

Untangling the Regulatory Barriers for High-Temperature Underground Thermal Energy Storage within the PUSH-IT Project

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ABSTRACT

The EU-funded project PUSH-IT (Piloting Underground Storage of Heat In geoThermal reservoirs) is piloting the implementation of high-temperature thermal energy storage in aquifers (HT-ATES), boreholes (HT-BTES) and mines (HT-MTES). The project will implement and test the potential for thermal storage at higher temperatures in six pilot sites (three demonstrator and three follower sites; two per technology) located in four countries: the Netherlands, Germany, the Czech Republic and the United Kingdom.

As with other new technologies, the widespread implementation and use of HT-UTES face a variety of scientific and social challenges that delay market uptake and implementation, including a lack of targeted regulation, uncertainty about the environmental impacts of high temperature storage and a lack of awareness about the new technology among the public, developers and policy maker.

In this paper, we present an analysis of current regulatory frameworks and approaches applied to the three HT-UTES technologies in the countries and sites represented in the PUSH-IT project. The analysis is based on literature studies and semi-structured interviews aimed at collecting direct experience of project stakeholders, including developers, operators, regulators and authorities.

1. INTRODUCTION

High-temperature underground thermal energy storage (HT-UTES) (>25°C) constitute a special and promising opportunity to combine underground storage with higher temperature output from other sources, including waste heat and renewables (geothermal, solar, biomass). This approach would allow to alleviate some demand-supply limitations and ultimately reduce costs.

PUSH-IT (<https://www.push-it-thermalstorage.eu/>) is an EU-funded project which aims to demonstrate the full-scale application and implementation of high-temperature underground thermal energy storage (HT-UTES), specifically the high temperature thermal energy storage in aquifers (HT-ATES), boreholes (HT-BTES) and mines (HT-MTES).

High-Temperature Aquifer Thermal Energy Storage (HT-ATES) (Fleuchaus et al., 2020) is the storage / recovery of thermal energy in / from aquifers, permeable layers that contain groundwater. High-Temperature Borehole Thermal Energy Storage (HT-BTES) use borehole heat exchangers to store heat in the ground. High-Temperature Mine Thermal Energy Storage (HT-MTES) take advantage of the water in closed and flooded underground mine as a carrier to transport and store heat.

Among its main objectives, the project aims to understand the social factors influencing the development of HT-UTES, and enable the joint decision making of citizens, regulators and operators to increase social acceptance and the deployment of the technology. This includes the analysis and comparison of the regulatory landscape at the project sites, focusing on identifying and reviewing the regulations for HT-UTES across the project countries and sites complemented with an evaluation of the effectiveness of existing frameworks.

Permitting and regulation in the geothermal sector varies between countries and for the different technologies. Typically, there are no specific regulatory frameworks or guidelines available for HT-UTES technologies. As a result, developers and regulators involved in the development and regulation of the PUSH-IT sites are often navigating new and complex permitting procedures. These are based on existing regulation and adapted to mitigate the anticipated impacts of these new technologies by way of defining additional requirements or exceptions.

In this paper, we review the current regulatory frameworks and procedures that apply to HT-UTES at

the project sites. The review provides the underpinning knowledge for the wider regulatory analysis that will involve interviews with developers and regulators across all sites.

2. PUSH-IT PROJECT SITES

The six project sites are located in four different countries: three demo-sites - Delft (Netherlands), Darmstadt (Germany) and Bochum (Germany) - and three 'follower' sites - Berlin (Germany), Litoměřice (Czechia) and United Downs (United Kingdom) - where future pilots are underway (Table 1).

Table 1: PUSH-IT project sites, countries and technology.

Site	Country	Technology
Delft	Netherlands	HT-ATES
Darmstadt	Germany	HT-BTES
Bochum	Germany	HT-MTES
Berlin	Germany	HT-ATES
Litoměřice	Czechia	HT-BTES
United Downs	United Kingdom	HT-MTES

2.1. Delft (Netherlands) (HT-ATES)

The system at TU Delft campus will be integrated in the TU Delft district heating network (DHN). The HT-ATES will store heat from the deep geothermal wells that will replace the current gas-powered Combined Heat and Power (CHP) supply. The deep geothermal wells (DAPwells), already drilled (Vardon et al. 2024b), will have a maximum flow capacity of 375 m³/h and a production temperature of 75-80°C

The HT-ATES will be used to store excess heat from the deep wells during periods of low heat demand (with minimum flow rate of the deep geothermal wells of 80 m³/h). To meet the desired capacity, the HT-ATES system will be composed of 2-3 hot wells (80°C and up to 90°C) and 3-4 warm (colder) wells of 50°C drilled into the sand aquifer at depths of 120-180 m below ground level. The project is ongoing, and the ATES permit has been granted for the site. An observation well has already been drilled and the design of the ATES wells with a target storage capacity of 25-50 TJ is being currently finalised.

