The pilot facility demonstrates MTES feasibility and supports broader deployment of mines as “geobatteries”.

Keywords: mine water geothermal, mine water heat, MTES

Introduction

Seasonal discrepancies between heat production and heat demand pose a major challenge for decarbonising heating networks across Europe. Although surplus heat from industry, cooling systems, data centres, geothermal plants, and solar thermal collectors is increasingly available, demand peaks in winter, while heat supply often peaks in summer. Hence, Underground Thermal Energy Storage (UTES) technologies like Aquifer (ATES), Borehole (BTES) and Mine Thermal Energy Storage (MTES) are considered key to balancing seasonal heat availability and consumption. These systems allow seasonal storage of surplus heat in the subsurface, enabling flexible and low carbon operation of district heating networks.

Flooded underground mines are particularly promising for high temperature seasonal storage (Hahn *et al.* 2022, 2024). Former mining regions contain extensive networks of galleries, shafts and mine workings, that have been flooded after mine closure. Under suitable geological and hydraulic conditions, these voids can act as large heat storage facilities. Their substantial

volumes, combined with the thermal capacity of both mine water and surrounding rock mass, allow injection of surplus heat during summer and its extraction during winter for heating applications (Oppelt *et al.* 2025). In typical MTES configurations, the system is operated as an open-loop system, where mine water is extracted, thermally conditioned via heat exchangers, and reinjected into the mine. The mine water itself is not directly used in the heating network. Former mining sites often host newly established industries with surplus heat potential or are attractive locations for future industrial development. By repurposing the underground infrastructure for seasonal heat storage, these areas become even more appealing for post mining utilisation. MTES thus offers a route to transform mining legacies into infrastructure for the energy transition.

Study site

As part of the EU funded project *Piloting Underground Storage of Heat in geoThermal reservoirs* (PUSH IT, grant no. 1011096566), a MTES pilot site is under development. The MTES pilot site is located beneath the



Technical Centre of Ruhr University Bochum (RUB), Germany, where a hydraulically isolated section of the former Mansfeld coal mine is being repurposed for thermal storage (Figure 1). The term “hydraulically isolated” refers to a section of the mine workings that is not connected to active mine water drainage systems. Instead, it represents a confined mine compartment with limited hydraulic exchange with surrounding mine voids, allowing controlled thermal storage and minimising heat losses. In the section of the Mansfeld colliery two parallel galleries on the first mine level, at approximately 120 m depth, form a mine void estimated of about 10,000 m³. These galleries are flooded and represent a confined underground space suitable for controlled heat injection and extraction (Mugova *et al.* 2026).

The site meets the three core criteria identified for successful MTES systems. First, sufficient quantities of surplus heat are available at the RUB Technical Centre, supplied by industrial cooling towers (each with an 11 MW capacity), data centre cooling

processes, as well as combined heat and power units. Second, a flooded, hydraulically isolated mine working lies directly beneath the heat source, providing an ideal subsurface storage volume. Third, during winter months, the stored thermal energy can be reintegrated into the university’s heating network, which currently depends largely on natural gas based systems. Well-documented mine plans make it possible to accurately plan the drilling work. Furthermore, the geological setting within the Ruhr Carboniferous strata, comprising alternating sandstones, mudstones and interbedded coal seams is well known and offers important information for designing well completions and selecting casing materials.

The planned MTES system follows an open-loop configuration, in which mine water is extracted from and reinjected into the flooded mine workings via multiple boreholes. At the surface, the extracted mine water is connected to the campus heating and cooling infrastructure via a heat exchanger and large-scale heat pumps. The overall

