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Challenges and Opportunities for High-Temperature Mine Thermal Energy Storage with Focus on Regulatory Barriers for Implementation

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Abstract

Mine thermal energy storage (MTES) is an innovative solution to use flooded mines to temporarily store heat during periods of low heating demand for later use during periods of high demand. Its implementation has associated technical and regulatory challenges that must be tested and understood. The PUSH-IT project is piloting the implementation of high-temperature thermal energy storage in aquifers, boreholes and mines. Two MTES sites are being assessed, a demonstration site in Bochum (Germany) and a follower site in Cornwall (UK). This paper presents a summarised review of the regulatory frameworks and barriers for MTES development in these two countries.

Keywords: Thermal Energy Storage, MTES, Regulation, PUSH-IT project

Introduction

A challenge for the decarbonisation of heating is balancing heat production with seasonal variations in heat demand, characterised by periods of very high heat demand in winter and very low heat demand in summer. Underground Thermal Energy Storage (UTES) is an innovative solution to use the subsurface space for thermal storage in periods of excess heat production and low heat demand (e.g. Kallesøe and Vangkilde-Pedersen, 2019).

Various technologies are grouped within UTES, including the storage of heat in aquifers (ATES), boreholes (BTES), and mines (MTES). Mine thermal energy storage (MTES) (e.g. Hahn *et al.* 2024) takes advantage of the mine water filling the void space in flooded mine workings and/or shafts, as well as the surrounding host rock to store heat.

MTES systems can be implemented using various technological solutions (e.g. Walls *et al.* 2021). Typically, mine water, used as heat carrier, is abstracted using boreholes or mine shafts. Heat is transferred to the water (e.g. when the mine water is used for cooling or as carrier for waste heat from industrial processes) via a heat exchanger, and the heated water is then reinjected back into the mine for storage. The process is reversed to recover the heat during periods of higher heating demand.

As mine water geothermal, the MTES concept has been tested at a few sites, but it is still not widely implemented. Commercial uptake is relatively slow due to multiple technical, economic and regulatory barriers. In this work we review existing regulatory frameworks for mine thermal energy storage, as part of the PUSH-IT project, with focus on Germany and the United Kingdom, where the two MTES sites are located.

The PUSH-IT Project

Project Overview

PUSH-IT (**P**iloting **U**nderground **S**easonal **H**eat storage **I**n geo**T**hermal reservoirs)

(Bloemendal *et al.*, 2024) is an EU-funded project that aims to demonstrate the full-scale application of high temperature underground thermal energy storage (HT-UTES) in geothermal reservoirs.

The project includes three types of HT-UTES technologies: Aquifer Thermal Energy Storage (ATES), Borehole Thermal Energy Storage (BTES) and Mine Thermal Energy Storage (MTES), with three demonstrator sites and three follower sites (one per technology). HT-ATES in Delft (Netherlands) and Berlin (Germany), HT-BTES in Darmstadt (Germany) and Litoměřice (Czechia) and HT-MTES in Bochum (Germany) and Cornwall (United Kingdom).

In parallel with the scientific and technical activities at each site, the project aims to investigate the regulatory landscape as well as social aspects of HT-UTES projects, such as public awareness and perception of the technology. As with other new technologies, the lack of specific regulation and limited technological awareness among stakeholders and users are factors that can prevent faster market upscaling.

This work summarises the regulatory frameworks for mine water geothermal and mine thermal energy storage in Germany and the United Kingdom. More specifically in the two MTES sites in the PUSH-IT project, the demo-site in Bochum (Germany) and the follower site in Cornwall (UK). As the moment only in Bochum it is planned to develop a MTES system.

Bochum

In Bochum (North Rhine Westphalia, NRW, Germany), the MTES will be installed at the technical centre of the Ruhr University Bochum (RUB). Boreholes are being drilled to a depth of 120 m into the Mansfeld Colliery, located directly under the RUB.

The system will be integrated in the university's heating and cooling network, currently fed by gas fired boilers and a CHP (combined heat and power) unit with a capacity of 9 MW. The local heating network also supplies heat to approximately 4,800 apartments, 760 houses and 115 other buildings, with supply temperatures in the range 80–120°C. The aim is to use the mine water from the colliery to store waste heat, at approximately 30°C, from the technical/data centre (700 kW peak load) (Fig. 1). The target storage capacity is between 2 and 8 TJ (considering an available storage volume of 5,000–7,000 m^3).