2.2. Darmstadt (Germany) (HT-BTES)

The HT-BTES project is located at the TU Darmstadt Lichtwiese campus. Currently, three deep geothermal borehole heat exchangers have been installed to a depth of 750 m (Seib et al., 2024).

The HT-BTES will be integrated into the TU Darmstadt district heating grid, first to two new buildings near the site and later to a larger district heating sub-grid (Sass et al., 2024). The system will store excess heat from various sources, including the CHP plant, waste heat from the supercomputer centre and from solar panels.

Drilling operations at the site started in 2022, initially with the intention to drill four boreholes. Three well were completed to a depth of 750 m, while the fourth well was deferred. The boreholes have a spacing (at surface) of 8.66 m. Recent work in the project have included numerical modelling and distributed geothermal response tests (Seib et al., 2024, 2025).

2.3. Bochum (Germany) (HT-MTES)

The HT-MTES in Bochum will be installed at the Ruhr University Bochum (RUB) technical centre, using the closed Mansfeld Colliery. The system will be integrated in the RUB district heating network, currently fed by gas boilers and a CHP unit.

In total, the system will be composed of 4 boreholes drilled into the abandoned mine at approx. 120 m depth (Hahn et al., 2024). The heat source of the HT-MTES will be the RUB data centre, with 700 kW peak load. The target storage capacity of the HT-MTES is between 2 and 8 TJ (considering an available storage volume of 5,000 – 7,000 m³).

The drilling work started in the second half of 2024 with the drilling of the two first boreholes. Water sampling and the first testing has been completed. In the first half of 2025 is expected that the other two boreholes are drilled. Permit from the water authority for initial water pumping and circulation tests up to 5,000 m³ per well was obtained in 2024.

2.4. Berlin (Germany) (HT-ATES)

The HT-ATES is being developed in the south-east of Berlin as a follower site in the project. The system will be integrated into an existing district heating network with a current heating supply of 650 GWh and operating service temperature of 95-115°C. The aim is to use the HT-ATES to store heat, primarily from a biomass CHP plant and other sources (waste heat, renewable) located in the vicinity of the site.

The first stage of the project included the drilling of a research well and the testing of storage capabilities by conducting Hot Push-Pull Testing (HPPT). The second stage includes the construction of the ATES system and integration with the heat network (this stage is part of the GeoSpeicher Berlin project and funded by the Federal Ministry for Economic Affairs and Climate Action (BMWK)).

2.5. Litoměřice (Czechia) (HT-BTES)

The HT-BTES site is located at the RINGEN (Research Infrastructure for Geothermal ENergy) in Litoměřice. The site is located at a former army barracks and is

being used by the Faculty of Sciences Charles University and the Czech Geological Survey (CGS) to develop the project SYNERGYS (<https://www.synergys.cz/en>). The project will combine geothermal from various sources, including a deep enhanced geothermal system (EGS) and thermal energy storage. The overall aim of the SYNERGIS project is to connect the HT-BTES and EGS to the district heating network of the town.

As part of PUSH-IT, two boreholes have been drilled to different depths to evaluate the subsurface geology and the hydrogeological conditions at the site; the deeper to 550 m and the hydrogeological borehole to 200 m. The wells have been equipped with fibre optic cables.

2.6. United Downs (UK) (HT-MTES)

The follower HT-MTES project in Cornwall (UK) is evaluating solutions for storing excess heat from the deep geothermal power production at the United Downs Deep Geothermal Project (Olver and Law 2025) in the nearby flooded metal (tin and copper) Consolidated Mines, closed in the 19th century.

The work so far has included a comprehensive compilation and analysis of the old mine working plans supported by new data from loggers installed at 7 locations. In addition, temperature profiles have been measured in 5 shafts aiming to identify mine water stratification and cross flow. The work is being integrated to build a conceptual model of the system that will be later used to evaluate operational scenarios for thermal storage in the mines with numerical modelling.