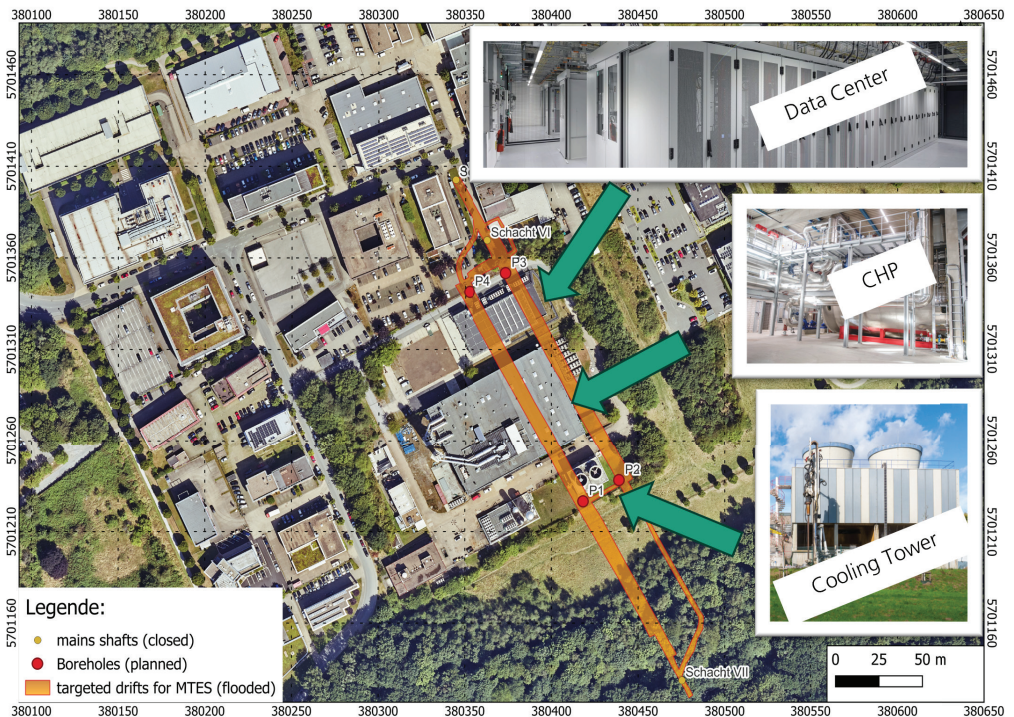


Figure 1 Aerial view of the RUB Technical Centre. In orange, parallel mine galleries, depth 120 m.

system design integrates surplus heat sources, a buffer storage, and the district heating network, enabling seasonal heat storage in the underground mine void and its recovery for heating purposes.

Drilling and field investigations

Since 2024, three boreholes have been drilled to depths of approximately 120 m to establish hydraulic connections to the flooded galleries. The drilling was executed using Fraunhofer IEG's Hütte HBR 207 GT drill rig and required refined technical solutions to ensure vertical well trajectories despite challenging geological conditions (Figure 2). The first borehole showed deviations of up to 5 m due to steep, alternating lithological layers. Static recalculations of the bottom hole assembly and the use of heavy weight drill collars enabled a pendulum effect that reduced deviation in subsequent boreholes to less than 0.5 m.

Advanced casing technologies were tested, including the installation of glass fibre reinforced composite tubulars (HCT casings)

designed for high temperature applications and corrosion resistance in potentially mineralised mine water. Installation procedures were developed specifically for this project, making it a pioneering field test for composite casings in MTES applications. Cementation quality and borehole integrity were validated using optical and acoustic televiwer logs, distributed temperature sensing, and camera inspections. No leakage or structural issues were detected in the completed wells (Klein *et al.* 2025). The mine water sampled during drilling shows moderate temperature (~ 13 °C), low mineralisation, and neutral pH, indicating favourable conditions for high temperature injection (up to 85 °C) without major risks of scaling, corrosion, or biofouling. However, under elevated temperatures of up to approximately 85 °C, geochemical conditions may change. Increasing temperature can alter mineral solubility and potentially induce scaling processes or changes in microbial activity. Therefore, ongoing monitoring and geochemical modelling are essential to assess



Figure 2 Drilling rig in front of the Technical Centre's cooling tower (on the right).



long-term risks related to precipitation, corrosion, and biofouling under high-temperature operating conditions.

Upcoming phases include additional drilling of two boreholes, hydraulic testing (including pumping and tracer tests), and a hot push pull test to determine thermal recovery efficiencies and flow regimes within the mine workings. The Hot push-pull test will be conducted as a standardised method to evaluate the thermal recovery efficiency and hydraulic behaviour of the storage system. During these tests, heated water is injected into the reservoir and subsequently extracted from the same well, allowing the analysis of thermal breakthrough behaviour, heat transport processes, and potential short-circuit flow paths within the mine workings.

