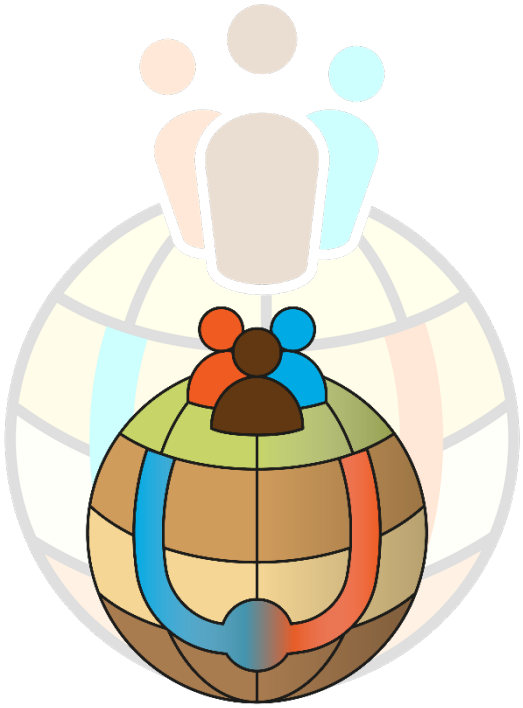

PUSH-IT

Piloting Underground Seasonal Heat Storage In geothermal reservoirs

D2.1 Review of state of the art in geothermal regulation and regulatory barriers and opportunities in different countries, relevant for technologies in use

Funded by
the European Union

Grant agreement number	101096566		
Project title	Piloting Underground Storage of Heat In geoThermal reservoirs		
Project acronym	PUSH-IT		
Start date	01-01-2023	DURATION	48 months
End date	31-12-2026		
Work Package No. and Title	WP2 Public engagement, societal benefit and risks		
Deliverable number	D2.1		
Deliverable title	Review of state of the art in geothermal regulation and regulatory barriers and opportunities in different countries , relevant for technologies in use		
Actual date of delivery	31-01-2025		
Nature	R	DISSEMINATION LEVEL	Public
Deliverable Leader	UXT		
Author	Andres Gonzalez Quiros		
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Disclaimer

Funded by the European Union

Funded by the European Union under the Horizon Europe programme (grant no. 1011096566). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor CINEA can be held responsible for them.

Document history

Version	Description (Section, page number)	Author	Role (Organisation short name)
V0.1	First draft	Andres Gonzalez Quiros, Corinna Abesser, Margaret Stewart	BGS
V0.1a	Review	Iain Soutar Merryn Thomas Katrin Kieling	UXT UXT GFZ
V0.2	Second draft Processed of feedback received from reviewers / partners	Andres Gonzalez Quiros, Corinna Abesser, Margaret Stewart	BGS
V0.2a	Review	Martin Bloemendal Magdalini Kechagia Stefan Klein Antonin Tym	TUD ARU F-IEG CGS
V0.3	Draft final Processed of feedback received from reviewers / partners	Andres Gonzalez Quiros, Corinna Abesser, Margaret Stewart	BGS
V1.0	Final version	Martin Bloemendal,	TUD

Quality control

Author	Organisation short name	Role	Date
Andres Gonzalez Quiros	BGS	Deliverable Leader	09-12-2024
Iain Soutar	UXT	Work Package Leader & Reviewer 1	16-12-2024
Martin Bloemendal	TUD	Reviewer 2	17-01-2025
Martin Bloemendal	TUD	Scientific Project Coordinator	31-01-2025
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Table of Contents

List of tables

List of figures

List of Abbreviations

AGA	Annotated Model Grant Agreement
ATES	Aquifer Thermal Energy Storage
Bal	Environment Activities Decree (Netherlands)
BBergG	Federal Mining Act (Germany)
Bbl	Environment Building Decree (Netherlands)
BGR	Federal Institute for Geosciences and Natural Resources (Germany)
BMWF	Federal Ministry of Education and Research (Germany)
BMWK	Federal Ministry for Economic Affairs and Climate Action (Germany)
BTES	Borehole Thermal Energy Storage
DHN	District heating network
DVGW	Deutscher Verein des Gas (Germany)
EA	Environment Agency (England, UK)
EC	European Commission
EU	European Union
GmbH	Private limited Company (Germany)
HSE	Health and Safety Executive (HSE) (UK)
HT-UTES	High-Temperature Underground Thermal Energy Storage
LCOE	Levelized Cost of Energy
LWG	State Water Act (Germany)
MRA	Mining Remediation Authority (UK)
MTES	Mine Thermal Energy Storage
NRW	North Rhine-Westphalia (Germany)
NSTA	North Sea Transition Authority (UK)
RUB	Ruhr University Bochum (Germany)
SIKB	Foundation for Infrastructure Quality Assurance Soil Management (Netherlands)
UK	United Kingdom
UTES	Underground Thermal Energy Storage
VDI	German Association of Engineers (Germany)
WGH	Water Resources Act (Germany)
WP	Work Package
WRA	Water Resources Act (UK)

1. Introduction

1.1. Project Background

PUSH-IT project 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 high temperature geothermal heat storage technologies: Aquifer Thermal Energy Storage (ATES), Borehole Thermal Energy Storage (BTES) and Mine Thermal Energy Storage (MTES). PUSH-IT works across seven countries and six sites (in four countries), including three demo-sites - **Delft (Netherlands)**, **Darmstadt (Germany)** and **Bochum (Germany)** - to demonstrate full-scale implementation of heat storage in geothermal reservoirs and three 'follower' sites - **Berlin (Germany)**, **Litoměřice (Czechia)** and **United Downs (United Kingdom)** - where future pilots are underway.

In addition to technical implementation, cross-cutting challenges for site specific implementation are investigated at both, the demo and follower sites to develop insights that can be applied across Europe, including:

- Social engagement, societal benefits, and risks and regulations
- Optimal system integration and control
- Enabling technologies

This document is an output of Work Package 2. Public engagement, societal benefit and risk, Task 2 **"Supporting regulation and governance"**. The objective of this task is to reduce the (potential) regulatory barriers for HT-UTES project development. This involves identifying and compiling the key regulations in the countries where PUSH-IT projects are being developed, evaluating the effectiveness of the regulatory framework in terms of achieving its intended purpose (e.g. protection of the environment and people) relative to the administrative effort and processes; and proposing guidelines for an effective and proportionate approach to regulating HT-UTES.

1.2. Purpose of this document

High-temperature underground thermal energy storage (HT-UTES) technologies constitute a special situation for regulation and no specific regulatory framework or official guidelines for either developers or authorities are available. Projects to date are usually pilot or research projects that had to navigate the permitting procedure and adapt to multiple exceptions and additional requirements, leading to delays.

This document forms the regulation review as part of Task 2 in Work Package 2, (hereafter Task 2.2). Knowledge gathered in this document provides the background information for stakeholder interviews undertaken for Task 2.2, exploring how the current regulations work in practice, how stakeholders are engaging in the process and how they perceive its overall effectiveness. The main outcomes and analysis of the interviews are part of years three and four of the project and results will be included in the final project report (see details in section 2.4 of this report).

This document reports the first stage of this work providing a review of the regulation applicable at the demo and follower sites through legislation in their respective regions and countries. It is intended to provide an overview of the current regulatory landscape in which underground thermal energy storage (UTES) projects are considered. The document summarises our understanding of how different UTES systems are regulated in the different countries and regions.

As high-temperature UTES are novel technologies, the availability of information about their regulation varies between the different sites. Often, specific regulation or guidelines for UTES do not yet exist. At some sites, e.g. follower sites, regulatory approaches have yet to be developed and tested. In addition, the legislative landscape is constantly changing. For example, new environmental legislation in the Netherlands has entered into force 1 year after the start of PUSH-IT and regulatory changes that may affect UTES are also currently being discussed in Germany. This document highlights the uncertainties originating from the changing rules and variations. It provides the basis for further exploration through interviews with regulators and operators that will capture the direct experiences at the project sites and help to develop recommendations for an effective regulatory framework.

2. Description of Work

2.1. WP2: General Overview and Objectives

The goal of WP2 is to understand the societal factors influencing the development of high-temperature thermal energy storage and develop recommendations of how regulations, public engagement and sustainable economic models might be developed and optimised to maximise public support and realise the proposed demonstrations as a pathway for achieving a just and sustainable energy transition. It focuses on how geothermal heat storage technologies can be integrated in society, including both engagement from societal stakeholders and recommendations of how to include in legislative frameworks.

WP2 is led by the University of Exeter (UXT) and includes 3 tasks:

- Task 2.1. Societal engagement and social acceptability, led by the University of Exeter and Anglia Ruskin University.
- Task 2.2. Supporting regulations and governance, led by the British Geological Survey.
- Task 2.3. LCOE generating a sustainable energy economy, led by the Universiteit Utrecht.

In PUSH-IT, we take a nuanced approach to societal engagement, where we recognise that societal engagement is complex and should involve a range of actors, including citizens, regulators and operators. By choosing this approach, we aim to develop a set of good practices that take into account the specificities of the local contexts at each of the PUSH-IT sites (including in terms of policy and regulatory frameworks), whilst also drawing out principles applicable more widely.

Within this context, the coordinated work in WP2 will provide information and recommendations to support application and development of regulations and engagement strategies for geothermal storage technology projects at future sites.

2.2. Task 2.2: General Overview and Objectives

Task 2.2 is led by the British Geological Survey. The main objective of Task 2.2. is to evaluate regulatory processes and identify potential regulatory barriers to project success. The work involves a desktop review of existing regulations as well as interviews with regulatory stakeholders and developers/operators with a focus on:

- Identifying existing regulations for underground geothermal storage across the countries of the demonstration and follower sites.
- Evaluation of the effectiveness of existing regulations for geothermal thermal energy storage and identification of existing regulatory oversights, gaps or inefficiencies.
- Identification of desired changes for more efficient, effective, and appropriate regulations to support the application of underground thermal storage projects.

2.3. General Description of the Work

The work in T2.2 has been planned in three-stages, to be performed during the 4 years of the project.

The first stage, which results are presented in Deliverable 2.1 (this document), includes the desk-based review of the regulation at the selected sites and countries.

The second stage includes interviews with stakeholders at the different sites, including operators, regulators and relevant authorities, to better understand regulatory requirements and challenges at the various stages of project development from both, the point of view of the applicant (e.g. the operator) and the regulator (e.g. the responsible authority).

In the third and final stage, the learnings from both stages, together with inputs from other work packages, both social and technical, will be used to evaluate and compare the various legal and governance systems at each site and develop a set of recommendations based on the evidence gathered during the project.

2.4. General Workplan for Task 2.2

The general workplan for Task 2.2 includes the following activities:

1. Desk-based review of existing regulations frameworks at national/regional/local level for thermal storage (or related activities) *[2023 (Q2) – 2024 (Q2)], including:*
   - Identification and mapping of stakeholders (licencing authorities, regulators, industry, etc) at the selected sites [2023 (Q2) – 2023 (Q4)].
   - Writing of deliverable 2.1 (this document) *[2024 (Q3) – 2024 (Q4)]*.
2. Site work and visits
   - Development of interviews and questionnaires and planning of site visits *and Ethics Approval [2024 (Q1)]*.
   - Collection of site-specific data, interviews/site visits *[2024 (Q2) - 2025 (Q1) for demonstrator sites (Delft, Bochum, Darmstadt), and 2024 (Q4) - 2025(Q3) – for the follow-up sites (Berlin, Litoměřice, United Downs)]* to complement information from the review and get inputs for further comparison and recommendations:
     - Regulatory aspects:
       - Temperature limits.
       - Well location and drilling.
       - Monitoring and control.
       - Abandonment and dismantling.
     - Enabling aspects:
       - Guidelines, best practices, masterplans.
       - Public databases.
       - Supporting policies. Subsidies, incentives.
       - Decision-making tools.
       - Groups of experts.
     - Workflows for project development, including permitting procedure and timeline of activities.
3. Evaluation and Comparison [*2024 (Q4) - 2026(Q1)]*.
   - Identification of barriers and drivers, gaps and variations within, and stakeholder perception of, regulatory approaches at each site [*2024 (Q4) - 2025(Q2)]*.
   - Comparison of regulatory practices and development of recommendations for developing underground thermal energy storage regulations *[(2025 (Q1) – 2026 (Q1)]*.
4. Reporting *[2026 (Q1)- 2026 (Q4)]*.

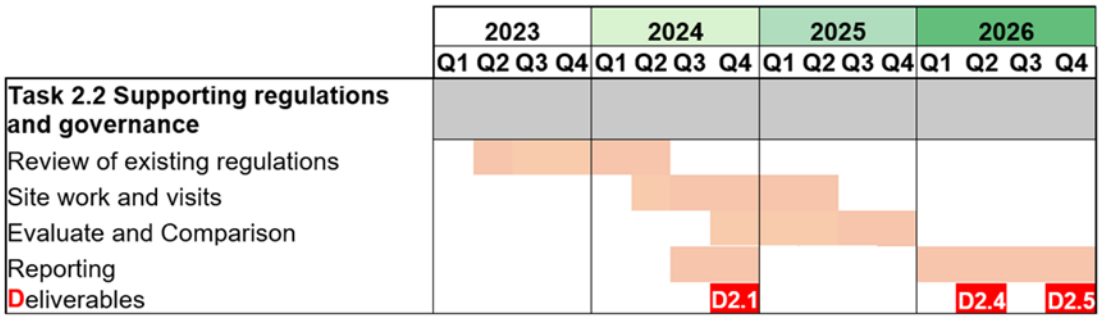

Figure 1: General workplan for task 2.2.

3. The Netherlands

3.1. General Regulatory Framework

3.1.1. Preamble

The Netherlands is a global leader in aquifer thermal energy storage, with a very mature market, hosting about 85% of the world's ATES systems (>3000 systems installed) (Stemmle et al., 2024). The country is also a pioneer in high temperature aquifer thermal energy storage (HT-ATES) which is increasingly used in residential and horticultural areas. The first significant HT-UTES project was installed in the Beijum district of Groningen in 1985, using borehole thermal energy storage (BTES) to store solar heat at 60°C. This was followed by HT-ATES projects at Utrecht University in 1991 and a health care institution in Zwammerdam in the late 1990s, both storing heat at 90°C from combined heat and power (CHP) installations (Godschalk et al., 2021).

The Dutch government supports energy storage through various policies, including financial incentives and a regulatory framework that encourages the adoption of innovative storage solutions. The extensive Dutch legal and regulatory framework for underground thermal energy storage stands out internationally, and regulations are the most mature compared to other countries in this study.

With the introduction of new legislation in January 2024, there has been a change in the general legislative framework, including permitting and decision making for shallow geothermal activities. The main change is related to the permitting procedure and how a single authority handles the application process for projects that require multiple permit applications now all being combined in one permit. For shallow open geothermal systems and ATES, this means that, even when the province has previously been the main competent authority, the municipality is now the authority that handles the permit. Under this new regulation, the province still needs to assess the ATES and retains the right to intervene if local authorities fail to enforce environmental regulations effectively, providing support or taking corrective action where necessary.

3.1.2. General Context under the New Regulations

On 1st January 2024, new environmental and planning regulations came into force in the Netherlands. Development of the regulation started in 2011 with the introduction of the new regulatory system, a process that continued until 2019 and, following various stages, culminated in the enactment of the new Environmental Act (**Omgevingswet**), on 1st of January 2024.

The Environmental Act regulates the physical environment in which people live, work and spend their leisure time. Almost all national legislation on the environment is incorporated in the Act which sets out the rules and laws for spatial planning, housing, infrastructure, the environment, nature, subsurface and (ground)water and defines the roles of national, provincial, regional, and municipal authorities in the regulation. The Act aims to simplify the regulation and permitting process and speed up regulatory decisions.

The Act is underpinned by a policy framework consisting of 6 core regulatory tools (Table 1):

- **The environmental vision.** The national government, the province and the municipality each adopt one environmental vision for their respective administrative territory. This vision defines the main national/regional/local policy and planning and what type of activities are allowed where.

- **The programme.** The programme includes measures to protect, manage, use and develop the living environment. The goal of a program may also be to meet environmental values. The program focuses on a topic, a particular business sector, or an area.
- **Decentralised rules.** The introduction of the Environment and Planning Act meant that several rules were transferred from the national government to provinces, municipalities and water boards. The rules are captured in the respective regulatory document for each responsible authority, i.e. the municipal environmental plan (for municipalities) , the provincial environmental ordinance (for provincial governments) and the water board bylaw (for water boards[1]).
- **General rules.** The general rules contain the most important rules of the Act which are set out within four key environmental decrees: the **Environment Activities Decree (Bal)**, the **Environment Buildings Decree (Bbl) Quality Assurance Decree (Bkl)** and the **Environment and Planning Decree.** These rules form the basis of the regulation, including the tasks and powers of public authorities. The rules also contain the standards for the quality of the living environment that the government sets in environmental values.
- **The environmental permit.** The Act aims to make it easier and faster to gain permission to carry out activities in the physical living environment by applying for an environmental and planning permit. Applicants submit one online application for as many activities they need for their project, and receive one decision, often within 8 weeks (compared to previously 26 weeks).
- **The project decision.** The project decision is a legal instrument for the national government, provinces and water boards used to approve and implement complex projects of public interest or necessity (e.g. infrastructure development, renewable energy installations) that have significant spatial or environmental implications. This is mandatory for some types of projects.