3. GENERAL REGULATORY LANDSCAPE

3.1 The Netherlands

The Netherlands is a global leader in shallow geothermal and, especially, in underground thermal energy storage. The country hosts thousands (>3000; Stemmle et al., 2024) of aquifer thermal energy storage (ATES) systems and is, by far, the world leader in the technology.

The first HT-UTES project was developed in the Netherlands in the 1980s, with a borehole thermal energy storage project in Groningen to store solar heat at 60°C. HT-ATES projects were developed in the 1990s at Utrecht University and a health care institution in Zwammerdam, aiming to store heat from combined heat and power (CHP) plants (Godschalk et al., 2021).

Regulation for geothermal energy and thermal energy storage has evolved in the Netherlands reflecting the increasing number of installations (especially ATES) and the leading role of the country among European counterparts. A new general regulatory framework entered into force in 2024 with the objective of streamlining permitting and reduce bureaucracy. The Environment and Planning Act (*Omgevingswet*) and

the Environmental Decree (*Omgevingsbesluit*) are the two main pieces of legislation of relevance to UTES.

The Environment and Planning Act is the law that regulates everything in the living environment, including setting the rules for spatial planning, housing, infrastructures, nature and the environment. The law unifies and integrates previous legislation, defines the roles of the competent authorities at different levels and simplifies the permitting process. The Environmental Decree covers the main rules for permitting, including procedure, enforcement and implementation.

A key objective of the new framework is to reduce the regulatory and administrative burden and simplify the permitting process. This is achieved by assigning responsibility for managing the application process to a single competent authority. Under this new approach, developers submit their application to one competent authority (e.g. local government office for ATES) who coordinates the permissions process for the various activities included in the project between all involved authorities.

Specific regulation for low temperature ATES, guidance and online tools are available for both operators and regulators. More details of the specific regulation relevant to ATES and HT-ATES are provided in the section describing the PUSH-IT demonstrator in Delft.

3.2. Germany

Germany is well established in shallow geothermal energy; however, the development of underground thermal energy storage, especially in aquifers and mines, is still in its infancy. Only two ATES are in operation in Germany, in Rostock and Bonn, with various research sites in Berlin, Kiel, Leipzig. MTES projects are restricted to research sites in Bochum and Freiberg (Stemmle et al., 2022, 2025).

Currently, regulations are evolving to support the increasing number of geothermal projects and targets aiming for carbon neutrality by 2045 (Federal Climate Change Act 2019, amended in 2024). The regulatory framework for shallow geothermal energy is well defined, but its application to thermal energy storage is still emerging. The regulatory framework is complex and involves national (federal) and regional (*Länder* or state) laws.

In general, the two most relevant laws for geothermal and thermal energy storage in Germany are the Federal Water Act (*Gesetz zur Ordnung des Wasserhaushalts*, WHG), and the Federal Mining Act (*Bundesberggesetz*, BBergG) which regulate access to and protection of natural resources, including water and heat. Additional provisions at each state provide specifications for most other activities.

The Federal Water Act (*WGH*) is the main piece of legislation regarding the protection of surface water and

groundwater, water management and provisions for flood protection. It entered into force in 2010.

The Mining Act (*BBergG*) regulates the exploration and extraction of raw materials and minerals. Geothermal energy (heat extraction) is considered a “bergfreie” (free-to-mine) resource (i.e. not automatically owned by the surface landowner) and the rights of exploitation must be obtained through authorisation (with some exceptions for shallow and low-capacity systems). The *BBergG* applies to geothermal extraction activities at depths of more than 400 m

In addition to these, some other federal laws may need to be considered for geothermal energy projects, including thermal energy storage:

- The Geological Data Act (*GeolDC*) introduces the obligation to developers and operators of notifying and submitting data from geological investigations to the competent authorities, in general the geological surveys of the state (*Länder*), and for them to ensure that this data is made publicly available.
- The requirements for Environmental Impact Assessment (EIAs) are regulated by the Environmental Impact Assessments Act (*Gesetz über die Umweltverträglichkeitsprüfung*, *UPVG*).
- The Heat Planning Act (*Wärmeplanungsgesetz*), that entered into force in 2024, provides a framework for the implementation of heat transition at the local level, aiming to provide more security to stakeholders and facilitating coordination for the development of energy infrastructure.
- The Building Energy Act (*Gebäudeenergiegesetz* or *GEG*) regulates and sets the requirements for the energy performance and use of renewable energy in buildings.
- The Federal Climate Adaptation Act (*Bundes-Klimaschutzgesetz*, *KSG*), amended in 2024, has set the national carbon reduction targets. Under the new legislation, greenhouse gas emissions must be reduced (compared to 1990 levels) by at least 65% by 2030, 88% by 2040 and achieve neutrality by 2045.