United Downs

In Cornwall (UK), the project is evaluating solutions to store the residual heat from deep geothermal power production at the United Downs Deep Geothermal Project (Olver and Law 2025) in nearby flooded metal (tin and copper) mines. To evaluate the feasibility of the installation of MTES technologies in this location, investigations are being carried in the Consolidated Mines, closed in the 19th century. The activities being carried out include water sampling, temperature logging

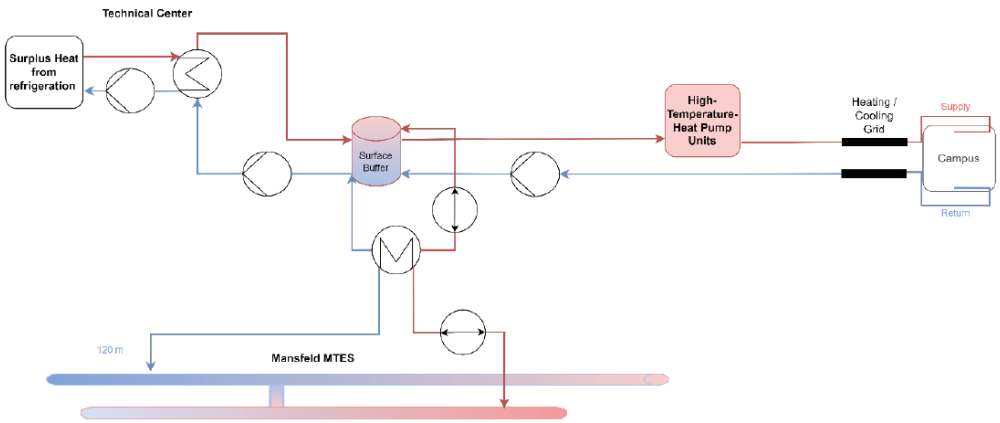

Figure 1 *Schematic diagram of the MTES integration in the heating and cooling network at RUB (F-IEG).*

and tracer testing using accessible shafts, supported by conceptual and numerical modelling undertaken to develop an understanding of the system and assess its potentiality for HT-MTES.

Regulatory Framework of Mine Thermal Energy Storage

Germany

Germany's regulation is decentralised, with national laws setting broad standards and implementation carried out by state (Länder) authorities.

Shallow geothermal projects which use groundwater require notification and permission from the Lower Water Authority (LWH), as stated by the Act on the Regulation of Water Resources (WGH – *Gesetz zur Ordnung des Wasserhaushalts*). The LWH must be notified of any activities that might be affecting groundwater quality and flow. In Bochum, both the WGH and the LWG (*Landeswassergesetz* – North Rhine Westphalia Water Resources Act) regulate the notification and approval obligations for the construction and operation of a shallow geothermal system. Deeper projects require authorisation from the mining authority.

According to the Mining Act (BBergG – *Bundesberggesetz*), drilling to depths of more than 100 m and developments across more than one property require the supervision of the Mining Authority. In NRW an online platform (https://www.bohranzeige.nrw.de/online/) is available to notify drilling activities. Potential issues related to methane must be considered. The drilling is supervised by the Mining Authority, Department 6 Mining and Energy of the Arnsberg District Government in NRW.

The geological information obtained during the investigation and construction of the project must be deposited (Geological Data Act – *GeolDG*) with the local geological survey (*Geological Survey of NRW* – Geologischer Dienst NRW) no more than 3 months after the end of the investigation.

The HT-MTES project in Bochum also obtained permissions from the land and mine owners and agreements with the main beneficiary of the project, the Ruhr University Bochum, prior to obtaining the necessary permits from the authorities.

New legislation in form of the Geothermal Heat Acceleration Act (GeoWG) ("Gesetz zur Beschleunigung der Genehmigung von Geothermie-Anlagen, Wärmepumpen sowie Wärmespeichern, GeoWG") (Deutscher Bundestag 2025) is being drawn up in Germany aiming to facilitate project development and simplify the permitting process. The proposed new law includes various amendments to the BBergG and the WGH aiming to facilitate and accelerate the approval and deployment of geothermal and heat storage systems.