Gradual Implementation

The implementation of the new Environment and Planning Act is gradual, and not all the instruments had to be implemented by the 1st January 2024. Some will follow a step-by-step approach. These include:

- Water Board Ordinance. The water boards have until 1st January 2026 to transition to the new legal framework, integrating their water management tasks into the Act's broader environmental planning and permitting system, and to update existing water board ordinances to align with the Act.
- Environmental Vision of the Municipality. Municipalities are given a transition period until 1st January 2027 to develop and finalise their Environmental Vision.
- Environmental Plan. Municipalities have a transition period until 1st January 2032 to develop the Environmental Plan for their territories, encompassing all spatial, environmental, and water management policies within the municipality's jurisdiction.

[1] Dutch water boards do not directly map to provinces. They are independent regional entities with boundaries based on catchment drainage systems rather than administrative or political divisions like provinces.

3.1.3. General Environmental Regulation

Environment and Planning Act

Omgevingswet- Environment and Planning Act

The Environment and Planning Act (Omgevingswet) is the law that regulates everything in the living environment, including the space in which people live and work. The new law unifies existing regulations and simplifies the application process. It came into force on 1st January 2024.

Environment Decree

Omgevingsbesluit - Environmental Decree

The Environmental Decree (Omgevingsbesluit) covers the rules for environmental permitting, including procedures, enforcement and implementation as well as the Digital System for the Environment and Planning Act (DSO).

General Government Rules

The General Government Rules are the mechanisms that enable the operation of the Environment and Planning Act. These rules are set out in the Environment and Planning Act and the Environment and Planning Decree and include:

- Besluit kwaliteit leefomgeving **(Bkl)** (Environmental Quality Decree) (In full)
- Besluit activiteiten leefomgeving **(Bal)** (Environmental Activities Decree) (In full). Contains the general rules for activities in the physical living environment and applies to all parties that are active, including citizens, companies and the government.
- Besluit bouwwerken leefomgeving **(Bbl)** (Environmental Construction Decree) (In full). Contains the rules on safety, healthy, sustainability and usability of buildings, about the state and use of the buildings and about carrying out construction and demolition work.

The Environmental Regulation (Omgevingsregeling, In full) is the ministerial regulation document that builds in the previous rules (Bkl, Bal and Bbl) and mainly includes specific technical and administrative rules.

Table 1: Core instruments of the government for the implementation of the Environment and Planning Act.

Core Instrument	Municipality	Province	Country (Rijk)	Water Board
Environmental vision	Municipal environmental vision[2]	Provincial environmental vision	National environmental vision	Not applicable
Programme	Action plans and other voluntary and compulsory programmes	Action plans, water programme, management plan and other voluntary and compulsory programmes	Action plans, water programme, spatial plan and other voluntary and compulsory programmes)	Water management programme and other voluntary and compulsory programmes
Decentralised rules	Environmental plan[3]	Environmental Ordinance	Not applicable	Water Board Ordinance[4]
General rules	Not applicable	Not applicable	1. **Omgevingswet**: Environmental Act **Bal, Bbl, Bkl** 2. **Omgevingsbesluit**: Environment and Planning Decree 3. **Omgevingsregeling**: Environment and Planning Regulation	Not applicable

3.1.4. Competent Authorities

In Dutch planning regulation, the competent authority (*bevoegde instantie*) refers to the administrative body designated to process and decide on permit applications, as well as to oversee the implementation of planning and environmental regulations. This authority is responsible for receiving reports, granting permits, ensuring compliance with legal requirements, and enforcing relevant laws and regulations within its jurisdiction. The competent authority can be a municipality, province, or national government body, depending on the nature and scale of the project.

The competent authority and contact point are dependent on the activity. For most permit applications, the Municipality or the Water Board will be the competent authority. This is based on the Decentralisation approach under which the Municipality is the competent authority unless exceptions apply (compiled in the Rules in Activities) because activities are considered harmful or require specific consideration.

For activities considered of national or strategic interest, ministers from the national government may be the competent authority or play a role as advisors to local and regional authorities. For example, regulation of activities like oil and gas exploration and extraction, deep geothermal energy and Carbon Capture and Storage are the responsibility of the Minister of Economic Affairs

[2] Gradual implementation until 01/01/27
[3] Gradual implementation until 01/01/32
[4] Gradual implementation until 01/01/26

and Climate Policy; National water management strategy, protection of the coastline and flood defences or impacts on the environment of national infrastructure (e.g. airports or the national railways), are the responsibility of the Minister of Infrastructure and Water Management.

3.1.5. General Permitting Procedure

One of the objectives of the Environment and Planning Act is to reduce the overall regulatory burden. Therefore, where possible, activities are regulated using general rules. These do not require a permit. Specific activities requiring a permit are defined in the General Rules for Activities, designated by the Provincial government / Municipality/ Water Board in the Environmental Ordinance / the Environmental Plan / the Water Board Ordinance, respectively.

Some activities or projects of national interest require a mandatory Project Decision from the Water Board (for example for the construction, relocation or reinforcement of flood defences); the Province (for the construction or expansion of a wind energy generation facility of at least 5 MW and a maximum of 100 MW) or from the National Government (for multiple projects of general interest including, among others, the construction or modification of motorways and railways, construction or modification of waterways or flood defences, the production of electricity, >50 MW for non-renewable except wind energy which is >100 MW, or of >500 MW if it is non-renewable, the construction and extension of high-voltage grids, the extension or construction of gas transport network or gas infrastructure or the construction of mining works and pipelines).

Environmental Desk

The Environmental Desk (Omgevingsloket) is the central online system through which permit applications are made and managed. It contains all necessary information about the living environment required under the Environmental and Planning Act. It enables applicants to determine whether a permit is needed and who the competent authority is. Applicants must use the Environmental Desk for their permit application and will be issued automatically with a response. The website also includes a map for each location with the rules and policies that apply and provides information about the permits and reporting requirements (if required) and the state of a permit.

The workflow and the options provided are as follow:

1. See a map for the location to see the rules and policies that apply for the current plans.
2. See if permits are required for the intended activity.
3. Check if it is needed to submit a report to the government.
4. Apply for permit.
5. Request a consultation with municipalities.

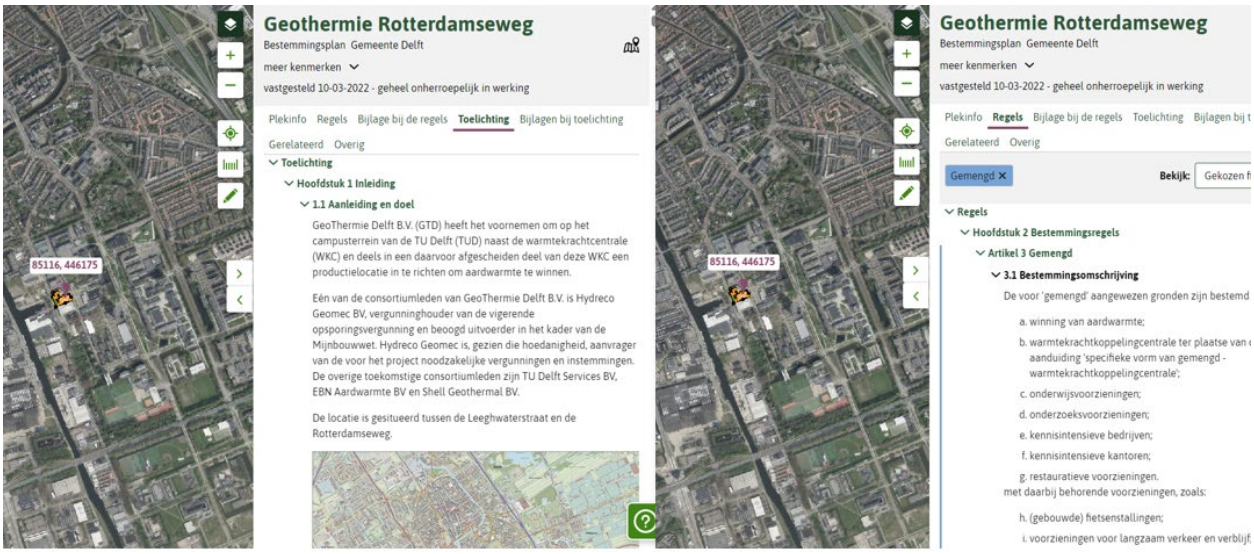

Figure 2: Example of two screenshots from the Environmental Desk for the deep geothermal project in TU Delft.

Supervision and Enforcement

Vergunningverlening, toezicht en handhaving (VTH) - Licensing, Supervision and Enforcement, plays a fundamental role in the implementation of the Environmental and Planning Act. The government has several enforcement instruments to deploy if a citizen or a company does not comply with the rules. These instruments are of three types:

- **Instruments aimed at recovery**. The responsible authority issues penalty charges to anyone failing to rectify activities or violating a rule. They allow a reasonable time (beneficiary period) to pass before penalty charges are issued and costs recovered from an offender.
- **Administrative fee**. This is usually applied when recovery is no longer possible. The administrative fine falls under administrative law, and the fine can be appealed to the court. The General Administrative Law Act (Algemene wet bestuursrecht, Awb) provides the general regulation of administrative fines.
- **Criminal Sanction**. An administrative penalty order (bestuurlijke strafbeschikking, BSB) is used for less serious violations and is regulated by the Code of Criminal Procedure. Under the Economic Offences Act (Wet op de economische delicten, Wed), more severe violations of the Environmental and Planning Act (article 4.3) are prosecuted by the Public Prosecutor's Office and can be taken to the criminal court.

3.2. Regulatory Framework for UTES

3.2.1. General Context – UTES in the Netherlands

Shallow geothermal energy / Underground Thermal Energy Storage (UTES) (bodemenergie) and deep geothermal energy (geothermie) are differentiated by depth and have different regulatory frameworks in the Netherlands.

Deep geothermal energy in the Netherlands refers to depths >500 m. Regulation of these systems fall under the jurisdiction of the ministry of Economic affairs who delegated this task to the State Supervision of Mines and is not included in this review.

Shallow geothermal energy refers to depth <500 m. Two types of technologies are considered:

- Closed-loop systems.
- Open-loop systems.

The construction of both requires a series of general rules, permits and approval steps for the different stages of development, including the mechanical drilling as well as underground and surface construction.

Under the new regulations, in general, UTES systems are considered “magnet activities”, that are associated to a larger or main activity. For example, an ATES system can be a “magnet activity” of the construction of a new building. In such a case, the building would be the focus of the main permit and with all the associated permits are meant to be handled and coordinated by a single authority, in general the municipality.

Relevant regulations and procedures are described below.

3.2.2. General Shallow Geothermal Regulation in the Netherlands

The installation and operation of geothermal energy systems are considered a cross-industry activity. They are included in section 3.2.6 of the Environmental Activities Decree (Bal) which regulates activities that impact the environment, setting out requirements and guidelines to ensure that their operations do not harm public health, safety, or the environment. The activity includes the preliminary investigation for drilling, construction of a geothermal energy system, the use of a geothermal energy system, and the maintenance and cleaning of installed systems. The rules in 3.2.6 Bal do not apply to deep geothermal energy, heat discharges to surface waters or district heating.

The Bal contains environmental rules that apply for shallow geothermal systems. Paragraph 4 of the Bal concerns both closed (§4.111) and open (§4.112) shallow geothermal energy systems.

Closed-loop geothermal energy systems (section 4.111 Bal)

The construction of a closed geothermal system requires notification to the competent authority - in general the municipality (see 0) - at least 4 weeks before the start of the activity. The applicant must provide additional information and documents, including:

- **Floor plan** and **drawings** showing the location of the loops, the centre of the system and the final depth**.**
- **Coordinates** of the centre of the system and its final **depth.**
- **Assessment of risk of Interference.** A document that demonstrates that there is no negative interference with already existing systems or with systems that are planned or for which an environmental permit has been granted.
- **Statement of energy efficiency** that the system will achieve, expressed as the Seasonal Performance Factor.
- **Geothermal capacity** of the closed system and how much of the heating and cooling demand will be me**t.**
- **Contact details** of the person/company responsible for design, installation and construction of the system and of the person/ company responsible for the drilling.

Companies active on the Closed loop UTES market must comply to the market standard and as proof of this have a certification.

Open-loop systems (section 4.112 Bal)

Open-loop UTES (i.e. ATES) systems are considered environmental harmful activities (*milieubelastende activiteit*) and require a permit, according to Article 3.19 of the Bal (Table 2). The responsible authority (the province, or the municipality for multiple applications, see 0) can decide to declare an ATES system a permit-free activity under general rules (2.16 Bal) if there is efficient use of subsurface and water, and abstraction rates are less than 10 m^3/hour. In the case of permit-free system, as for the closed-loop systems, it is forbidden to start the activity without at least 4 weeks' notice.

Table 2: Regulation of shallow geothermal energy systems in the Netherlands (modified from the BUM BE, 2023)

Activity		System Type	
		ATES System	**Closed UTES System**
1	Designation Environmentally Harmful Activity	Art 3.18 Besluit activiteiten leefomgeving (Decree on Activities in the Living Environment)	Art 3.18 Besluit activiteiten leefomgeving (Decree on Activities in the Living Environment)
2	Indication of Permit Requirement	Art 3.19, first paragraph Besluit activiteiten leefomgeving (Decree on Activities in the Living Environment) Possibility for additional permit requirement based on article 2.15, par. 2, under c, Bal An exemption may be granted by for systems < 10 m^3/hour on the basis of Article 2.16 Bal.	No permit requirement on the Besluit activiteiten leefomgeving (Decree on Activities in the Living Environment) A permit might be required for systems within interference areas and a ground-side capacity ≥ 70 kW Possibility for additional permit requirement in environmental regulations based on Article 2.15, paragraph 2, under c, Bal.
3	General Rules	§4.112 Besluit activiteiten leefomgeving (Decree on Activities in the Living Environment)	§4.111 Besluit activiteiten leefomgeving (Decree on Activities in the Living Environment)
4	Custom Rules	Art. 2.12 Bal	Art. 2.12 Bal
5	Custom Regulations	Art. 2.13 Bal	Art. 2.13 Bal

Not all regulations are included in the Bal. Some rules concerning the construction of the system are included in the Living Environment Building Decree (Bbl) or in local regulations such a municipality environmental plan, the province environmental ordinance or the water board legislation. The best way to identify all relevant regulations is to consult the Rules section on the map of the Environmental Desk.

The general rules in the Bal apply in the permit. It is considered that an ATES system complies with the general rules of the Environmental Activities Decree when it meets various requirements. These are listed and described below.

a. Negative Interference

It is stipulated that a new UTES system must not lead to negative interference with other UTES systems in the vicinity for which a notification has been made, or a permit has been granted.

To evaluate the risk of negative interferences, the potential overlap of the hydrological and thermal areas of influence of the existing systems must be assessed by the project developer. Annex 4 of the BUM OBES includes information and decision trees to evaluate interference between ATES systems and between ATES and BTES systems.

Provinces and municipalities can appoint areas where general rules regarding interference are different to allow more optimal planning of ATES wells / BTES boreholes. This is usually done in densely built-up areas where demand for such systems is large.

ATES systems with high pump rates of >50 m^3/h are considered more likely to cause thermal or hydraulic interference with neighboring systems. Interference is defined as temperature changes of 0.5°C and/or groundwater level changes of 0.05 m at the property boundary. The hydrothermal influence area considers 20 years of operation. Additional information is required about other potential impacts such as subsidence, ground settlement, risk of damage to buildings and archeological and geological values, impact on valuable green areas, agriculture and groundwater extractions and infiltrations.

b. Efficiency

Under article 4.1154 of the Environmental Activities Decree it is stipulated that an ATES system should deliver an efficient energy yield, as expressed by the SPF (Seasonal Performance Factor). This value is usually supplied by the designer or installer, and although no minimum requirements are established, the competent authority must include a criterion to grant permits. In addition, some limitations on groundwater use include a standard of minimum productivity of 4.65 kWh/m^3, that assumes an average delta T between abstracted and reinjected temperatures of 4°C.

c. Groundwater Temperature

Typically, regulation requires that for ATES systems, the maximum injection temperature is 25°C, as it is considered that temperatures lower that 25 °C do not have a negative impact on the subsurface (Bonte et al., 2013, Hartog et al., 2013, STOWA, 2022). Typical injection water in the cold well is usually between 5 and 12°C, while the temperature injected in the warm well ranges from 12-25°C.

Bespoke regulation is possible to allow for higher operational temperatures, for example to allow higher-temperature systems. The Environmental Act does not limit injection temperature, the environmental Ruling does. Hence provinces can issue permits for higher temperatures storage systems, however, no general rules are in place for this. As a result, these systems require a dedicated decision from the Provencial board. Currently provincial boards allow HT-ATES as research or pilot projects[5], to learn about their positive and negative impacts and to assess if general rules should be made. For example, by testing or modelling that this activity will not cause chemical or microbiological impacts. In these cases, the province can include additional permit requirements where necessary to protect the environment and the subsurface.

d. Energy Balance

Article 4.1154 of the Bal stipulates that ATES systems must aim to operate as balanced systems, i.e. generating equal amounts of heating and cooling, and must not be under- or over-dimensioned for the anticipated heating/ cooling demand. The Bal specifically stipulates that at least once within a period of 5 years, the amount of heat added must be equal or less than the

[5] As in the HT-ATES project in Delft.

amount of cold added (Research Criteria for Energy Balance - Onderzoek criteria energiebalans. At that time a new period of 5 years starts again until the requirement is met again, etc.

As with the operational temperatures, there are situations where tailor-made regulation can be set and additional requirements included by the relevant authority in the permit. This include heat surplus systems (such as High-Temperature systems), cold surplus systems of limited space, or heat surplus systems if because of other individual systems in the area there is not net warming on the area.

Drilling

The BRL SIKB 2100 provide information and guidance and describe the requirements for drilling, completion and abandonment for wells/boreholes of less of 500 m depth. As with the general legislation, with the new Environmental Act, the BRL SIKB 2100 has been amended. The protocol 2100 compiles the main legal requirements, including a duty of care to protect the subsurface, by preventing the introduction of contaminants or use excessive water, or construction requirements to avoid the creation of preferential flow paths for contamination or mixing of waters from various sources[6]. Companies carrying out these activities must be certified.