The relevant regulations and competent authorities for the PUSH-IT sites in the states of Hesse (Darmstadt) and North Rhine Westphalia (Bochum), and the city-state of Berlin, are discussed later in more detail.

3.3. Czechia

The number of ground source heat pumps in Czechia has been increasing lately and the country has established a regulatory framework for the installation of ground source heat pumps (Česká asociace hydrogeologů, 2023), but currently there is no specific detailed legal framework for permitting and licensing of UTES projects.

Geothermal projects in Czechia fall under Czech regulatory frameworks and are subject to planning, construction, water, geological and mining laws and environmental impact assessment at state (mining/drilling), regional (EIA) and local (water) levels.

Drilling to depths of more than 30 m is regulated by national and regional mining law. Mining law also regulates the resource (heat from the rock or the rocks where heat is stored) and the way that this is extracted. Drilling requires an Environmental Impact Assessment, although the level of detail required varies depending on the type of project being developed. Project must adhere to the “Do No Significant Harm” (DSNH) EU principle, although in general geothermal projects are considered compliant with DSHN by the Czech Ministry of Environment.

3.4. United Kingdom

The number of shallow geothermal projects in the UK is increasing although still considerably lower when compared to other European leaders (Gonzalez Quiros et al., 2024). The market for open loop UTES systems is still in its infancy. Recent works (Stemmle et al., 2024; Jackson et al., 2024) have reported a total of 12 ATES in the UK, while MTES have not been implemented yet, even though the country has seen increasing interest in the development of mine water geothermal systems.

Geothermal energy is not legally recognised as a natural resource in the UK (Abesser et al., 2018; McClean and Pedersen, 2023), and therefore the extraction or storage of heat are not directly regulated. Although none of the devolved administrations (i.e. England, Scotland, Wales, Northern Ireland) have bespoke legislation for geothermal exploitation, they have published guidance to facilitate geothermal development and permitting. Current regulations and legislation are determined by law related to activities undertaken during the exploration and exploitation of geothermal energy (i.e. water abstraction, drilling, etc.) (McClean and Pedersen, 2023; Abesser et al., 2023).

Environmental regulators – Environment Agency (EA) in England, Scottish Environment Protection Agency (SEPA) in Scotland, Natural Resources Wales (NRW) in Wales, and the Northern Ireland Environment Agency (NIEA) in Northern Ireland – regulate activities that may cause pollution or be a risk to the environment, including abstractions and discharge of water.

Local planning authorities are responsible for granting planning permission for works associated with borehole construction or surface works. They also decide if an Environmental Impact Assessment is required.

The Health and Safety Executive (HSE) oversee the compliance with regulation of workplace health, safety

and welfare. This is of special relevance for deep geothermal drilling.

For mine water geothermal, the Mining Remediation Authority (MRA) (formerly the Coal Authority) plays a key role in the permitting of any activity in or around coal mining areas. Mine water geothermal projects in coal mines require prior notification and authorisation from the Mining Remediation Authority (MRA), and, in addition to drilling permits, the geothermal operation requires a heat access agreement from the MRA (IEA, 2023; MRA, 2024).

New geological or geophysical data acquisition during drilling of geothermal wells must be reported to the British Geological Survey.

4. REGULATION AND PERMITTING AT THE PUSH-IT PROJECTS

4.1 HT-ATES

4.1.1 Delft (Netherlands)

New environmental and planning regulations came into force in the Netherlands on 1st January 2024. The new regulatory system has been implemented and culminated with the enactment of the Environmental Act (*Omgevingswet*) that incorporates all national legislation relevant to the physical environment. The main objectives of the new Act are to simplify the regulation and permitting process and to accelerate regulatory decisions. The implementation of the Act will be gradual, leaving time to municipalities and water boards to transition and adapt to the new framework.

Shallow geothermal activities in the Netherlands (<500 m depth) are considered a cross-industry activity regulated by the Decree of Activities in the Living Environment (*Besluit activiteiten leefomgeving; Bal*). ATES permitting is considered in article 3.19 and the general rules and requirements in §4.112 of the *Bal*. The requirements are described in more detail in the BUM BE deel 1 – OBES (SIKB, 2023). In general, ATES are not considered activities requiring an Environmental Impact Assessment report.