Modelling Approaches

Thermohydraulic reservoir modelling with the software SPRING is applied to simulate heat injection, storage, and recovery within the flooded mine workings. Modelling results are transferred from the WINZER project (Fraunhofer IEG, 2026). The models account for coupled fluid flow and heat transport processes, including heat exchange between the mine water and the surrounding rock mass. These models provide estimates of temperature evolution, storage capacity, and recoverable heat under cyclic operation.

Building on this, a co-simulation approach is used to evaluate the integration of the MTES system into the campus heating and cooling infrastructure (Spengler, 2025). The subsurface reservoir model is coupled with a dynamic model of the surface energy system, including heat pumps, cooling processes, and the district heating network. It is implemented in separate simulation environments and linked via an external control algorithm, enabling the exchange of thermal and operational data during runtime. Charging cycles are defined as seasonal sequences consisting of heat injection in summer and heat extraction in winter. The co-simulation framework allows the analysis of multiple consecutive cycles, providing insight into long-term system behaviour and the interaction between storage operation and energy demand.

Public Outreach and Stakeholder Engagement

Effective communication and public engagement are essential pillars of the PUSH IT project, ensuring that emerging underground heat storage technologies such as MTES are understood, trusted, and embedded within broader societal and institutional contexts. As MTES might rely on utilisation of former mining infrastructure beneath populated areas, the technology intersects with regulatory frameworks, environmental concerns, regional identity, and long term energy planning. Transparent communication therefore helps address questions around safety, environmental compatibility, and the practical implications of operating a high temperature storage system in abandoned mines.

Throughout the project, a broad range of outreach activities has been carried out to connect with key groups. Engagement with authorities and regulatory bodies has ensured that legal frameworks, environmental aspects, and permitting processes are discussed openly and informed by current scientific findings. Regular exchanges with industry representatives, utilities, and energy planners have helped align MTES development with practical needs in heat transition strategies and district heating networks. Within the scientific community, the project team contributed to knowledge exchange by presenting MTES concepts, technical progress, and preliminary results in academic and professional settings. These activities facilitated collaboration with researchers working on geothermal energy, mine water systems, and underground thermal energy storage, while also helping to establish MTES more firmly within the broader UTES research landscape. Public facing communication has been equally important. The team has consistently provided accessible explanations of MTES principles through interviews, articles, digital content, and social media communication, helping to increase general awareness of underground heat storage. Drilling site tours and on site communication with information fence banners made the project visible to local communities and provided opportunities for informal



dialogue. Educational activities for university students and early career researchers further supported long term knowledge building and created opportunities for direct interaction with the technology.

Across all formats, the overarching goal has been to ensure that MTES is understood not only as a technical innovation but also as a socially relevant component of the energy transition.

Outlook and Transferability of MTES systems

Preliminary modelling and drilling results demonstrate that the Bochum pilot site could achieve recoverable temperatures between 25 °C and 50 °C after several charging cycles, suitable for low temperature district heating, heat pumps, or hybrid heating systems. Field data from the PUSH IT site will be used to calibrate reservoir and co simulation models, improving predictions of heat dispersion, storage capacity, and long term thermal behaviour. The MTES system is intended to be connected to the university's district heating network.

The results and implications of the PUSH-IT project extend well beyond the Ruhr region. Many former mining districts worldwide, contain extensive flooded mine workings that could be repurposed as MTES systems. The combination of large available void volumes, proximity to urban heat suppliers and consumers, and existing infrastructure provides unique advantages compared to other UTES systems. Scaling MTES globally depends on several enabling conditions, including advances in drilling and completion technologies for accessing flooded mine workings, the establishment of robust geochemical and hydraulic monitoring practices, the development of streamlined regulatory frameworks for underground heat storage, and the availability of validated numerical models to support engineering design. Equally important is active community engagement supported by transparent communication of risks and benefits. The Bochum pilot is among the first large scale MTES demonstrators and will provide essential operational

data and best practice guidance for future sites. By converting abandoned mines into “geobatteries,” MTES can deliver resilient, low carbon heating solutions, promote the circular reuse of industrial infrastructure, and contribute to socio economic revitalisation in former mining regions.

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