All regulations contain prohibitions regarding drilling in groundwater protection areas (except for the purpose of groundwater extraction). These are of various types (an example for South Holland is shown in Figure 3):

- **Water catchment areas for drinking water.** Have the strictest regime and are bounded by a line from which the groundwater in the aquifer needs a maximum of 60 days to reach the abstraction zones.
- **Groundwater protection zones.** Bounded by the line at ground level from which the groundwater will reach the extraction points within 50 years, both vertically and horizontally.
- **Drilling-free zones**. Determined by the (horizontal) travel time of at least 50 years to the extraction points in the aquifer.
- Additional strategic stocks. Same conditions as drilling-free zones.

The provinces have some freedom on defining these zones, and some allow drilling if certain general rules are met.

Considerations about drilling fluids and their discharge are explained in the next subsection.

[6] The BRL SIKB 6000 is a similar document / industry standard for the surface parts of the ATES / BTES systems.

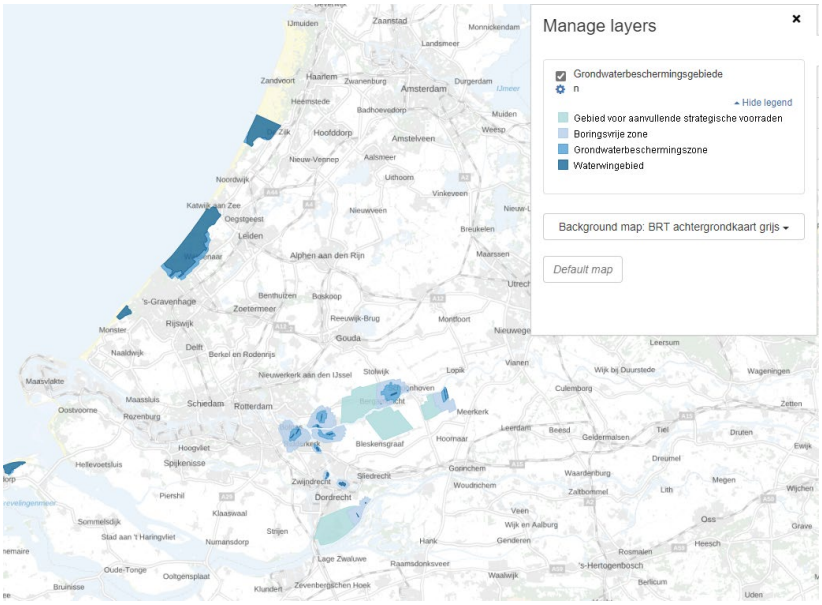

Figure 3: Groundwater protection zones in South Holland (darkest blue for the strictest).

Discharge

Discharge of water into a surface water body during construction or operation of an ATES system is regulated by article 3.19, paragraph 2, of the Environmental Activities Decree (Bal)

> *"The prohibition, referred to in Article 5.1, paragraph 2 of the Environment Act, of carrying out a discharge activity to a body of surface water without an environmental permit shall apply to the discharge of waste water into a body of surface water of waste water activities that are harmful to the environment, as referred to in the first paragraph". (Bal, art. 3.19, par. 2).*

The Water Board is the competent authority for the discharge of water into regional water, while the national government is the competent authority for discharging water into national waters.

The Municipality is the competent authority for discharge of water into a sewer.

Table 3: Regulation of related activities (modified from the HUM BE, 2023)

Activity		System Type	
Discharge (waste water) into surface water		**ATES**	**BTES**
6	Indication of Permit Requirement	Art 3.9, par 2, Bal Possibility for additional requirement by Water Board regulations based on art. 2.15, par. 2, under b, Bal	No permit requirement in the Environmental Activities Decree. Possibility for additional requirement by Water Board regulations based on art. 2.15, par. 2, under b, Bal
Discharge of water from drilling into the sewage system or into the ground			
7	General Rules	No general rules for the discharge activity	Art. 4.1140 Bal, par. 1

3.2.3. Competent Authorities - Netherlands

Construction and Use

For ATES systems, the Province Executive is the main competent authority for both the construction and use of ATES systems for single applications.

However, under the new Environment and Planning Act, the Municipalities can be the competent authorities when multiple applications are made at the same time (such as in applications that include surface construction works). This has the objective of facilitating the evaluation and decision on the application. Within these circumstances, the province can safeguard their interests through the rights of advice and consent, as well as the Water Board (but the WB has not right of approval).

Table 4: Competent authorities in shallow geothermal in the Netherlands

Activity	System Type	
	Open Ground Source Energy System	**Closed Ground Source Energy System**
Construction and Use	Province Executive / Municipality (when multiple applications are made) The province and the Water Board advice and consent (the Water Board does not have right of approval)	Municipality
Supervision and Enforcement	Province (for general rules). Municipality (for additional permit requirements and customized rules).	Municipality
Discharge of waste water	**On surface water**	**On soil or sewer**
	Water Board or National Government	Municipality or Province Executive

Supervision and Enforcement

The province is the competent authority for supervision and enforcement of ATES systems. However, the municipality can include custom rules and additional permit requirements than those considered in the general rules. In these cases, the municipality is the competent authority for supervision and enforcement but only for the customized rules. Because of this it is required consultation between both the municipality and the province and that appropriate agreements are in place for the division of supervision and enforcement rules.

Details on the supervision and enforcement of open-loop geothermal energy systems are detailed in the HUM OBES.

Discharge of Waste Water

For discharge of water on surface water the Water Board (for discharge on regional waters) and the National Government (on national water) are the competent authorities (Table 4).

For discharge of waste water on soil or sewer the municipality is the competent authority.

3.3. Permitting Procedure for ATES

3.3.1. General Framework

For ATES system, the BUM BE deel 1 - OBES (Handreiking besluiten open bodemenergiesystemen) presents the requirements for open shallow (up to 500 m depth) geothermal systems. This is a key document providing guidance for decision makers and for the competent authority. The last version of this document (version 3; June 2023) was written to be used from the 1st January 2024, with the entry into force of the new Environmental Act.

The BUM BE OBES does not address the aspects related to the installation of the ground energy system, the installation during the operational phase and the decommissioning of the systems, which fall under the HUM BE OBES (HandhavingsUitvoeringsMethode voor open bodemenergiesystemen).

3.3.2. General ATES Permit

The permit procedure varies depending on whether an Environmental Impact Assessment (EIA) report is required. If this is not required, a **regular procedure** is followed. When an EIA is required, the procedure is a **Uniform Public Preparatory procedure** (openbare voorbereidingsprocedure, UOV) is required, and this applies to the entire multiple application.

Activities requiring an EIA are listed in the Annex V of the Environmental Decree. ATES are not considered as an activity requiring an EIA.

Under a regular procedure, the general Environmental Permit[7] application includes various steps. The procedure is summarised below, more details can be found in the BUM and HUM OBES guidelines.

The main steps include:

1. Pre-consultation. Determines the legal framework and procedure, check whether an EIA is necessary. The environmental desk is used to check what permits are required and for the application.
2. Permit application:
    a. Check if the system meets the general rules by complying with the Environmental Activities Decree in order to:
        i. Prevent negative interference.
        ii. Meet requirements regarding efficient use of geothermal energy and energy efficiency.
        iii. Meet groundwater temperature limits (maximum 25°C).
        iv. Meets energy balance considerations.
    b. Multiple applications. For multiple applications, under the new Environmental Decree, it is stipulated that only one competent authority can decide on the application. For these cases the municipality will be the competent authority

[7] Before introduction of the new Environmental Act in 2024 the main permit was named the Water Act permit. This was the permit application submitted in 2023 for the Delft demonstrator project.

Permit Application and Procedure

Companies and legal entities submit the application digitally[8]. The administrative body that received the application must confirm the receipt with date of reception and the decision period begins. The competent authority shall also confirm that it is the authorised entity to decide on the application and explain what procedure will be followed for granting the permit.

Following EU regulation reflected in Dutch Law and based on a policy to accelerate the deployment of renewable energy (EU 2022/2577), a permit procedure for ground source heat pump may not take longer than 3 months and the competent authority has to grant the environmental permit within this timeframe.

When no EIA is required, the decision period takes a maximum of 8 weeks, with possibility of extending by another 6 weeks. If there is conflict or other authorities are involved in the process who might have the right of approval an additional extension can also be considered.

Elements in the Decision

The environment permit generally contains four elements:

1. Reason. Date of receipt of application, and documents received and belonging to the environmental permit environmental ordinance.
2. Decision. With the outcome of the application decision that can be refused, granted or not processed.
3. Regulations. Here additional conditions and requirements under which the authority grants the permit are included.
4. Justification. Indicates why the permit has been granted or refused, and details aspects of the construction, operation and whether the project is compatible with the protection of the water quality.

The competent authority can include additional information useful for the applicant in the development of the system. This is usually provided as an appendix, separate from the main environmental permit.

Objection and Appeal

When the decision is published, instructions and timeframes for appeal are provided. In general, appeals should be submitted to the court within 6 weeks of the publication of the decision.

3.3.3. Drilling and Construction

Requirements for the drilling process are compiled in the BRL SIKB 2100. When a project developer requests mechanical drilling, the drilling company must demonstrate that the work falls within its expertise and technical competence and show that it complies with the requirements from the SIKB certification scheme.

A detailed design and plan of approach must be produced and followed, and the construction comply with the Working Conditions Act.

All information of the construction must be included in an action plan, including the purpose of drilling, depths, diameters, flow rates, number of filters, materials, and expected durability. This information can be requested at any point by the client, the competent authorities (including the municipality, the province or the water board), or to be included in the online tools such as WKOtool.

[8] Citizens can submit paper applications, but this is not common for open shallow geothermal systems.

A summary of legal requirements is included in Table 5.

Table 5: Summary of requirements for drilling boreholes for shallow geothermal energy. More detailed information is available in the SIKB Protocol 2101.

Requirement	Legislation	Assessment
Use of soil and groundwater and prevention of spread of contaminants	Environmental Act and associated legislation, additional provincial regulations and water board requirements.	Demonstrate that requirements have been checked for the drilling location. Operations only start after a permit has been obtained or mandatory notification has been submitted. All the conditions have been incorporated into the Action Plan.
Working Conditions	Working conditions act (Arbeidsomstandighedenwet)	Use of personal protective equipment (PPE). Gas monitoring at drilling location.
Prevent damage to underground cables, pipes and structures	Above-ground and underground networks and networks (ICT) Act (Wet informatie-uitwisseling bovengrondse en ondergrondse netten en netwerken)	Notification has been submitted to the Land Registry. Information about drilling locations regarding the presence of cables and pipes has been requested. Any presence and safety measures are included in the Action Plan.

3.3.4. Monitoring and Reporting Obligations

Monitoring and reporting general obligations are compiled and explained in the HUM BE OBES. Special monitoring obligations can be added for specific projects.

The operator / permit holder must monitor and keep a record of the following information:

1. The amounts of heat and cold that the system adds to the soil/subsurface at least every 15 minutes with a measurement accuracy less than or equal to 5%. This is needed to calculate the energy efficiency using the Seasonal Performance Factor (point 3).
2. The quantities of heat and cool added to the soil from the date on which the system was put into operation (calculated from 1).
3. The annual energy efficiency using the Seasonal Performance Factor (DWA SPF registration and reporting memorandum,) (calculated from 1).
4. The average monthly temperature of the groundwater discharged into the soil.

The information and documents shall be provided annually (article 4.1150a Bal) to the competent authority before the 1st April each year.

3.3.5. Decommissioning

At the end of the activity, the permit holder must perform a series of actions to decommission the boreholes safely (Article 4.1157 Bal), including (section 7 of the SIKB Protocol 2101):

- The underground part of the system up to a depth of 10 m is removed and restored. The initiator does not remove the deeper parts.
- Sealing and backfilling the borehole with impermeable grout or clay to prevent mixing of water from different aquifers. The casing is not removed to prevent collapse of the borehole. The sealing material should have a hydraulic conductivity of less than 10^{-9} m/s and how the sealing operations are performed is established in the Protocol requirements.

The rules for the decommissioning apply to all constructed open-loop geothermal systems, except those whose permit has been granted before 1st July 2013.

3.4. Regulation and Permitting for HT-ATES

As HT-ATES systems operate at temperatures higher than 25°C and with a heat surplus to the subsurface (meaning the system is not in equilibrium), the general rules do not apply to HT-ATES systems.

HT-ATES are only permitted as exceptions if 1) the interests of protecting the subsurface and the groundwater are not compromised and 2) there is an additional interest because of higher efficient energy use.

A permit application under these premises is assessed against various criteria, that impose additional requirements to those for normal ATES (that are included in the BUM OBES). Because these criteria are outside of established regulation, both the applicant and the competent authority do not have guidelines to follow, either to supply the specific information in the permit application, or to make an informed decision on this application. As a result, this might lead to extended periods to reach a decision or granting of permits that might cause harm to the environment because of incorrect design or assessment as requirements may vary across different authorities.

Because the BUM OBES is limited to ATES under the general rules, specific guidance for HT-ATES is not easily accessible for developers and authorities. Bloemendal et al. (2021) developed a guidance document within the WarminUp programme as part of the WINDOW project with application requirements and criteria for assessment of the application for an HT-ATES permit.

Some of the effects of high temperatures on groundwater quality were reported by Schout and Hartog (2020) and compiled by Bloemendal et al. (2021) as part of the WINDOW project and include:

- Acceleration of chemical and microbiological reactions.
- Faster breakdown of sedimentary organic matter. From 40°C also increased Dissolved Organic Carbon.
- Changes in the sorption of some substances, either increased or decreased.
- Higher solubility of silicates.
- Reduced solubility of carbonates which in groundwater with high concentration can lead to precipitation (mainly from 40-60°C) causing well clogging problems.

With the introduction of the new legislation in 2024, some of the regulations and permit workflows for UTES systems have changed. This could lead to project delays and complications. In addition, new research results can provide additional information to refine and add certainty to some of the measures provided in the previous guidelines.

A key aim of PUSH-IT is to further understand HT-ATES systems and reduce the uncertainty for the development of HT-ATES. New information gathered at PUSH-IT's Delft site, and interactions with the competent authorities, will be used to inform new approaches and develop a new set of guidelines for a faster project approval and development.

Information of the HT-ATES project in Delft is included below with information about the permitting at the end of 2024 when this report has been produced. It must be noted that the project started in 2023, before the implementation of the new legislation in 2024.

3.5. Delft (HT-ATES)

3.5.1. Technical Background

The High Temperature Aquifer Thermal Energy Storage (HT-ATES) system at the TU Delft campus will be integrated in the TU Delft district heating network (DHN), currently fed by gas boilers and a combined heat and power (CHP) unit, with a current maximum required capacity of 35 MW. The current CHP supply will be replaced by a geothermal well producing heat at around 75-80°C from a sandstone reservoir at a depth of over 2 km.

The current TU Delft demand is 160-190 TJ/yr, but it is expected to be reduced by insulation measures to approximately 80 TJ/yr by 2040. The district heating network will be extended to the city of Delft from 2025 onwards. The extended DHN will increase demand to up to 120 TJ/yr by 2030 and to 200-400 TJ/yr towards 2040.

The geothermal wells, called DAPwells ("Delft Aardwarmte Project" wells) will replace the boilers and CHP as the primary heat source for the campus district heating network and will also be the heat source for loading the HT-ATES. The maximum flow capacity is 375 m^3/h, at an approximate temperature of 75-80°C. The minimum flow rate is 80 m^3/h. To meet the required temperature in the DHN during peak demand, a heat pump will be placed between the DAPwell and the DHN to increase the supply temperature. The heat pump can also be used to increase the water temperature of HT-ATES during charging conditions at low or negative energy price conditions. The target storage capacity of the ATES system is 25-50 TJ (considering a storage volume of 400,000 - 800,000 m^3).

The HT-ATES will be used to store excess geothermal heat from the deep wells during periods of low heat demand that can be recovered in periods of high heat demand. To meet the desired flow rates and heat demand the HT-ATES system requires 2 hot wells (of 80°C and up to 90°C) and 3 warm (colder) wells of 50°C. These are increased temperature compared to conventional ATES systems that operate at lower maximum temperatures of around 25°C.

Given the required storage volume (between 400,000 and 800,000 m^3) and an aquifer thickness of 40 m, a minimum distance of 200 m has been calculated as necessary between the hot and the warm well clusters. The distance between the production wells within each cluster is approximately 10 m and has been considered a thermal radius (the more or less cylindrical volume of warm/cold water around the well; Bloemendal et al., 2018) of ~50 m. The infrastructure will be completed with an observation well (pilot well), fibre optic boreholes and, possibly, an EM (electromagnetic / geophysics) borehole (Figure 4).

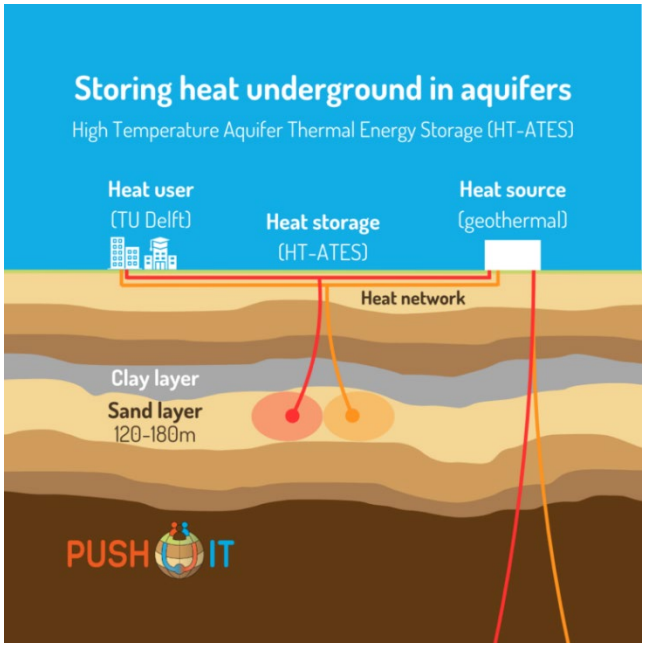

Figure 4: Infographic showing the concept design of the project with the HT-ATES wells used to store high-temperature from the deep geothermal wells.