The main steps during the permitting procedure for an ATES system include:

1. Pre-consultation: to determine the legal framework, the permits that are required and to check whether an EIA is required, The Environmental Desk (*Omgevingsloket*) (<https://omgevingswet.overheid.nl/>) is used to see a map of locations and the rules and policies that apply, check permit requirements and submit the application.
2. Permit application: First the developer must confirm that the system meets the General Rules by complying with the *Bal*, including confirmation that the system:

- a. Prevent negative interference with other systems, defined as temperature changes of 0.5°C and/or water level changes of 0.05 m.
- b. Meet requirements of efficient use of geothermal energy and energy efficiency, expressed by the SPF (seasonal performance factor) with guidelines available for its calculation.
- c. Meet groundwater temperature limits (25°C).
- d. Meet energy balance between heating and cooling. A period of five years is considered for the calculations.
- e. Drilling complying with requirements of groundwater protection.

The new Environment Act in 2024 stipulates that for ATES system that are part of a project that requires multiple applications (e.g. the ATES is part of a building construction) only one competent authority decides on the application, usually the municipality (i.e. Delft municipality in this case). Previously such application would have gone to the main authority responsible for the protection of groundwater (i.e. South Holland Province for the Delft project). Under the new regime, the province is consulted by the municipality and maintains a key role in the permit evaluation.

For HT-ATES systems the General Rules do not apply. This is because these systems inject water at temperatures greater than 25°C, and therefore they are not in energy balance of heating and cooling and create heat surplus in the subsurface (i.e. system not in equilibrium). Permission for the operation of HT-ATES out of these general rules can then be granted if:

1. The interest of protecting the subsurface and groundwater are not compromised.
2. There are additional interests because of higher energy efficiency.

To grant permission for HT-ATES, the competent authorities define additional requirements that developers must supply as part of the permit application (Bloemendal et al., 2021), these include additional monitoring wells and chemical and microbiological water sampling.

The main permit required for operation of the HT-ATES project in Delft was the Water Act permit (*Waterwet*). Project developers applied for this permit before 2024 under the old regulatory systems. While largely following the consultation and application procedure explained above, the application was made through the province as the main point of entrance. The permit was issued in January 2025 by the Regional Environmental Agency (*Omgevingsdienst Haaglanden*) on behalf of the South Holland Province Executive. After the permit was granted the permit holder and operators had to design a monitoring plan that had to be approved by the competent authority. In addition to the main permit, a permit application for

drilling and testing of the pilot monitoring borehole was submitted to South Holland Province, and notification of discharging the abstracted water was submitted to the Local Delfland Water Board.

4.1.2. Berlin (Germany)

Geothermal operations in Berlin require a permit from the water authority according to the Water Resources Act (WGH) and the Berlin Water Act (BWG). There is an exception for small shallow closed-loop systems that are at least 1 m above the shallowest groundwater level, i.e. the one nearest the surface. The application for a geothermal permit is directed to the Water Authority of the Senate Department for Mobility, Transport, Climate Protection and the Environment. In general, because of the elevated groundwater temperatures beneath Berlin, cooling only systems are not allowed, and systems for heating and cooling are evaluated on a case-by-case basis. Around 50% of the city area are within a restriction zone, aimed to protect groundwater, where open-loop systems are not allowed.

For geothermal drilling, contractors must report drilling operations to the Senate Department for the Environment, Mobility, Consumer and Climate Protection (Geology and Groundwater Management) two weeks before work begins using a “Notification of drilling operations” form. Public participation is possible and those affected can submit comments on the application.

As there is no specific HT-ATES legislation, the project developers of the Berlin site applied for an “exploration license for brine and heat”, submitted to the Mining Authority (State Office for Mining, Geology and Raw Materials, LBGR). The permit has been extended but the operators had to submit an additional special operations plan to the mining authority for the drilling of the sidetrack. The plan was submitted in October 2023 and approved in March 2024 and contains additional obligations, including the share of new geological data. An additional plan was required to conduct the hot push-pull test, also submitted to the mining authority (that consults the water authority). The application contains information of the injected and produced volumes, tracers to be used and details of the procedure (times, monitoring, fluid handling, etc.).