United Kingdom

Geothermal energy is not recognised as a natural resource in UK legislation, and there is no regulator with allocated remit for geothermal and thermal energy storage. Regulatory oversight in the United Kingdom is devolved to the nations, with the nation's environmental regulators playing a key role in regulating potential environmental impact alongside local planning authorities.

In Great Britain (i.e. England, Scotland, Wales), any activity which intersects, disturbs or enters coal seams also requires prior notification and written authorisation from the Mining Remediation Authority (MRA), formerly the Coal Authority (IEA 2023). The MRA is a non-departmental public body that manages the UK's coal assets and legacy, including liabilities associated with past coal mining and unworked coal. In addition to the drilling permit, the abstraction of heat from closed coal mines requires a heat access agreement from MRA (MRA 2024). To support future licensing and regulation, the MRA has built a Living Lab in Gateshead (NE England), located between two mine water heat schemes in the area, the Gateshead Energy Company Network and Lanchester Wines. The site will provide data to help in understanding thermal and hydraulic interactions and support the MRA permitting, environmental regulators and new developers. Access to mine workings in Northern Ireland required authorisation from the Department of the Economy. When

the mine water is abstracted from a borehole, a supplementary agreement for the actual borehole location is required.

Metalliferous mines, such as the Consolidated Mines in Cornwall, do not require permission from the MRA. As currently, there is no legislation relating to the ownership of geothermal energy in the UK (Abesser *et al.* 2023a, b), accessing these mines for geothermal / thermal energy storage only requires permission from the land and mine owner as well as planning permission from the responsible mineral planning authority (this is the scenario for a hypothetical MTES project in Cornwall). Planning permission is necessary for most construction works, such as a mine water geothermal or MTES system involving drilling. The competent authority, most likely the local planning authority is the responsible for planning, development management and enforcement. The authority can also ask for additional requirements such as an Environmental Impact Assessment (EIA) or a Habitat Regulation Assessment. Health and Safety regulations (regulated by the Health and Safety Executive) apply to all construction workplaces.

The Environment Agency (in England), or the equivalent environment agencies in the other nations (Scottish Environment Protection Agency, SEPA in Scotland; Natural Resources Wales, NRW in Wales; Northern Ireland Environment Agency, NIEA in Northern Ireland) are the responsible for protection and regulation of groundwater related activities. For geothermal use, borehole construction, abstraction and discharge require authorisation from the relevant environment agency. In England, open loop systems require a groundwater investigation consent, an abstraction license (for abstractions of more than 20 m3 per day) and an environmental permit for the discharge of water from the EA (some exceptions apply) (McClean and Pedersen 2023, EA 2023).

In addition to the previous requirements, the British Geological Survey (BGS) must be notified of the intend to drill boreholes of more than 15 m depth, and the records must subsequently be deposited with the BGS.

Discussion and Conclusion

The increased use of the subsurface for energy applications, as in the case of geothermal energy and thermal energy storage, require an appropriate regulatory framework that both achieves its purpose (e.g. protect people or the environment, prevents interference with other users) while at the same time does not introduce additional excessive administrative burden for projects to be developed.

The project PUSH-IT aims to demonstrate the full-scale application of high-temperature underground thermal energy storage, including the potential of mines to store excess heat. In parallel with site construction and development and related technical activities, the project intends to reduce the potential regulatory barriers for HT-UTES development.

This work has presented a summary of the regulatory and permitting regimes of HT-MTES systems at the project sites: the demonstrator site in Bochum (Germany) and the follower site in Cornwall (UK).

In Germany and the UK there is not bespoke regulation for mine thermal energy storage. Geothermal legislation is under review in Germany (GeoWG expected to enter into force in 2025). In the UK regulation is still evolving drawing on existing frameworks developed for related activities and involves a mix of national, regional, and local authorities. Some authorities, such as the Mining Remediation Authority, consider heat resources as part of managing and granting access to their assets (i.e. flooded coal mines) but there is no national regulation for the abstraction and storage of heat. Although guidance exists for project developers (e.g. IEA 2023; ScotGov 2024), new technologies such as MTES must follow permit workflows with specific requirements set for each project by the competent authorities, leading to project delays and excess costs.

The regulatory review presented in this work will be used in combination with site specific learnings obtained during construction and interviews with authorities and project developers, to identify gaps and inefficiencies in the regulation and develop a set of recommendations for UTES project success.

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