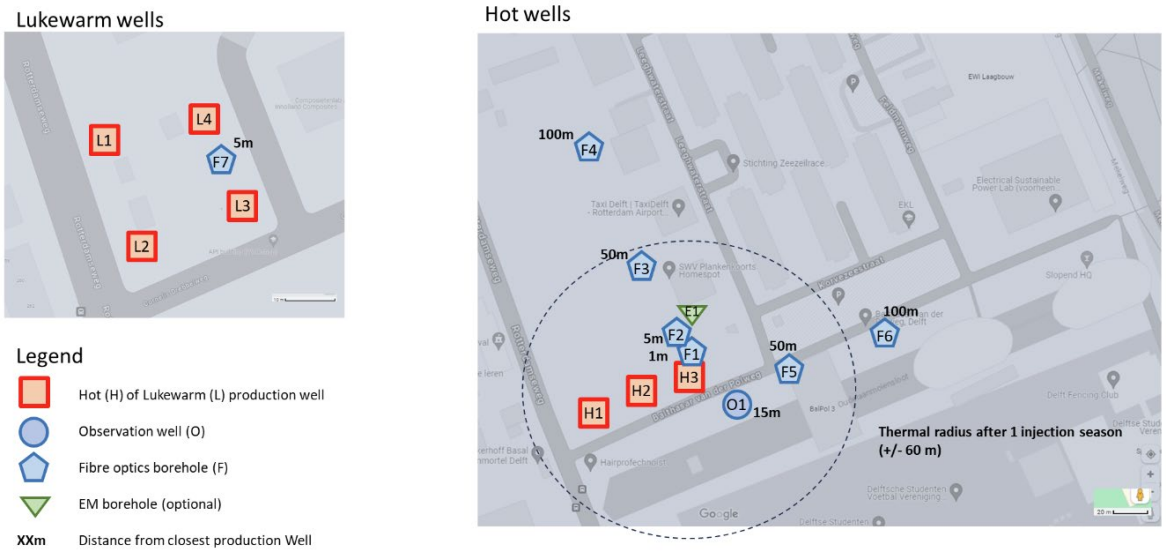

Figure 5: Location of the hot and warm wells in the Delft campus.

3.5.2. Site History

The projected initial location of the hot wells was moved 1) to avoid impact with the cold wells of a low temperature ATES located in a shallower layer nearby (which was not assessed in the initial feasibility), and 2) because of new BTES wells located near the initial site planned for the hot wells (installed after the feasibility study and therefore not known before). The final design is shown in Figure 5. This process has caused some delays, including the permitting process.

The first exploratory and observation well (O1 in Figure 5) was drilled by Haitjema in Spring 2024. The well was drilled to a depth of 220 m with the objective of characterising the subsurface for the heat storage project. Initial results show potential for heat storage in the sand layer in the depth ranging between 120 and 180 m depth.

Prior to installing the ATES, the drilling of the two DAPwells had been completed at the end of 2023. The abstraction well reached a depth of 2931 metres in borehole length and 2341 metres vertical depth. The injection well, completed in December 2023, reached a depth of 2580 m. Following the construction of the wells the next stages to connect with the heat network is being carried out in 2025. With the new mining law[9] in force since 1st July 2023, the next stages in the deep geothermal project have required new permits (https://mijnbouwvergunningen.nl/page/view/e0f9f1c8-3282-48c2-b277-d61287f9464b/delft-i), as the drilling and extraction permits were obtained separately. At the end of September 2024, the deep geothermal project entered a new phase that includes the construction of the heat pump building for future the connections with the heat network Delft. More details of the deep geothermal project in Delft and updates of the construction are available in the project website: https://geothermiedelft.nl/.

3.5.3. Stakeholders

Authorities

Delft Municipality (Gemeente Delft)

The municipality has policy in place to plan ATES systems because of the high demand of these systems. It can influence policy on a local level. Under the new regulatory framework, the municipalities will have a more important role as the main contact point and will handle permits for multiple activities, but there is still a transition and adaptation period as outlined above.

South-Holland Province (Provincie Zuid-Holland)

The province previously had a key role in the coordination and issuing of ATES permits. With the new law, the municipality is the new coordinator, although there is still some adaptation because of the recent changes. The province keeps the coordination of everything related to groundwater, but it is not clear yet how the communication and coordination across municipality and province will be done under the new legislation.

Delfland Water Board (Hoogheemraadschap van Delfland)

The Water Board has no competences in subsurface activities related to deep groundwater or geothermal, however, for discharges to surface waters, such as during well testing or during maintenance work, this is the competent authority, and a permit is required as explained in 0.

Neighbourhood / Clients

TU Delft

- *Faculty of civil engineering and geosciences (CEG)*: Coordinator of the PUSH-IT project and doing the research on the HT-ATES system.
- *Campus Real Estate (CRE)*: Responsible for buildings and physical environment at the campus. Responsible for the heat supply of the buildings. CRE also manages the subsurface infrastructure and physical environment and is a key stakeholder in identifying

[9] The new Mining Act is of application for deep geothermal (considered at depths of more than 500 m), but it is not of application of the HT-ATES project which is the focus of this report which target is 120-180 m depth.

the well locations and locate connecting pipes. CRE also owns and operates the LT-ATES at the campus, close to the HT-ATES well, but in a shallower aquifer.

- *TU Delft services (TDS)*: holding that takes part in enterprises on behalf of TU Delft.

Commercial

Geothermie Delft (GTD)

A joint venture of TDS, Shell, EBN and AARDYN/EQUANS, who jointly own the geothermal well at the TU Delft campus (https://geothermiedelft.nl/en/). On behalf of GTD, AARDYN is the intended operator of the geothermal well. It is the intention that GTD will also own and have AARDYN operate the HT-ATES, as their operation is strongly interconnected. However, because the owner of AARDYN is selling the company, AARDYN cannot currently invest in the HT-ATES. Shell and EBN are able and willing to invest in the HT-ATES. Until the end of the realisation phase of the TU Delft, Shell and EBN agreed to equally contribute to the required costs of the HT-ATES (on top of the costs funded by the EC in PUSH-IT, and additional ~4.5 m€ is needed to make the system). In the course of the realisation, it is expected that a new owner of AARDYN will be willing to invest, to get everything aligned with GTD. If not, a separate entity owned by TDS, Shell and EBN will be created to own and operate the HT-ATES. AARDYN and EQUANS are both partner in PUSH-IT and currently have a special role in GTD and development of HT-ATES. They will carry out the required activities needed to realise the HT-ATES, within and outside PUSH-IT.

3.5.4. Permitting

The main permit for the ATES before the introduction of the new Environmental Act in 2024 was the Water Act[10] permit (**Waterwet**), as the HT-ATES Delft permit was applied for before 2024, January 1st, this was still the legal rule in place. This Water Act was policy neutral embedded in the Environmental Act. So apart from the Municipality being the main point of entrance, the same procedural steps were followed as described above for the Environmetnal Act. The permit was issued in January 2025 by the Regional Environmental Agency (Omgevingsdienst Haaglanden) on behalf of the South Holland Province Executive. The province was the relevant authority and the legislation harmonised in the Wijzigingsbesluit bodemenergiesystemen (WbBES) (Soil Energy Systems Amendment Decree)[11], which regulates these activities up to 500 m depth. For the specific case of the High Temperature Storage, because of the higher operational temperatures (>25°C) and the energy imbalance (net warming of the subsurface) these types of projects are not considered within the normal ATES framework that helps provinces in the decision-making process (BUM BE deel 1 - OBES).

As part of the permit application, it is required an environmental impact study on the effects of the ATES in the surrounding environment. An assessment guideline and protocol (BRL SIKB 11000) must be used as they form the certification scheme for the underground parts of the geothermal energy systems. The environmental impact assessment was performed in 2023, and the permit application was submitted in December 2023. The permit application also included a request to inject and abstract tracers as part of the hot Push-Pull Tests to be performed during the characterisation stage.

After the Water Act permit is obtained, the operators and permit holders must design a monitoring plan that has to be approved by the competent authority. In the monitoring plan is based on ATES

[10] Large parts of the Water Act have been transposed to the new Environment Act, that entered into force in January 2024. More details are provided in this document.

[11] The Environment and Planning Act introduced in 2024 has changed rules for open geothermal energy systems and might result on delays in the application process.

monitoring requirements, but because of the specific characteristics of this project the is a set of extended and additional requirements using as a reference the extended framework. Among the monitoring to be included this includes piezometers at the ATES and monitoring wells, groundwater sampling to determine chemical and microbiological changes and fibre optic DTS monitoring.

For drilling and testing of the pilot monitoring borehole a permit was submitted to the province. For testing, notification for discharging the abstracted water was submitted to the Local Delfland Water Board.

4. Germany

4.1. General Regulatory Framework

4.1.1. General Context – Federal Government

Germany has significant potential for thermal energy storage systems, particularly for aquifer thermal energy storage (ATES) (Stemmle et al., 2022). While shallow geothermal systems are well established, the market for thermal energy storage systems is still emerging with only 2-4 installed ATES systems identified in a recent survey (Stemmle et al. 2024).

Regulations are evolving to support this growth, with the Federal Climate Change Act 2019 (an amended in 2024) aiming for carbon neutrality by 2045. However, the regulatory landscape is complex, involving national and regional laws, and regulatory processes vary between the different federal states (Bundesländer), involving different authorities, requirements and timescales.

While the regulatory system for shallow geothermal systems is well established, its application to thermal energy storage is still emerging. Germany comprises sixteen federal states (Bundesländer), and the regulation of geothermal energy is largely set and controlled by the individual states. A number of general Federal Laws for water, mining, etc. form the basis of regulation for the whole country, and additional provisions at each state provide additional specifications for most of the activities. This section includes information of the general laws at federal level with relevance for the UTES technologies in PUSH-IT. The review also includes some preliminary understanding of the new geothermal regulation that is being drafted and will lead to important changes for geothermal projects.

Specific legislation, relevant authorities and details of the permitting procedure relevant to PUSH-IT are developed later in more detail for each individual state in which a site is being developed: the **Darmstadt** site is situated with the state of **Hesse**, **Bochum** within **North Rhine-Westphalia**, and **Berlin** within its own city-state but with links to Brandenburg.

Generally, geothermal drilling and operations are regulated depending on depth; shallower systems are regulated by state water authorities, and deeper systems by state mining authorities. Drilling requires notification to the mining authority at depths of more than 100 m (this will change with the new regulation), and operational temperature limits are considered in the regulation. State geological surveys are involved in the process with respect to data provisions, monitoring, and some aspects of regulation.

4.1.2. Federal Legislation

An overview of the relevant federal legislation in Germany is provided below, including some new legislation that has come into force in 2024. The review also includes our preliminary understanding of the new geothermal regulation that is currently being drafted and is expected to lead to important changes for geothermal projects.

Water Resources Act (WGH)

Gesetz zur Ordnung des Wasserhaushalts* - *Act on the Regulation of the Water Balance

Full citation:

["Wasserhaushaltsgesetz vom 31. Juli 2009 (BGBl. I S. 2585), das zuletzt durch Artikel 7 des Gesetzes vom 22. Dezember 2023 (BGBl. 2023 I Nr. 409) geändert worden ist"][12]

The WGH (2009) is the main piece of legislation regarding water resources in Germany since it entered into force in 2010, it contains provisions for the protection of surface water and groundwater, water management and flood protection.

Federal Mining Act (BBergG)

Bundesberggesetz - Federal Mining Act

Full citation:

["Bundesberggesetz vom 13. August 1980 (BGBl. I S. 1310), das zuletzt durch Artikel 4 des Gesetzes vom 22. März 2023 (BGBl. 2023 I Nr. 88) geändert worden ist"][13]

The Federal Mining Act (BBergG) regulates the exploration for and extraction of raw materials and minerals. It applies to mining activities at depth of >100m.The act distinguishes between so-called “bergfreie” (free-to-mine, i.e. not automatically owned by the surface landowner) and “grundeigene” (land-owned) mineral resources. “Bergfreie” mineral resources are not included in land ownership, but the right to appropriate them must be obtained through an independent authorisation procedure before operating licences can be granted. Geothermal energy is a “bergfreie” resource that currently is regulated under BBergG – except for systems <100m deep which do not fall within the scope of the mining law.

Geological Data Act (GeoIDG)

Gesetz zur staatlichen geologischen Landesaufnahme sowie zur Übermittlung, Sicherung und öffentlichen Bereitstellung geologischer Daten und zur Zurverfügungstellung geologischer Daten zur Erfüllung öffentlicher Aufgaben - Law on the state geological survey and on the transmission, securing and public provision of geological data and on the provision of geological data for the performance of public tasks

Full citation:

["Geologiedatengesetz vom 19. Juni 2020 (BGBl. I S. 1387)" Ersetzt G 750-1 v. 4.12.1934 I 1223 (LagerstG) und V 750-1-1 v. 14.12.1934 I 1261 (LagerstGDV)][14]

This regulation introduces an obligation for the responsible authorities (typically the state geological surveys) to secure data from geological investigations and to ensure the permanent availability of the data. It also standardizes the obligations for the submission of geological data across the entire federal territory and establishes rules for the public availability of geological

[12] Water Resources Act of 31 July 2009 (Federal Law Gazette I p. 2585), as last amended by Article 7 of the Act of 22 December 2023 (Federal Law Gazette 2023 I No. 409)

[13] Federal Mining Act of 13 August 1980 (Federal Law Gazette I p. 1310), last amended by Article 1 of the Act of 14 June 2021 (Federal Law Gazette I, p. 1760)

[14] Geology Data Act of 19 June 2020 (Federal Law Gazette I p. 1387)" Replaces G 750-1 of 4.12.1934 I 1223 (LagerstG) and V 750-1-1 of 14.12.1934 I 1261 (LagerstGDV)

data derived from both, public as well as commercial investigations. Under the Act any geological investigation must be notified to the competent authority no later than 2 weeks before it starts. The Sates might add specifications and stipulate the scope of the Act for geological investigations up to 10 m depth.

Environmental Impact Assessment Act (UVPG)

Gesetz über die Umweltverträglichkeitsprüfung – Environmental Impact Assessment Act

Full citation:

["Gesetz über die Umweltverträglichkeitsprüfung in der Fassung der Bekanntmachung vom 18. März 2021 (BGBl. I S. 540), das zuletzt durch Artikel 10 des Gesetzes vom 23. Oktober 2024 (BGBl. 2024 I Nr. 323) geändert worden ist "][15]

The UVPG regulates environmental impact assessment (EIA) procedures in Germany. EIA are European and international requirements for some types of activities and include potential impacts of a project on humans and the environment. The competent authority responsible for approving the project must evaluate the information of the EIA. The act includes the requirements to complete an EIA, and in Annex 1 it provides a list of projects subject to EIA.

Geothermal projects subject to EIA can be those in points 13.3 (abstraction or discharge of groundwater) and 13.4 (deep drilling for the purpose of water supply. For abstraction, projects of more than 10 million m^3 per year require an EIA, while those of more than 100,000 m^3 or if are more than 5,000 m^3 and can significantly adverse groundwater-dependent ecosystems require general or location-specific preliminary examinations of the individual case. Deep drilling requires a general preliminary examination of each specific case.

Heat Planning Act (WPG)

Wärmeplanungsgesetz– Heat Planning Act

Full citation:

["Wärmeplanungsgesetz vom 20. Dezember 2023 (BGBl. 2023 I Nr. 394)"][16]

The recently passed Heat Planning Act (passed on December 2023 and entered into force the 1st of January 2024) is an instrument for the implementation of heat transition at the local level. The aim of the Act is to provide more security to stakeholders and ensure a better coordination for the development of the energy infrastructure and heat supply in towns and municipalities. A key element in the Act is the requirement of designation of heat supply areas. The Heat Planning Act compliments, and is aimed to be coordinated, with the Building Energy Act, which also entered into force the 1st of January 2024.

[15] Act on Environmental Impact Assessment in the version published on 18 March 2021 (Federal Law Gazette I p. 540), which was last amended by Article 13 of the Act of 8 May 2024 (Federal Law Gazette 2024 I No. 151

[16] Heat Planning Act of 20 December 2023 (BGBl. 2023 I No. 394)

Building Energy Act (GEG)

Gebäudeenergiegesetz– Building Energy Act

Full citation:

> *["Gebäudeenergiegesetz vom 8. August 2020 (BGBl. I S. 1728), das zuletzt durch Artikel 1 des Gesetzes vom 16. Oktober 2023 (BGBl. 2023 I Nr. 280) geändert worden ist"]*[17]

The new Building Energy Act regulates and sets the requirements for the energy performance and use of renewable energy in buildings and the issuing of energy performance certificates. The main rule is the mandatory switch to main supply from renewable energies when installing new heating systems. From January 2024, any newly installed heating system in a new development area must use at least 65% renewables, although there are transitional periods that give cities and municipalities a specific timeframe to adjust and comply with the new regulations. For example, large cities (over 100,000 inhabitants) have until 1st July 2026 to comply with the new regulations while smaller cities (under 100,000 inhabitants) have until 1st July 2028. The Act also regulates which energy efficiency standards applies to new roofs, windows and insulated walls.