4.2. HT-BTES

4.2.1. Darmstadt (Germany)

Requirements and regulation for the HT-BTES project in Darmstadt are primarily set by the Federal Mining Act (BBergG), due to drilling depths (750 m) and size of the system. In the state of Hesse, the competent and relevant authorities for geothermal and energy storage projects are the Mining (Darmstadt Regional Council; *Umwelt und Energie – Bergbau*) and Water (Lower Water Authority Darmstadt; *Gewässer Überwachung*) Authorities and the Hessian State Agency for Nature Conservation Environment and Geology.

A main operating plan is submitted to the regional mining authority and, if approved is valid for 2 years. After submission of the main operation plan, the mining authority can request further information or changes, and, if approved, a license for exploration is granted. After exploration is completed, the mining authority regulates the operation of the geothermal or storage site. The main operating plan for extraction and processing is a comprehensive document that includes details and information regarding size and workforce of operators; location and boundaries; company information; details of the local authority works council; occupational safety; mining rights; property rights; geology; conflicts of use; an overview of the mining operations and work; seismic monitoring; construction compliance including machinery, storage and transport; waste; noise emissions; water protection; public information; and drilling operations. The operating plan must also address plans for the decommissioning of the site after operations are ceased. For the Darmstadt project, a 30-page operating plan was submitted to the authority with details of the exploration and operation activities.

A permission is also required under the water law. The permission evaluates if the project will be developed in one of the water regimes defined as favourable, unfavourable or unauthorised areas for such developments. Applications are submitted to the lower water authority and can also be reviewed by the Hessian Agency for Nature Conservation, Environment and Geology (HLNUG). Projects in favourable areas that do not exceed 30 kW heat output (such as domestic GSHPs) have a simplified application approach and do not require to go through a full permitting procedure. A report on the planned testing and monitoring is also submitted to the water authority and reviewed by HLNUG.

4.2.2. Litoměřice (Czechia)

The permitting of geothermal project in Czechia includes various stages of permitting which are required prior to drilling. These are regulated by various authorities, mainly the Ministry of Environment and the Czech State Mining Authority, with other authorities having a role, including the Nature Conservation Agency, the local public water administration body, and regional and local public authorities.

The current framework of permitting includes the following stages:

1. Preparatory stage. Comprises an evaluation of the site to assess if it is suitable for its purpose (i.e. thermal energy storage) and the works are legally feasible without any conflict of interest or other spatial restrictions (land ownership, areas of protected nature, mining rights, old mine workings or geological risks).

2. Exploratory stage. Aims to characterise the subsurface and the geological suitability for the project. Individual permission from landowners and infrastructure operators are required if the project involves seismic operation; if it takes place in protected areas, additional special permits are required.
3. Pre-drilling stage. Submission of final documentation including details of the contractor and well plan, timeline of works, details on health and safety operations, and any impact on local water and electricity supply. The mining authority must be notified at least 14 days prior to well spudding.
4. Permitting procedure stage. The geothermal exploitation requires two main permits:
 - a. Protected area for the Specific Impacts on the Earth's crust (Protected Area SIOEC) issued by the Ministry of Environment. This defines and delineates the territory that can be used for the project and where heat will be extracted/stored.
 - b. License for mining works for Specific Impacts on the Earth's crust (Licence for mining works) for drilling of boreholes of more than 30 m depth. As part of the application, the developer must provide: i) information of the intended well, including its purpose, type of works, information about the investors/stakeholders, and a description of the environmental and geological conditions at the site; ii) detailed geological information based on the previous exploratory stage and other preliminary information, and, iii) details of the technical operation, including well design and drilling contractor.

4.3. HT-MTES

4.3.1. Bochum (Germany)

The competent authorities in geothermal projects are the lower water authority of the City of Bochum and the mining authority (Department 6 "Mining and Energy in NRW" of the Arnsberg District Government). The Geological Survey of North Rhine-Westphalia is the competent authority in the application of the Geological Data Act.

The use of water bodies for geothermal energy requires a water permit (§9 WHG) and the point of contact is the water authority. The mining law applies for drilling to depths of more than 100 m or developments done across properties. Geothermal is regulated and heat considered a resource, and its extraction requires a mining permit, however, thermal storage with net heating of the subsurface are exempt.

For the project in Bochum an initial permit for testing from the water authority was granted for up to 5,000 m³ per well to be performed after the drilling phase in

2024-2025. Written permissions from the mine and landowners were obtained in the first semester of 2024.