Federal Climate Adaptation Act (KSG)

Bundes-Klimschutzgesetz **– Federal Climate Adaptation Act**

Full citation:

> *["Bundes-Klimaschutzgesetz vom 12. Dezember 2019 (BGBl. I S. 2513), das zuletzt durch Artikel 1 des Gesetzes vom 15. Juli 2024 (BGBl. 2024 I Nr. 235) geändert worden ist"*[18]

The amended Federal Climate Adaptation Act sets the national carbon reduction targets. Greenhouse gas emissions shall be progressively reduced (compared to 1990) by at least 65 % by 2030, at least 88 % by 2040, and, by 2045 net greenhouse gas neutrality must be achieved. After 2050, negative greenhouse gas emissions are to be achieved.

Other Federal regulations to be considered

In addition, there are some Federal Laws– e.g. the Repository Site Selection Act (StandAG) or the Administrative Procedures Act (Verwaltungsverfahrensgesetz - VwVfG) – that need to be considered. These are not further discussed here as they are related to planning, but not specifically to geothermal energy.

New Upcoming Regulations

Geothermal Heat Acceleration Act (GeoWG)[19] (“*Gesetz zur Beschleunigung der Genehmigung von Geothermie-Anlagen, Wärmepumpen sowie Wärmespeichern*)

New regulations are being drawn up (at the end of 2024) in the form of the Geothermal Heat Acceleration Act (GeoWG) (“*Gesetz zur Beschleunigung der Genehmigung von Geothermie-*

[17] Building Energy Act of 8 August 2020 (BGBl. I p. 1728), last amended by Article 1 of the Act of 16 October 2023 (BGBl. 2023 I No. 280)

[18] Federal Climate Protection Act of 12 December 2019 (Federal Law Gazette I p. 2513), last amended by Article 1 of the Act of 15 July 2024 (Federal Law Gazette 2024 I No. 235)

[19] As with the new regulation in other countries, new German regulation aims to implement and translate to national level EU regulation, especially those in the DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources.

Anlagen, Wärmepumpen sowie Wärmespeichern, GeoWG"). The draft bill proposes a new set of laws to collectively establish the legal framework for simpler and faster development and expansion of geothermal infrastructure, heat pumps and storage systems[20]. It includes several amendments to the Federal Mining Act (BBergG) and the Water Resource Act (WGH), as well as exemptions from approval requirements for certain projects.

The bill will also establish a predetermined priority for development of geothermal projects. Where relevant, we will mention the new regulations.

German Bureaucracy Relief Act IV (Viertes Bürokratieentlastungsgesetz)

Most imminent is the German Bureaucracy Relief Act IV (Viertes Bürokratieentlastungsgesetz) which will come into effect on 1 January 2025. Article 35 includes an amendment to the BBergG Section 3 Paragraph 3, 2, b, to which it specifies that as mineral free resource from boreholes with a depth of 400 m or more. Under this amendment, near-surface geothermal systems (<400 m) do not fall within the scope of mining law, and thus mining law approval procedures will no longer be required for near-surface geothermal systems. This will be an important change; currently, mining law applies to all drillings > 100 m deep.

4.1.3. Competent Authorities and Regulators – Federal Government

The Federal Ministry for Economic Affairs and Climate Action (Bundesministerium für Wirtschaft und Klimaschutz, or BMWK) is responsible for country-wide federal policy relating to energy, industry, and climate action. It also provides funding such as for the SKEWS[21] project that has cofounded the HT-BTES project in Darmstadt.

The BMWK also oversees the German Federal Institute for Geosciences and Natural Resources (Bundesanstalt für Geowissenschaften und Rohstoffe, BGR) which advises the German Federal Government on geological aspects of geothermal energy, as well as on mining and groundwater. The BGR also collects data on behalf of the government alongside state geological surveys.

Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research) provides funding for research projects and institutions, such as for example the project SpeicherCity, a collaborative project to evaluate models for the system integration of aquifer storage systems, or funding for the HT-ATES project in Berlin.

4.1.4. Competent Authorities and Regulators – Länder (States) in PUSH-IT

Table 6 compiles the main authorities in the three German States and cities where PUSH-IT projects are being developed. Government authorities are the various levels of administrative government at city, region or state level.

[20] https://www.noerr.com/en/insights/geothermal-energy-update-draft-acceleration-law-for-heat-transition-presented-to-parliament

[21] https://www.geo.tu-darmstadt.de/geothermie/forschungsprojekte_ag/laufende_projekte_ag/skews.en.jsp

Table 6: Summary of agencies and authorities in the three German States (Länder) included in this project.

	Government Authority	Groundwater Regulator	Mining Regulator	Geological Survey/equivalent
Darmstadt / Hesse	Darmstadt Regional Council (Regierungspräsidium Darmstadt) State of Hesse Hessian Ministry of Agriculture and Environment, Viticulture, Forestry, Hunting and Homeland (Hessisches Ministerium für Landwirtschaft und Umwelt, Weinbau, Forsten, Jagd und Heimat)	Hessian Agency for Nature Conservation, Environment and Geology (HLNUG) (Hessisches Landesamt für Naturschutz, Umwelt und Geologie) The Lower Water Authority Darmstadt (Gewässer Überwachung)	Mining authority - Darmstadt Regional Council (Unwelt and Energie – Bergbau).	Hessian Agency for Nature Conservation, Environment and Geology (HLNUG)
Bochum / North Rhine-Westphalia	City of Bochum (*Stadt Bochum*) Arnsberg District Government (*Bezirksregierung Arnsberg*) State of North Rhine-Westphalia (*Landes Nordrhein-Westfalen*)	Lower Water Authority Bochum (*Untere Wasserbehörde State Bochum*) Upper Water Authority Arnsberg District Government (*Obere Wasserbehörde Bezirksregierung Arnsberg*)	Department 6: Mining and Energy in NRW of the Arnsberg District Government (*Abteilung 6 "Bergbau und Energie in NRW" der Bezirksregierung Arnsberg*)	Geological Survey NRW (*Geologische Dienst NRW*)
Berlin / Brandenburg[22]	State and City-state of Berlin (*Bundesland / Stadtstaaten Berlin*)	Water Authority of Senate Department for Mobility, Transport, Climate Protection and the Environment Berlin (*Senatsverwaltung für Mobilität, Verkehr, Klimaschutz und Umwelt Berlin*)	State Office for Mining, Geology and Raw Materials State Brandenburg (LBGR[23]) (*Landesamt für Bergbau, Geologie und Rohstoffe Land Brandenburg*)	Senate Department for Urban Development, Construction and Housing "Department of Integrative Environmental Protection" Berlin (*Senatsverwaltung für*

[22] Berlin is an independent City State but some of the competent authorities, such as LBGR, are shared with the neighbouring State of Brandenburg.

[23] Higher state authority subordinate to the Ministry of Economic Affairs, Labour and Energy of the State of Brandenburg

	Government Authority	Groundwater Regulator	Mining Regulator	Geological Survey/equivalent
				Stadtentwicklung, Bauen und Wohnen - Integrativer Umweltschutz Berlin)

4.2. Germany – Hesse. Darmstadt HT-BTES

4.2.1. General Regulatory Framework for Geothermal and UTES

The Darmstadt PUSH-IT site is a demonstration BTES (MD-BTES) system. Requirements for geothermal energy regulations and permitting in Hesse are firstly set out by the regulations of the German Federal Mining Act (BBergG, see Section 4.1.2 of this report). Subsequently, Geothermal and Geothermal Energy Storage projects in the state of Hesse are regulated by the Mining (Bergamt) and Water authorities of the Darmstadt Regional Authority, including the lower water authority for the Darmstadt-Dieberg region. Regulation is also carried out by the Hessian State Agency for Nature Conservation Environment and Geology (HLNUG).

4.2.2. Geothermal Regulation in Hesse/Darmstadt (in addition to the Federal Laws)

Guidelines for deep geothermal drilling were published by Darmstadt Regional Authority and the Hessian State Office for Environment and Geology in 2011 and are under revision. Further documentation, largely focused on shallower systems and published by the Darmstadt Regional Authority and HLNUG were published in 2019.

Further details on these publications can be found here:

https://rp-darmstadt.hessen.de/umwelt-und-energie/bergbau/geothermie

Details of water protection requirements are outlined by the lower water authority (through the Ministry of Agriculture and Environment, Viticulture, Forestry, Hunting and Homeland). Details and regulations can be found here:

https://rp-darmstadt.hessen.de/umwelt-und-energie/gewaesser-und-bodenschutz

Water-related regulations for systems up to 30kW were published in January 2022 and are valid until the end of December 2024. Details can be found here:

https://www.rv.hessenrecht.hessen.de/bshe/document/VVHE-VVHE000018149

Mining Authority

For drilling in the state of Hesse that penetrates more than 400m below the surface, and has a heat output greater than >30kW, regulations set out in the German Federal Mining Act (BBergG, see Section 4.1.2 of this report) must be complied with. This requires the notification and involvement of the regional Mining Authority (Bergamt), who will specify what further actions are required.

For exploration and operational activities, a main operating plan is submitted to the mining authority for approval and subsequent permitting; the operating plan is usually valid for 2 years. The main operating plan provides an overview of the project and usually requires details of all activities associated with exploration, to include geophysical surveying, exploratory drilling and background modelling, as well as details of the project finances, workforce management, insurance, a quantitative risk assessment and health and safety. The main operating plan may include full details of the operation and contracting, or it may be possible to supply these later as special operating plans or supplements if the operator does not yet have these details while in the initial planning phase.

After submission of the main exploration plan, the mining authority will request further information or changes, and if these are approved, a license for exploration is granted.

Once exploration is complete, the Mining Authority is also responsible for regulating the operation of geothermal and storage sites. Detail of the operational plans may be included in the main

operational plan (valid for 2 years) or may be additional to the main plan. Details for operational planning are required to include information regarding: size and workforce of operators; information on location and boundaries; company information; details of the local authority works council; occupational safety; mining rights; property rights; geology and 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 mining authority specifies that the operational report must address the possibility of natural seismicity, and a quantitative risk assessment for the hazards associated with operation. Finally, the operational plan must address plans for the decommissioning of the site after operations are finished.

After submission of the operational plan, the mining authority will request further information or changes, and if these are approved, a license for operation is granted. The involvement of the mining authority ceases after all operating plans are approved, and implemented, and when it is considered that the operation will pose no risk to the life and health of all third parties, other mining operations, and deposits which are protected.

Water

For geothermal boreholes and heat storage in the state of Hesse, permissions are also required under water law. The degree of regulation is based on the type of water regime where each federal territory is split into three water regimes and managed by the lower water authority:

- Favourable areas – where hydrological and water management are favourable (outside of a water protection area; not in a catchment area for public drinking water; not in an area of contaminated land or groundwater contamination), and no separate assessments are required.
- Unfavourable areas – where hydrological and water management are unfavourable, and separate assessments for the project are required.
- Unauthorised areas – where no installation is permitted.

If a geothermal project in a favourable area does not exceed 30kW heat output, then the application for permission from the water authority can be simplified and does not require a full permission process through the mining authority. This simplified regulation tends to apply to systems such as those used for domestic heat pumps. Further details of the simplified planning procedure can be found here: https://www.rv.hessenrecht.hessen.de/bshe/document/VVHE-VVHE000018149.

Otherwise, the geothermal project must apply to the water authority for a permit, which involves submitting full details of the planned testing, monitoring and concept for the site. This plan may also be reviewed by experts from HLNUG at the request of the lower water authority.

4.2.3. Competent Authorities in Geothermal Projects – Hesse/Darmstadt

- Hessian Agency for Nature Conservation, Environment and Geology (HLNUG) (https://www.hlnug.de/)
- Darmstadt Regional Government Mining Authority (https://rp-darmstadt.hessen.de/umwelt-und-energie/bergbau)
- The Lower Water Authority Darmstadt area (https://www.ladadi.de/bauen-umwelt/landwirtschaft-und-umwelt/wasser.html)
- Hessian Ministry of Agriculture and Environment, Viticulture, Forestry, Hunting and Homeland (Hessisches Ministerium für Landwirtschaft und Umwelt, Weinbau, Forsten, Jagd und Heimat) (https://landwirtschaft.hessen.de/).

4.2.4. Permitting Procedure – Hesse/Darmstadt

For the Darmstadt HT-BTES project, the first steps of permitting related to drilling. As the boreholes were planned to penetrate more than 400 m beneath the surface, the first part of permitting involved an application to the Mining Authority (Bergamt) of the Darmstadt Regional Authority. The mining authority then required a detailed operation plan.

A 30-page operating plan was submitted to the Mining Authority with full details of the exploration and operating plan. Further information was requested and then submitted to the mining authority relating to:

- StandAG §22: The site must not be considered for nuclear waste disposal
- §11 BNatSchG: An expert report on species protection for the drilling site had to be obtained

Because the Darmstadt HT-BTES project deals with heat storage with a larger output than 30 kW, a permit and further assessment had to be authorised by the lower Water Authority. A report on the planned testing and monitoring concept was also submitted to the Water Authority and reviewed by experts from HLUNG.

The permitting process was then followed in conjunction the Mining and Water Authorities as described in Section 4.2.2 above. A summary of the project phases as outlined by the Mining Authority is show in Figure 6.

project phase	1	2	3	4	5
Required application documents	Application -Permission	Main operating plan for the exploration	Application approval	main operating plan for extraction and processing	final operating plan
activity of the entrepreneur on site		exploration		Operation	decommissioning

Figure 6: Example of project phase procedure from Darmstadt Regional Mining Authority.

4.2.5. Technical Background- Darmstadt BTES project

The Darmstadt Borehole Thermal Energy Storage (BTES) project is located at the Lichtwiese Campus of the Technical University of Darmstadt, and is a medium-deep demonstration BTES (MD-BTES) system with three deep geothermal borehole heat exchangers installed to a depth of 750 m. The MD-BTES system targets deeper crystalline rocks for heat storage. The boreholes are insulated in the upper part to reduce potential heat losses and minimise the risk of adverse effects on the shallower aquifer system. MD-BTES systems also require fewer boreholes compared to a conventional shallow BTES (see Figure 7 and Sass et al., 2024; Seib et al., 2024).

The Darmstadt MD-BTES will be integrated into the district heating system of the TU Darmstadt (scheduled for 2025). The overall aim is to store excess heat (mostly in the summer months) from various sources including the gas district heating network (DHN) at TU Darmstadt, solar panels on campus and the TU Darmstadt high-performance computing facility. Temperature on injection

from the district heat network is anticipated to be around 20°C to 45°C, then increased to temperatures around 55 - 75°C by high temperature heat pump before being returned to the DHN (Sass et al., 2024). The demonstration site aims to accomplish a storage capacity of 270kW, or around 20 TJ per year.

4.2.6. Site History

Two 2D seismic profiles were acquired in March 2021 to support geological interpretation of the TU Darmstadt Lichtwiese site. Gravimetric data was collected from 267 stations in February and March 2022, and along the location of the seismic profiles at 10 metre intervals. Further gravimeter readings were taken at TU Darmstadt Lichtwiese campus, over a total of 10 days in 2022. Further, electrical resistivity tomography (ERT) was used to acquire 18 2D profiles across the study site, and perpendicular to the margins of proposed geological boundaries (Seib et al., 2022; 2024).

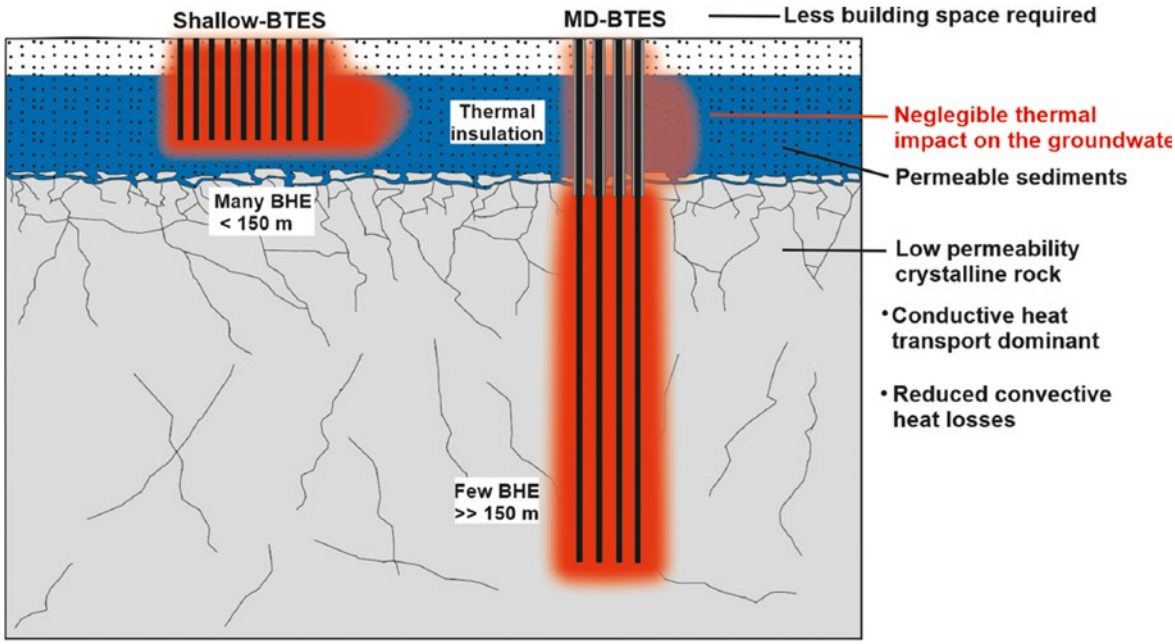

Figure 7: Characteristics of a MD-BTES compared to conventional shallow BTES. Copied from Figure 1 of Seis et al. (2024).

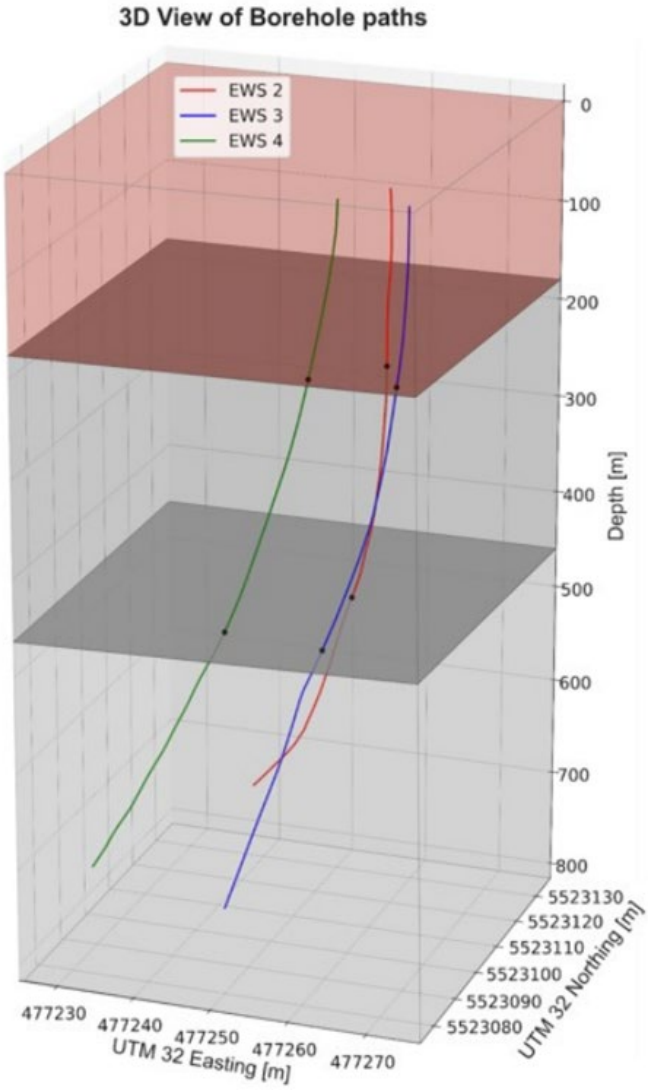

Figure 8: Borehole paths at TU Darmstadt showing vertical deviation and site spacing for the three boreholes (EWS 2, 3, 4). Copied from Figure 6 of Sass et al., (2024).

Drilling operations at the site began in 2022. In February, three groundwater monitoring wells were drilled to depths between 24.5 m and 36.5 m using a rotary drill. In June 2022, construction and drilling began of four MD-BTES boreholes using a pneumatic hammer system; these were insulated in their upper part to a depth of 46 m. After switching to rotary drilling, one of the boreholes was deferred, and three boreholes were completed to depth of 750 m. The boreholes are sited with a surface spacing of around 8.66 m to achieve efficient spacing of around 5 m at depth for maximum thermal efficiency (Sass et al., 2024). Maintaining the anticipated vertical spacing between boreholes is important in MD-BTES systems to achieve optimum thermal efficiency in reservoir. However, the use of rotary drilling meant that some deviation occurred from the designed spacing averaged to around 5.0° from vertical and equivalent to around 20 m horizontally (see Figure 8). Current work (as of October 2024) includes numerical modelling and enhanced geothermal response tests (Seib et al. 2022; 2024).

4.2.7. Stakeholders

TU Darmstadt hosts the project site at its Lichtwiese campus. Stakeholders include:

Neighbours/Clients

- Geothermal Science and Technology: research group at TU Darmstadt is co-ordinating the activity(https://www.geo.tu-darmstadt.de/geothermie/arbeitsgruppe_ag/index.en.jsp).
- Department V – Construction Management and Technical Operations are responsible for construction and maintenance at TU Darmstadt (https://www.intern.tu-darmstadt.de/verwaltung/dez_v/index.en.jsp).
- Department IV - Real Estate Management is responsible for property, occupational safety and environmental safety at TU Darmstadt (https://www.intern.tu-darmstadt.de/verwaltung/dez_iv/index.de.jsp).
- The boreholes at TU Lichtwiese are also part of the SKEWS (Seasonal Crystalline Borehole Thermal Energy Storage) project within the Geothermal Science and Technology research group at TU Darmstadt (https://www.geo.tu-darmstadt.de/geothermie/forschungsprojekte_ag/laufende_projekte_ag/skews.en.jsp). Other projects operation using the pilot SKEWS site include EnEffCampus (https://www.tu-darmstadt.de/eneff/eneff_campus/index.en.jsp) and HOCLOOP (https://www.hocloop.eu/).
- The Leibniz Institute for Applied Geophysics (LIAG) is a project partner for SKEWS and is a non-university-based research group based in Hanover established in 1999. Previously, LIAG was part of the Geological Survey of Lower Saxony (https://www.leibniz-liag.de/en/institute.html).

4.3. Germany – North Rhine-Westphalia

4.3.1. General Context

This section provides a general framework on the geothermal regulation landscape in North Thine-Westphalia, summarising the most important rules and procedures that apply to shallow geothermal and thermal energy storage projects, and compiles some guidelines and documents of interest with links to the originals.

The North Rhine-Westphalia government (NRW) published in April 2024 a **Geothermal Energy Masterplan** (Masterplan Geothermie). It is expected that by 2045 geothermal energy will account for about 15-20% (between 25-30 TWh) of the total heat demand. It is expected that shallow geothermal will be the main technology, with a growth rate driven by legal requirements especially related to the entry into force of: a) the **Building Energy Act** (***Gebäudeenergiegesetzes - GEG***) in January 2024, which included CO2 reduction measures to increase renewable energy use and end fossil fuel use in buildings by 2045; and b) the **Heat Planning Act** (***Wärmeplanungsgesetz - WPG***), which included requirements for all municipalities to develop heat plans. NRW presented in August 2024[24] the first draft of the State Heat Planning Act that passes responsibility to municipalities to draw up heat plans with the aim of providing additional information and security to citizens and developers.

The NRW Geothermal Energy Masterplan includes a roadmap with a series of measures to accelerate the development of geothermal (shallow, medium-deep and deep, especially hydrothermal) projects, including protection against discovery risks, collecting and making available additional geological data through the NRW Geological Survey, introduce new funding mechanisms, accelerate the permitting and approval mechanisms and increase public awareness and acceptance.

Among the legal framework, the NRW government aims to revise current legislation and harmonise the approval process to reduce legal uncertainty. It is also expected that shallow geothermal will be removed from Mining Law.

Water management requirements for the use of shallow geothermal energy are compiled in Wasserwirtschaftliche Anforderungen an die Nutzung von oberflächennaher Erdwärme (LANUV-Arbeitsblatt). The document is being revised and updated as part of the geothermal strategy developed in the Masterplan.

The short document **Utilization of geothermal energy (geothermal energy) in North Rhine-Westphalia** (Nutzbarmachung geothermischer Energie (Erdwarme) in Nordrhein-Westfalen) outlines the fundamental guidelines and regulations for the sustainable use of geothermal energy in the region.

4.3.2. Geothermal Regulation (in addition to the Federal Laws)

Some of the Federal Laws compiled in 4.1.2 have specific and additional requirements and rules in the state Acts. Of direct application

State Water (Landeswassergesetz) Act (LWG)

Wassergesetz für das Land Nordrhein-Westfalen - ***Water Act for the State of North Rhine-Westphalia***

[24] https://www.land.nrw/pressemitteilung/waermewende-erfolgreich-gestalten-land-legt-entwurf-des

Full citation:

["Wassergesetz für das Land Nordrhein-Westfalen - Landeswassergesetz – LWG vom 08. Juli 2016 "][25]

In addition to the WHG, the State Water Act (LWG) for NRW determines the activities that require notification, authorisation, approval and licensing in the state.

Environmental Impact Assessment Act (UVPG-NRW)

Gesetz über die Umweltverträglichkeitsprüfung* - *Environmental Impact Assessment Act

Full citation:

["Gesetz über die Umweltverträglichkeitsprüfung im Land Nordrhein-Westfalen (Landesumweltverträglichkeitsprüfungsgesetz – UVPG NRW) Vom 29. April 1992"][26]

The Act provides additional specification to the Federal Law, although in principle this is not relevant to shallow geothermal or thermal energy storage projects like the HT-MTES developed in PUSH-IT that will have lower abstraction rates. In cases of high abstraction rates and some location- and project-specific circumstances an EIA might be required.

4.3.3. Competent Authorities in Geothermal Projects

Mining Authority

The **Department 6 "Mining and Energy in NRW"** of the Arnsberg District Government (https://www.wirtschaft.nrw/bergbehoerde), is the Mining Authority in NRW. The Authority seats in Dortmund and has more than 200 employees.

Water Authority

The upper water authorities are the five district governments of Arnsberg (where Bochum is located), Detmold, Düsseldorf, Cologne and Münster.

The districts and cities act as lower water authorities. In general, for cities with a population of more than 200,000 there is a lower water authority (Bochum is about 370,000 people). The **Lower Water Authority of the City of Bochum** (Untere Wasserbehörde) is responsible of the protection of surface water and groundwater and of the monitoring of water use in the city.

Geological Data Competent Authority

The **Geological Survey of North Rhine-Westphalia** (Geologischer Dienst NRW), based in Krefeld, is the competent authority in the application of the Geological Data Act. It has the tasks of the geological survey of the state and the collection, and provision of geoscientific data for the administration, business and science.

[25] Water Act for the State of North Rhine-Westphalia - State Water Act - LWG from July 8, 2016

[26] Act on Environmental Impact Assessment in the State of North Rhine-Westphalia (State Environmental Impact Assessment Act – UVPG NRW) of 29 April 1992

4.3.4. Specific Regulatory Elements for Open Shallow Geothermal Systems

Temperatures

According to section 48 (WGH) the introduction of substances in groundwater is only allowed if there is no detrimental change to groundwater quality. Temperature changes are tolerable within regional natural limits. In general, minimum and maximum injection temperatures are 5°C and 20°C, with a maximum Δ of ±6°C.

Hydrogeological Conditions

All groundwater must normally be returned to the same aquifer and groundwater horizon, and usually to the uppermost groundwater level (exceptions can be considered by the water authority as part of the approval process). Only the water abstracted from the aquifer can be reinjected, and there must be no additional connections for water consumption other than for the heat pump.

Requirement for completion of EIA depends on the volume of water. For annual abstractions of more than 10 million m^3 it is necessary to obtain a permit with EIA approval (13.3 in Annex 1 of the UVPG). For lower abstraction rates[27] it is only needed a justification with the water board.

Drilling

Drillings to depths >100 m or drillings that are not located on the same parcel of land as the heat utilization requires notification to the competent mining authority, as required by the BBergG. If this is not the case, a permit from the water authority as part of the water abstraction project is required.

An online platform (https://www.bohranzeige.nrw.de) is available in NRW to notify drilling activities. Through the platform, it is possible to report the activities to the Geological Survey and to the Mining authority of NRW. Consideration of potential methane related issues must also be given. The NRW Mining Authority has made available a document (Bohrungen in Bereichen mit dem Georisiko Methangas) including key aspects and potential risks.

In any case, drilling activities must comply with the Geological Data Act regarding notification and deposit of data.

The drilling must be reported to the Geological Survey NRW (GD NRW) no later than two weeks before the start of the works. Drilling information and results must be deposited with the Geological Survey in NRW (GD NRW) no later than three after completion of the drilling works. The GD NRW online platform (https://www.bohranzeige.nrw.de) can be used for these.

Operational Monitoring

An operation log with recording of water level and temperatures during abstraction and before reinjection must be kept and presented to the water authority upon request. Temperatures must be kept within the limits explained above. The quantity of water extracted and discharged must be read at least once a month and added to the operation logbook. Maintenance obligations are specified as general duty of care (section 5 WHG).

Any changes to operations, such as new mechanical equipment, mode of operation, flow rates or intended use of the abstracted water must be reported to the authority at least two months in advance.

Additional monitoring requirements are necessary for installation in areas with risk of methane gas emissions.

[27] The planned maximum abstraction rate for the HT-MTES in Bochum is 5,000 m^3.

Decommissioning

In NRW this is regulated by the LWG (section 33) which refers to sections 22 and 25.

End of operation requires authorization and must be reported at least two months in advance and the well must be dismantled in accordance with the technical rules.

Additional Requirements for Thermal Energy Storage

In systems where heat (or hot water) is introduced in the subsurface the operator must ensure that no adverse effects on groundwater are caused by the activity. The water Authority will assess whether the activity can cause a negative impact.

A distinction is made between those systems operating at maximum temperatures of 20°C and medium to high TES (operating between 20-90°C).

4.3.5. Permitting process

Application of Water Law

Sections 8, 9 and 49 of the WGH (Water Resources Act) and section 34 of the LWG (NRW Water Act) regulate the notification and approval obligations for the construction and operation of a shallow geothermal system.

The use of aquifers for geothermal energy is a type of use of water bodies and therefore requires a water permit (§ 9 WHG). The point of contact for the notification and application of the water permit is the Lower Water Authority of the respective district or independent city.

In addition, the LWA must be notified of activities that can affect the quality, flow or level of groundwater must be notified at least one month before the work begins (WHG). For the specific case of NRW, under certain circumstances the notification obligation is not required for very shallow installations as specified in the LWG. In any case, even if a permit is not required, notification to the water authority is recommended.

Application of the mining law

When a geothermal development is done across properties or for drilling depths of more than 100 m the project has also to notify the Mining Authority,

According to the BBergG (Section 3), a mining-free natural resource can only be explored or extracted with a mining license. If this is the case all the extraction and related activities are subject to this license. However, if it is related to the land (for example geothermal probes in the same land of the building that these will supply) is not considered extraction (section 4 of the BBergG), and, in fact, according to section 4, paragraph 3, clause 2 of the BBergG, “the use of geothermal energy is equivalent to further processing” and therefore in these circumstances geothermal use does not fall under the BBergG. The BBergG does not provide either legal basis for thermal or hydraulic effects on neighbouring properties in these cases.

Another exception is the introduction of heat (thermal energy storage) if there is net heating of the subsurface. If there is both injection and extraction of heat, the application of the mining law must be examined for cases where systems are intended to extract more heat energy from the subsurface in the long term that was originally introduced (BBergG, section 4, paragraph 2).

The point of contact for mining law related activities is the Mining Authority (Arnsberg Government, Department of Mining and Energy in NRW). The application must submit an operation plan according to sections 54 and 55 of the BBergG.

Geological Data

In any case, the geological investigations must be reported to the competent authority, the geological survey of NRW (GD NRW) according to the Geological Data Act, at least two weeks before the start of the project. Results and information of the geological investigation must be submitted to the competent authority no more than 3 months after the end of the geological investigation. Additional details and requirements can be found in the explanatory leaflet prepared by GD NRW.

Information about the subsurface conditions for the planning of geothermal systems in NRW is available in https://www.geothermie.nrw.de/. Among the information available are the areas with best conditions and potential for various geothermal settings (including shallow and deep geothermal), the location of wells and boreholes as well as the distribution of water protection areas (Figure 9).

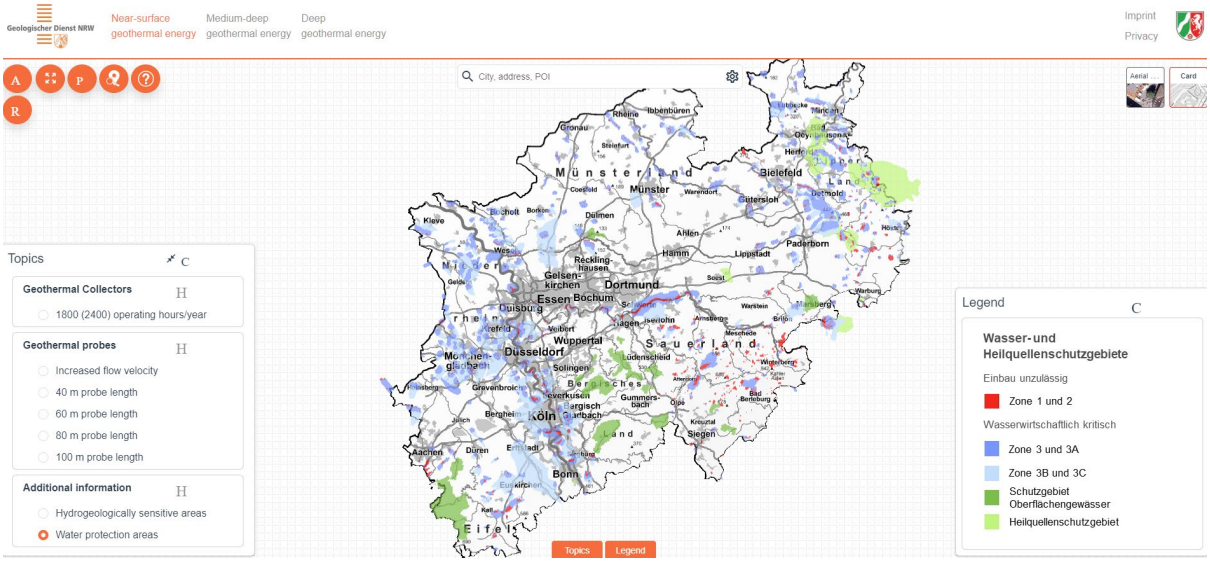

Figure 9: Screenshot from the portal of geothermal information from the Geological Survey in NRW.