4.3.2. United Downs (United Kingdom)

Mine water geothermal exploration and operations in the United Kingdom is mainly regulated by the national environment agencies and the Mining Remediation Authority for coal mines, in addition to planning permission from the local authorities. Drilling of any borehole of more than 15 m depth must be reported to the Natural Environment Research Council (UKRI), and the records must be deposited with the British Geological Survey.

The environmental agencies (e.g. the Environment Agency is the responsible authority in Cornwall, England) grant permits for water abstraction and discharge. Open-loop geothermal 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 (EA, 2023).

For the specific case of the Cornwall follower site, metalliferous mines do not require permission from the MRA. Presently, accessing the mines for the geothermal or thermal energy storage project requires permission from the land and mine owner as well as planning permission from the competent planning authority (in this case the local authority, Cornwall Council) and the relevant permits from the Environment Agency. In addition, the relevant Health and Safety regulations (regulated by the Health and Safety Executive) need to be observed for any construction workplace.

5. DISCUSSION

HT-UTES technologies, targeted in the PUSH-IT project, are not widely adopted or developed across European countries. As a result, there is no specific regulation for HT-UTES technologies in the project countries and regulation relies on existing legislation that provide a general framework for the permitting and use of UTES technologies.

Regulatory frameworks for HT-UTES differ between the countries in the project, all in general requiring environmental permits, particularly concerning environmental impacts and protection of groundwater, as well as various types of permits from the competent authorities.

Regulation and permitting is based, to different degrees, on laws developed for associated subsurface activities such as low temperature underground thermal energy storage, shallow geothermal energy or other uses of the subsurface, such as groundwater abstraction, in addition to drilling, planning, surface construction works and environmental impact assessment. The level of similarity (i.e. HT-UTES technology compared with the most similar or applicable regulated activity) varies

between countries depending, mainly, on market maturity. This ranges from the most advanced status and mature market in the Netherlands -with specific UTES regulation, roles clearly assigned to competent authorities, available guidance and frameworks in place - to Czechia and the United Kingdom that rely on regulation for associated activities (water abstraction and discharge, drilling, surface works, etc.). Germany is currently on an intermediate state, with geothermal regulated but not as advanced as the Netherlands, especially regarding the higher level of bureaucracy and the roles of the various competent authorities.

The permitting process and role of the competent authorities is indeed one of the main differences found between the countries and sites in the project. In the Netherlands, the new regulatory framework developed to streamline permitting grants and assigns a more relevant role to a single competent authority that manages and coordinate the application. For ATES projects that are part of a larger application (for example a building), the municipality will be the authority managing the application. As a result, the new system will require adaptation to its new role and direct communication and consultation with other authorities, such as the province, which is the competent authority for groundwater use and ATES but releases some pressure to project developers by reducing bureaucracy.

The levels of administration involved in the regulation of UTES also varies between countries. This may constitute a barrier depending on the specific role of each authority, especially regarding factors such as expertise and personnel dedicated to the assessment of permit applications. This analysis has shown how there is an inverse correlation between the level of authorities handling the main applications and the market maturity, from the local (the Netherlands under the new framework) to district (e.g. lower water authorities in Germany), to regional and national (e.g. environment agencies in the UK). This factor, when combined with the absence of clear regulation and guidelines in non-mature markets and with low technological awareness and experience, regulators might follow a “minimum damage approach” and be more restrictive or increase additional requirements for HT-UTES projects to progress, resulting on increasing times and costs.

6. CONCLUSION

PUSH-IT aims to demonstrate the full-scale application and implementation of high-temperature underground thermal energy storage (HT-UTES) in various countries. One of the objectives of the project is, at the same time, to identify the key barriers and enablers for project and technology development and provide a set of recommendations to facilitate the deployment of the technology.

The review and analysis conducted during the first stage of the project have shown how regulation is one of the key factors for project development and could be a cause of delays for projects to progress. However, the specific causes of these “regulatory barriers” are multiple, and range from technology understanding, difficult access to information or lack of guidance, imposition of additional requirements, prolonged project and application evaluation, difficulties on the communication between developers and authorities or between authorities. When some of these are available or facilitated (e.g. online information, guidance, direct and quick communication) constitute, however, enablers for the technology and the projects to progress. These results are currently being combined with site interviews with operators and regulators and will result in the proposal of a series of best practices and recommendations for the development of the technology at each site and at the European level.

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