Standards and Certifications

The construction of the geothermal system must be in accordance with the Standards developed by the German Association of Engineers (Verein Deutscher Ingenieure, VDI): "VDI 4640 – Thermal use of the subsurface"[28].

Drilling companies should have a certification W 120 from the DVGW (German Technical and Scientific Association for Gas and Water). Complete documentation including geological logs, details of the installation, and details of well completion must be retained to provide evidence in case of assessment or malfunctions.

[28] https://www.vdi.de/fileadmin/pages/vdi_de/redakteure/richtlinien/inhaltsverzeichnisse/1540489.pdf and https://www.vdi.de/fileadmin/pages/vdi_de/redakteure/richtlinien/inhaltsverzeichnisse/3041420.pdf

4.4. Germany - Bochum (HT-MTES)

4.4.1. Technical Background

The MTES will be installed in the Mansfeld Colliery, at the Ruhr University technical centre and will be integrated in the university's heating and cooling network, currently fed by gas fired boilers and a CHP unit with a capacity of 9 MW. The local heating network also supplies heat to approx. 4,800 apartments, 760 houses and 115 other buildings. Supply temperatures are in the range 80-120°C. The aim is to use the mine water from an abandoned colliery to store waste heat, at approximately 30°C, from the technical/data centre (700 kW peak load) (Figure 10). The target storage capacity is between 2 and 8 TJ (considering an available storage volume of 5,000-7,000 m^3).

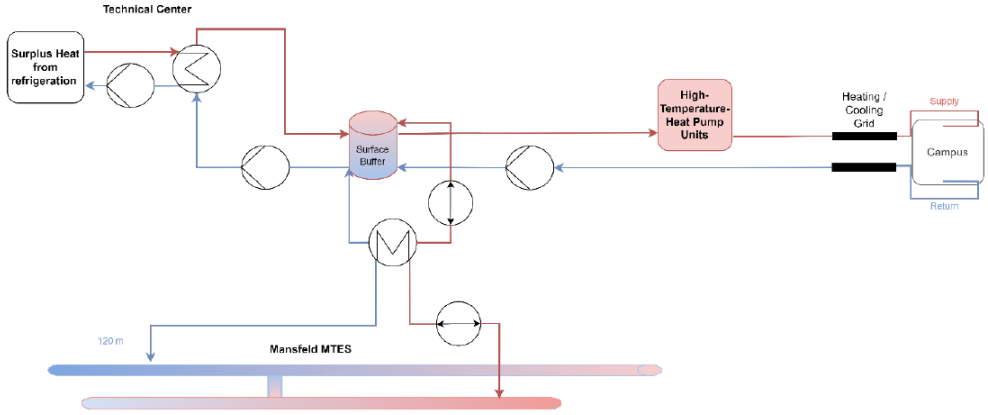

Figure 10: Schematic diagram of the MTES integration in the heating and cooling network at RUB.

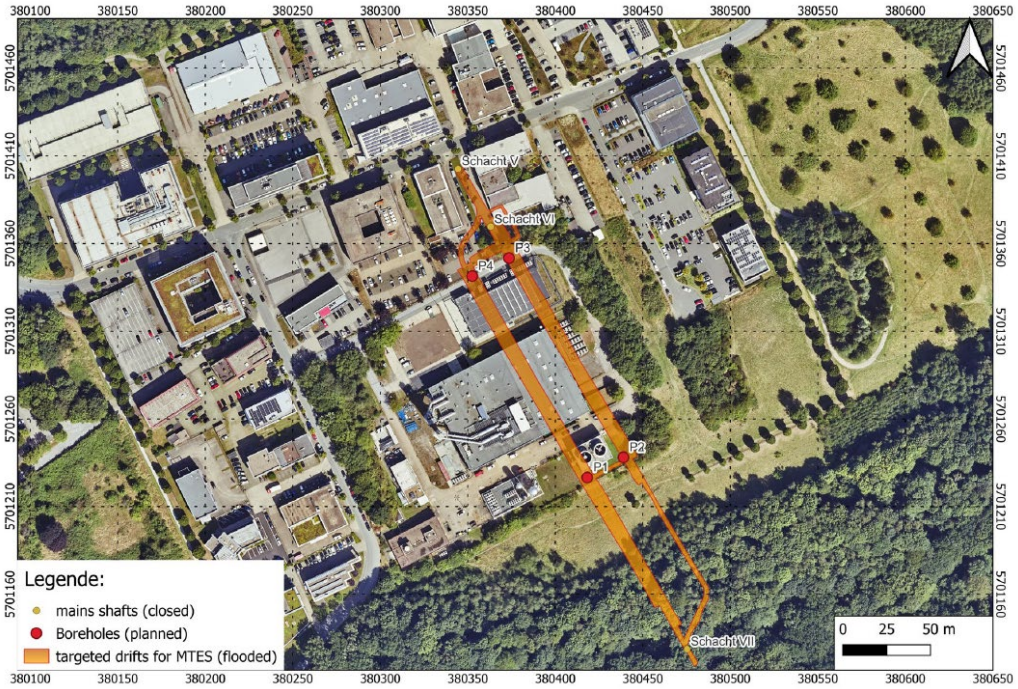

Figure 11: Aerial view of the Bochum demo site with the target galleries of the abandoned Mansfeld colliery located about 120 m below the technical centre.

4.4.2. Site History

Some legal issues have led to delays in the first year of the project (M1-M12) causing a deviation from the original workplan. Written permissions from the landowner and the mineowner were obtained in January 2024 and July 2024, respectively. Additionally, an agreement with the Ruhr University Bochum was obtained as main beneficiary of the project.

Most of the work in the first months of 2024 was focused on planning of the drilling work, including the analysis of mine plans to develop an underground model, plan the well design, preparing the site and purchasing installation items.

Permission from the water authority has been obtained for initial mine water pump and circulation tests up to 5,000 m^3 per well.

The spudding of the first drillings in the locations P1 and P2 started in September 2024, with a campaign of in-situ tests (geophysics, logging, pumping and circulation tests) planned for M21-M24 (October to December 2024).

4.4.3. Stakeholders

Water Authorities

*The Lower Water Authority of the City of Bochum (*Untere Wasserbehörde*).*

The LWA is the responsible for the protection of groundwater and surface water. It monitors water use and the correct application of the Water Resource Act (WGH). For geothermal systems, the LWA grants permits for both open and closed-loop systems.

The Upper Water Authority is the Arnsberg District Government.

The UWA is the responsible for decisions and planning involving water bodies, as well as the supervision of water bodies. It also manages the state-wide monitoring of water bodies, including the processing and evaluation of data.

Mining Authority

Department 6: Mining and Energy in North Rhine Westphalia (NRW) of the Arnsberg District Government

The Mining Authority is the department for Mining and Energy of the Arnsberg District Government (https://www.wirtschaft.nrw/bergbehoerde) and has its headquarters in Dortmund.

Geological Survey

Geological Survey of North Rhine Westphalia (Geologischer Dienst NRW)

The NRW Geological Survey (Geologische Dienst NRW) is based in Krefeld and is the competent authority for application of the Geological Data Act.

Neighbourhood / Clients

Ruhr University Bochum

Operates the heating and cooling network in the campus. The heat network has a length of 8 kilometres with a total output of around 70 MW (https://einrichtungen.ruhr-uni-bochum.de/de/waermeversorgung-wv).

K+S Mining Group

K+S Mining Group (https://www.kpluss.com/) is the mine owner.

Building and Real Estate Management of NRW

The Building and Real Estate Management NRW (Bau- und Liegenschaftsbetrieb NRW) is the landowner. BLB NRW is the owner of more than 4,000 properties in the state. It manages and rents these properties to state institutions, ministries and authorities, universities, the police or tax offices, among others.

4.4.4. Permitting – update for Bochum HT-MTES

The first stages in the MTES project in Bochum were dedicated to obtaining the land and mine owner's permission in written form. This process was delayed compared with the original estimations (landowner permission was obtained at M13, January 2024 and mine owner permission in M17, May 2024). These were steps necessary before achieving permission from Ruhr University Bochum (main project beneficiary) for the construction and drilling.

An application for test operation permit was submitted to the water authority and received in M15 (March 2024). This was approved for a maximum of 5,000 m^3 per well.

In total, the legal framework has required 12 extra months, this is an important deviation from the original plan.

4.5. Germany – Berlin

4.5.1. General Context

Berlin obtains 100% of its drinking water from groundwater and most of it is pumped from shallow, unconsolidated aquifers beneath its own urban area. The protection of Berlin groundwater is also based on stipulations on the Berlin Water Act (Berliner Wassergesetz, BWG), which legislates activities with potential impacts to groundwater in addition to the Water Resources Act (WGH).

As a result, the requirements for geothermal systems are high and strict, and the Water Authority (see section 4.5.3) has put in place a strict approval procedure aiming to protect the groundwater resources. In general, the use of geothermal energy is prohibited in designated groundwater protection areas in Berlin. In addition, closed-loop systems are preferred to prevent associated quantitative impacts on groundwater resource and effects associated with recurring investigations (e.g. pumping tests) on groundwater quality. Special caution is required when drilling to avoid connecting different aquifers or create potential pathways for groundwater contamination. The potential influence of temperature changes in the aquifers and soils is considered as a critical element that can influence the biological, chemical and physical properties of water, and hence groundwater quality. Potential biological effects of temperature changes include the disruption of microbiotal growth and the change in species composition of bacteria, amoebae and other microorganisms. In areas with artesian groundwater, the authorities are stricter and impose

4.5.2. Regulation (in addition to the Federal Laws)

Berlin Water Act (BWG)

Berliner Wassergesetz (BWG) **– Berlin Water Act**

Full citation:

["Berliner Wassergesetz (BWG) in der Fassung vom 17. Juni 2005 (GVBl. S. 357, 2006 S. 248, 2007 S. 48) zuletzt geändert durch Gesetz vom 6. Juni 2008 (GVBl. S. 139)"][29]

4.5.3. Competent Authorities in Geothermal Projects

Mining Authority

The **State Office for Mining, Geology and Raw Materials Brandenburg** (LBGR) is the Mining Authority responsible for the permissions for exploration and exploitation of heat. The LGBR is a higher state authority subordinate to the Ministry of Economic Affairs, Labour and Energy of the State of Brandenburg (MWAE).

Water Authority

The Water Authority of **the Senate Department for Mobility, Transport, Climate Protection and the Environment (Government of Berlin)** (website) is the main responsible authority for the regulation of water related issues.

[29] Berlin Water Act (BWG) in the version of 17 June 2005 (GVBl. p. 357, 2006 p. 248, 2007 p. 48) last amended by law of 6 June 2008 (GVBl. p. 139)

Geological Survey

Senate Department for Urban Development, Construction and Housing "Department of Integrative Environmental Protection" (Senatsverwaltung für Stadtentwicklung, Bauen und Wohnen - Integrativer Umweltschutz).

4.5.4. Permitting Procedure

General Framework

According to the Water Resources Act (WGH) and the Berlin Water Act (BWG), for any geothermal operation it is necessary to obtain a permit from the water authorities, with the only exception being small shallow geothermal collectors that are at least 1 metre higher above the highest groundwater level. In the case of Berlin, the application must be directed to the Water Authority of Senate Department for Mobility, Transport, Climate Protection and the Environment. An application form is available on the Senate Department website.

Guidance for the installation of closed-loop systems of less than 30 kW has been published (Senatsverwaltung für Mobilität, Verkehr, Klimaschutz und Umwelt Erdwärmenutzung in Berlin, 2022). For closed-loop systems of more than 30 kW, it is necessary to perform a geothermal response test which requires application to the water authority following the WGH. As part of the application numerical modelling of the thermal and hydrodynamic impacts of the geothermal system must be provided for systems of more than 50 kW and for systems between 30 and 50 kW a case-by-case decision is made. The full procedure is available in https://www.berlin.de/sen/uvk/umwelt/wasser-und-geologie/publikationen-und-merkblaetter/#Pflichtenheft and the methodology and guidance to prepare the numerical models is available in https://www.berlin.de/sen/uvk/_assets/umwelt/wasser-und-geologie/publikationen-und-merkblaetter/erdwaerme-pflichenheft.pdf?ts=1726206892

A preliminary dimensioning of the system must be provided in the application, with information of the estimated extraction capacities. Maps with extraction capacities at the planned drilling depth of 1800 annual operating hours (only heating) or 2400 hours (heating and hot water) are available in Geothermal potential - specific thermal conductivity and specific extraction capacity 2017

In general, because of the risen groundwater temperatures in Berlin, cooling systems are not allowed, and systems for heating and cooling are evaluated in a case-by-case basis.

There are additional restrictions for geothermal related with the protection of groundwater in the city. Geothermal systems are not permitted in groundwater protection zones, open-loop systems are not allowed in contaminated sites and there is a close examination in the main aquifers and zones with potential saline waters. These restricted areas cover approximately 50% of the city.

Drilling

Drilling contractors must report drilling operations, according to the GeoIDG Act 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. Information is then made available via the Bohranzeige website, with spatial drilling information available in the Berlin Geoportal. The application must contain detailed information of the type of drilling and the planned utilisation of the results, the potential impact on the environment and public and public safety and protective measured to be taken. The Mining Authority examines the application and has the option of conducting on-site inspections to check that the conditions are met.

Public participation is part of the process and registered affected citizens and associations can submit comments to the application. Other organisations (Water Authority, Nature Conservation Authority, companies providing critical infrastructure, etc.) are also contacted by the Mining Authority. All the comments by both the public and the consulted organisations are considered and evaluated by the Mining Authority to decide on the granting of the drilling license.

The certification of companies in the construction of geothermal plants is in accordance with the requirements of the DVGW (Deutscher Verein des Gas; German Association for Gas and Water) W 120 or worksheet W 120-2. The guidelines of DVGW W 116 apply for the flushing of drilling fluids.

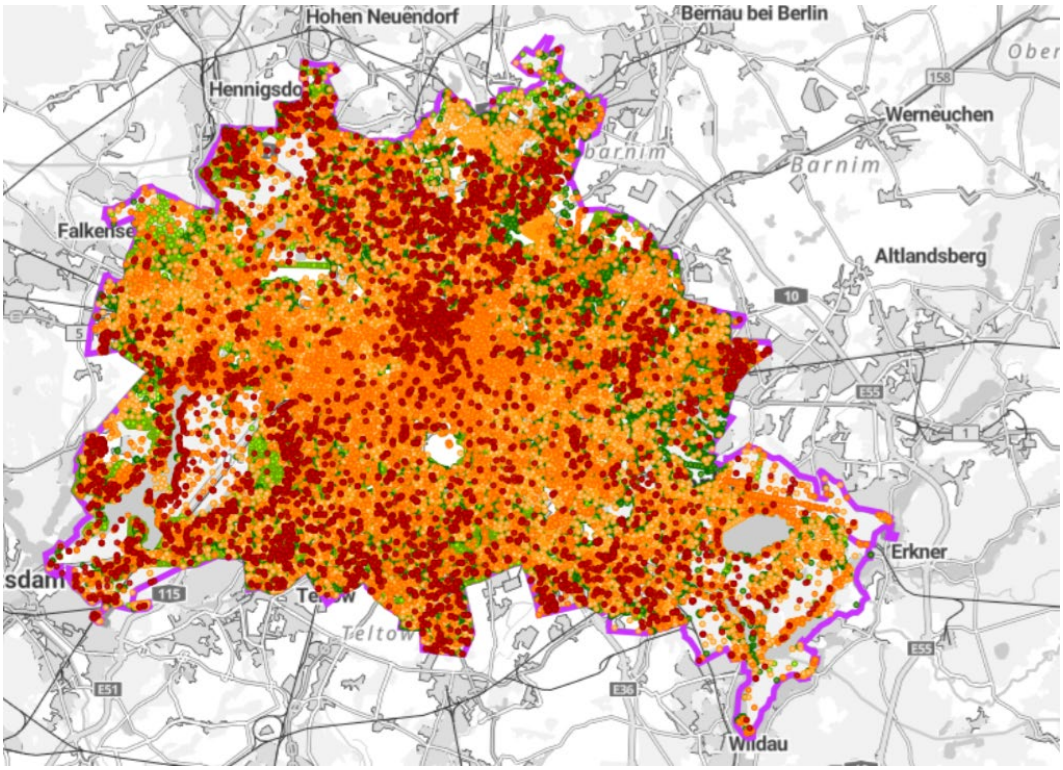

Figure 12: Berlin Geoportal with drilling information.

Other information

In addition to the websites and portals relevant to the permitting shown above, there are some information that is relevant for both project developers, operators and authorities, including maps of Geothermal potential - specific thermal conductivity and specific extraction capacity 2017

4.6. Germany - Berlin (HT-ATES)

4.6.1. Technical Background

A high-temperature aquifer thermal energy storage (HT-ATES) system in the south east of Berlin will be the follower site of the demonstrator HT-ATES project in Delft. The aim is to integrate the system into an existing district heating network, that belongs to BTB GmbH (the second largest heat provider in Berlin) and has a current heating supply of 650 GWh/a, operating supply temperatures of 95-115°C and return temperatures of 55-65°C.

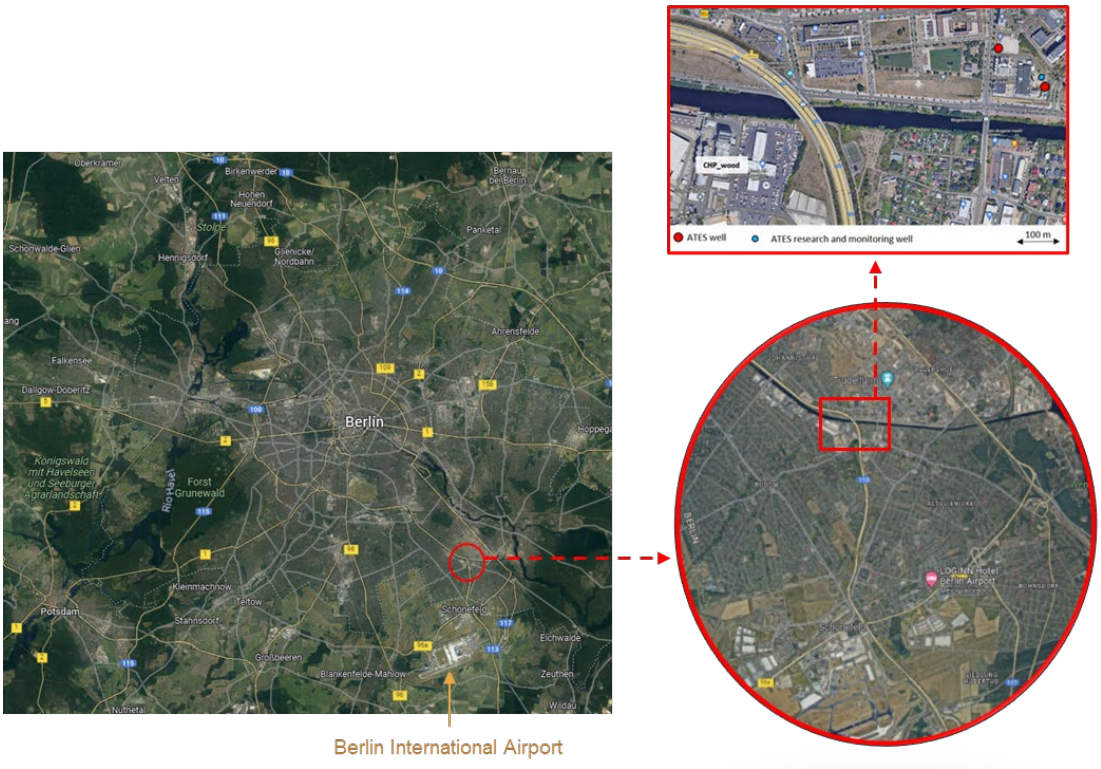

Figure 13: Location of the Berlin ATES site (©Google Maps).

The target system temperature for the ATES is 90°C. The district heating network is expected to increase supply to 900 GWh/a over the next 10 years. The ATES system is expected to store heat from a biomass combined heat and power plant in summer to substitute heat from fossil fuel plants in winter. It is expected that heat from other sources (renewable, waste water, etc.) in the vicinity of the ATES site will also be stored.

The project in Berlin consists of two stages:

1. In the first stage, a research well was drilled as part of the research project GeoFERN[30] to test the capabilities of the subsurface to store heat using Hot Push-Pull Testing (HPPT).
2. In the second stage, an ATES system will be built with integration into the existing heat network. Installation of this system is not within the scope of PUSH-IT but is part of the Reallabor GeoSpeicher Berlin[31] project, funded by the German Ministry of Economics and

[30] https://www.gfz-potsdam.de/sektion/geoenergie/projekte/2019-2022-geofern; Saadat et al. (2023) Geothermische Fernwärmeversorgung in Berlin (GeoFern) : Abschlussbericht des Vorhabens : Berichtszeitraum: 01.07.2019-31.03.2023. https://doi.org/10.2314/KXP:1892405717

[31] https://www.btb-berlin.de/innovationen/geospeicher-berlin/

Climate. However, some aspects of the preparatory work (development of monitoring concept, heating storage testing, social engagement) are included in PUSH-IT. The TES wells will be drilled at approximately 800 m from the CHP plant at a nearby parking space. The distance between the two wells in the ATES system should be >100 m, assuming a flow rate up to 140 m^3/h.

4.6.2. Site History

An ATES exploratory well was drilled in 2021 as part of the GeoFERN project funded by the German Ministry for Economic Affairs and Climate Action. The drilling and coring of that well led to the identification of a potentially suitable formation for thermal energy storage at depths between 350-400 m.

For the PUSH-IT project, a Hot Push-Pull Test (HPPT) is planned. The test was delayed because of problems during well completion that caused the injection of cement into the filter section of the well. Remedial works were carried out between April and August 2024, including the drilling of the sidetrack. This process required various steps, including the removal of the old tubing, the cementation of the old well, the drilling of the sidetrack itself with mud sampling, and the installation of new tubing with fibre optic cable.

As of December 2024, the sidetrack is now ready for testing, but the approval of the testing permits is still pending. Current activities include a program of well testing, thermal, chemical and microbiology monitoring and preparation for the HPPT test to be performed at the end of 2024.

4.6.3. Stakeholders

Authorities

The Senate Department for Mobility, Transport, Climate Protection and the Environment (Government of Berlin) (SenMVKU)

Is the main responsible for the regulation relevant to water issues.

The State Office for Mining, Geology and Raw Materials (LBGR)

Is the mining authority responsible for the permissions for exploration and exploitation of heat. The LGBR is a higher state authority subordinate to the Ministry of Economic Affairs, Labour and Energy of the State of Brandenburg (MWAE).

Commercial

BTB GmbH

Is the energy supply company that operates the district heating network and various combined heat and power plants. The company is a 100% subsidiary of E.ON.

Neighbourhood

WISTA Science and Business Technology Park in Adlershof

Research, technology and media campus with around 1,200 companies and 22,000 employees.

4.6.4. Permitting

Exploratory ATES well

An exploratory license and a general operations plan were granted for the drilling of the research ATES well in 2021 as part of the GeoFern[32] project (Norden et al., 2023). The application was directed to the Mining Authority. An extension of the license (also submitted to the Mining Authority) was approved to continue activities until August 2026.

During the authorisation procedure, public participation takes place and interested parties (including citizens, associations or authorities) can submit their comments and objections to the project. Organisation with direct links or with interests in the project are contacted directly by the mining authority.

Because there is no specific regulation for HT-ATES in Germany, the developers applied for an "exploration licence for brine and heat", similar to the ones for a conventional geothermal well.

Drilling of the sidetrack

The drilling of the sidetrack required an additional special operations plan submitted to the Mining Authority, even when the activities are still within the framework of the general operations plan. No public participation is required for the special operations plan. The special operations plan was submitted on 27 October 2023 and approved on 7 March 2024. Additional obligations were included, such as the share of geological data, were included in the special operations plan.

Hot Push-Pull Test

An additional special operations plan must be submitted to the Mining Authority (which consults the Water Authority) to carry out the Hot Push-Pull Tests. The application must contain the volumes produced and injected, information about the tracers and details of the procedure (working times, fluid handling, monitoring).

[32] Project funded by the German Ministry for Economic Affairs and Climate Action.

5. Czechia

5.1. General Regulatory Framework

5.1.1. General Context

In Czechia, government incentives are available for the installation of ground source heat pumps (GSHP) through the "New Green Savings" (Nová zelená úsporám or NZÚ) program, which provides financial support for various energy-saving measures (Weber, 2023). While the number of GSHPs in Czechia is rising, a recent report identified that there are no aquifer thermal energy systems (ATES) installed in Czechia.

Czechia has established a regulatory framework for GSHPs[33], which includes requirements for obtaining permits and ensuring environmental protection. This framework is designed to facilitate the safe and efficient use of geothermal energy. It is primarily governed by existing legislation, including Construction Law, Geological and Mining Law, and Water regulations. How these will apply to UTES is largely untested. However, Ministry of Environment published (2023) a methodical guideline for GSHP installation focusing on the whole process chain from planning, permitting to drilling. It is highly probable, that this document will serve as a foundation for all kinds of UTES together with current legislation.

There is still no specific detailed legal framework for drilling and operation of geothermal or BTES wells in the Czechia and very limited experience from the state and local authorities for permitting and licensing such operations. Operational regulations are also limited by the lack of previous work. The Litoměřice test site will therefore play an important part in supporting the development of relevant regulatory and legal frameworks and identifying gaps. Generally, drilling in the Czechia is regulated through mining and water authorities at state, regional and local levels.

5.2. Regulatory Framework for Geothermal and Thermal Energy Storage

5.2.1. General Context

Geothermal projects at all state and local levels fall under Czech regulatory frameworks for mining and water and are also subject to planning laws and environmental impact assessments all at state (mining/drilling), regional (EIA) and local (water) levels. Regulations differ for the drilling/exploration phase and operational phases.

Drilling to depths greater than 30 m is regulated by national and regional mining laws, which relate to: i) the subject which is regulated (e.g. heat from rocks or the rocks where heat is stored); and ii) the way heat is extracted (related to type of mining/drilling technologies).

Drilling works in Czechia also require an Environmental Impact Assessment (EIA), as mandated by the EU, although the level of detail required is dependent on the nature of the geothermal system being explored (e.g. closed versus open systems and those that extend beyond 200 m). Also relevant is the EU mandated 'Do No Significant Harm' (DNSH) regulation, for which an assessment will be required if geothermal projects may have impacts on climate change, resilience and water, amongst other factors. Generally, geothermal projects are considered to be

[33] Příručka pro projektování, povolování a realizaci vrtů pro tepelná čerpadla systémů „země x voda" a „voda x voda": https://www.mzp.cz/C1257458002F0DC7/cz/prehled_vyzkumnych_metodik/$FILE/OG-Metodika_CAH_TC_prirucka-20240119.pdf

compliant with DNSH regulations by the Czech Ministry of Environment, and so regulation and permissions in this area are considered to be fairly straightforward.

Further environmental regulation relating to geothermal activity is carried out by the Czech Ministry of Environment and by its regional branches and includes water authorities. Regulation of construction and operations are carried out by city/regional planning, construction, and transport authorities, depending on scope and scale of the project.

5.2.2. Geothermal Regulation

Specific regulations relating to geothermal energy relate to two aspects: i) the **subject which is regulated**, i.e. the heat from a rock massif where the heat is to be "stored" and can be used to generate energy. In this case the main norm is Act No 44/1988 Coll. (novelised in 2021 as Act No 88/2021 Coll.) on the protection and utilisation of the mineral /natural/ resources [*Zákon o ochraně a využití nerostného bohatství /horní zákon/*], also known as "Mining bill". The second aspect relates to ii) **the way the heat is extracted**, and in this case the main norm is Act No 61/1988 Coll. on mining works, explosives and on the state mining authority [*Zákon č. 61/1988 Sb. o hornické činnosti, výbušninách a o státní báňské správě*] together with Ordinance No 104/1988 Coll. of the Czech mining authority (also "State mining authority of the Czech Republic") on Economical utilisation of exclusive reservoirs, on permitting and announcement of the mining work and on announcement of the work realised through mining technologies [*Vyhláška Českého báňského úřadu o racionálním využívání výhradních ložisek, o povolování a ohlašování hornické činnosti a ohlašování činnosti prováděné hornickým způsobem*].

5.2.3. Competent Authorities

- Czech State Mining Administration (https://cbu.gov.cz/cs/h-ouradu) – state authority responsible for permitting and regulation.
- Czech Geological Survey (ČGS) (https://cgs.gov.cz/en) – responsible for advising on geological risks and potential conflicts of interest in the subsurface.
- District mining office for the territory of the Ústecký region (this branch is relevant for Litoměřice site, i.e. there more district offices spread over the country) – local authority responsible for permitting and regulation.
- Czech Central Construction, Transport and Energy Authority - Dopravní a energetický stavební úřad – DESÚ (responsible since 1st January 2024). To become responsible overall at a state level for large-scale energy projects, including geothermal high temperature borehole storage; however, all competencies are to be set from 2025 on.
- Local Construction Authority [*Stavební úřad*] – responsible for design and planning aspects and permitting of construction works related to the energy source (i.e. everything what is constructed on the surface such as pumps, piping, buildings and other infrastructure) and its safe, long-term operation.
- Regional Authority - usually department of environment [*Krajský úřad - odbor životního prostředí*] approving the design of the energy source and provides EIA evaluation; also other special entities such as those dealing with environmental protection [*Agentura ochrany přírody a krajiny - příslušné správa CHKO - Chráněna krajinná oblast*] – responsible for regional environmental permitting and water use, protected areas and wildlife may be relevant in case the locality belongs to one of the environmental protected areas.
- Civil Aviation Authority (due to the height of the drilling rig) – responsible for regulation of drilling rig safety if this may interfere with air traffic.

- Administrator of the watercourses [*Správy povodí řek*] – responsible for regulation of water and groundwater supply; if the energy source is close to the river or other surface water are (lakes, dams) or if the, potentially, the energy source will use water for feeding the energy system, it needs an approval from this authority.

5.2.4. Permitting Procedure

Several stages of permitting are required prior to drilling and are regulated by a number of authorities, mainly the Ministry of Environment and the Czech State Mining Authority. In addition, the Nature Conservation Agency, the local public water administration body, and regional and local public authorities. The new centralised construction and transport authority (DESU) will most likely permit major energy sources in the future. Currently, the framework for permitting is as below.

1. **Preparatory Stage** - basic evaluation of drilling works to ascertain i) that the site is suitable for deep drilling coincident to its intended purpose (e.g. geothermal heat storage) and ii) that the works are legally feasible, i.e. without conflict of interest or issues arising from matters such as land ownership, areas of protected nature, mineral extraction, old mine workings, landslide risk and similar, as advised by the Czech Geological Survey.
2. **Exploratory Stage** – geophysical exploration commences and should include an exploration of the wider area using several methods, and an analysis of the existing geological data. 2D or 3D seismic data should be acquired to characterise the geological characteristics of the area to a depth suitable for the geothermal system (relevant for deep drilling systems).
    a. If seismic exploration is needed, it requires individual permits from all landowners and infrastructure operators where the seismic exploration will be carried out. As seismic lines require km-scale campaigns, this stage of permitting may take some months, and requires basic consent for access, as well as special permits if seismic exploration takes place in protected areas.
3. **Permitting Procedures Stage** – follows if stages 1 and 2 prove that the area is suitable for geothermal heat extraction / storage - it covers input from public and legal authorities at local, regional and national levels. Two main permits are issued: i) Protected area for the Specific Impacts on the Earth's crust (Protected Area SIoEC) issued by the Ministry of Environment based on the Act No 44/1988 Col. and Ministry ordinance [Vyhláška MŽP č. 364/1992 Sb. o chráněných ložiskových územích] and ii) License for mining works for Specific Impacts on the Earth's crust (Licence for mining works) [Povolení hornické činnosti - zvláštního zásahu do zemské kůry podle Zákona č. 61/1988 Sb. o hornické činnosti, výbušninách a o státní báňské správě a podle Zákona č. 44/1988 Sb. o ochraně a využití nerostného bohatství, tzv. horní zákon].
    a. The SIoEC defines and delineates the territory that can be used for a geothermal project, as well as where heat will be extracted/stored.
    b. The license for mining works allows for the drilling of deep (more than 30 m) geothermal wells and requires: i) information on the intended well including purpose, type of works, information on the investors/stakeholders and a description of environmental and geological conditions at the site based on the work carried out at the exploratory stage; ii) Detailed information on geology including rock properties, geological risks, monitoring for induced seismicity, and decommissioning and restoration. Schematics should be included that include the siting of wells and affected infrastructure (pipelines, electricity etc). Further, financial planning and reserves should be included in this section. iii) Optionally at this stage, details of the technical operation including well design and drilling

contractor can be included during this phase, if already known. This information can be provided during the later pre-drilling phase if not yet known.

4. **Pre-drilling Stage**: All details of contractor and well plan must be finalised, and the Czech mining authority notified of the start of drilling at least 14 days prior to well spudding. The necessary documentation must include details of the borehole construction, timeline of works, information on health and safety operations, and any impact on local water and electricity supply. At this stage, the mining authority may issue a license and then supervises the drilling so that they fulfil Czech law.

Details of operational and post-operational permitting and licensing are not yet finalised in the legal framework for BTES.

5.3. Litoměřice (HT-BTES)

5.3.1. Technical Background

The Litoměřice site is a large research infrastructure (RINGEN – Research Infrastructure for Geothermal ENergy) in Czechia for research on geothermal heat extraction and storage. The site is located at the former army Jiřík barracks in Litoměřice. Charles University - Faculty of Science and Czech Geological Survey (CGS) are currently using RINGEN (2023-2027) for a major project (SYNERGYS[34]), which is exploring green heat, green hydrogen, and green building concepts (see Figure 14) as one complex system. The site is a 'follower' site within the PUSH-IT project focused on medium and high-temperature borehole thermal energy storage (HT-BTES) (system 3 in Figure 14), and together with planned enhanced geothermal system (EGS) (system 4 in Figure 14) will feed the existing district heating system.

Within PUSH-IT the project will:

- Drill a cored exploration well to 550 m to evaluate the subsurface geology of the BTES field
- Use rock properties from the cored well to model energy flows and subsurface response for BTES
- Drill a hydrogeological well to 200 m to evaluate hydrogeological conditions of the aquifer
- Use the hydrogeological well for groundwater sampling, pump testing, and long-term monitoring to assess BTES design

Within SYNERGYS project:

- Develop bespoke options for future BTES arrays at depths of 100 m, 200 m, 500 m for storage of excess heat ranging between 30 and 70 °C for the Litoměřice district heating system.
- Store excess heat from surface technologies (solar PV, solar thermal panels, hydrogen electrolyser)
- Develop deep stimulated underground heat exchanger with 100 °C water for Litoměřice district heating system

The overall aim of SYNERGYS is to connect the HT-BTES and EGS to the district heating network for the town of Litoměřice, which has a population of around 24 000 residents. The total capacity of the HT-BTES is expected to be around 5-10 GWht. Together with EGS, the system might be able to cover 100% of heat requirements during the summer (off season) and up to 10% during the winter peak season.

[34] www.synergys.cz/en

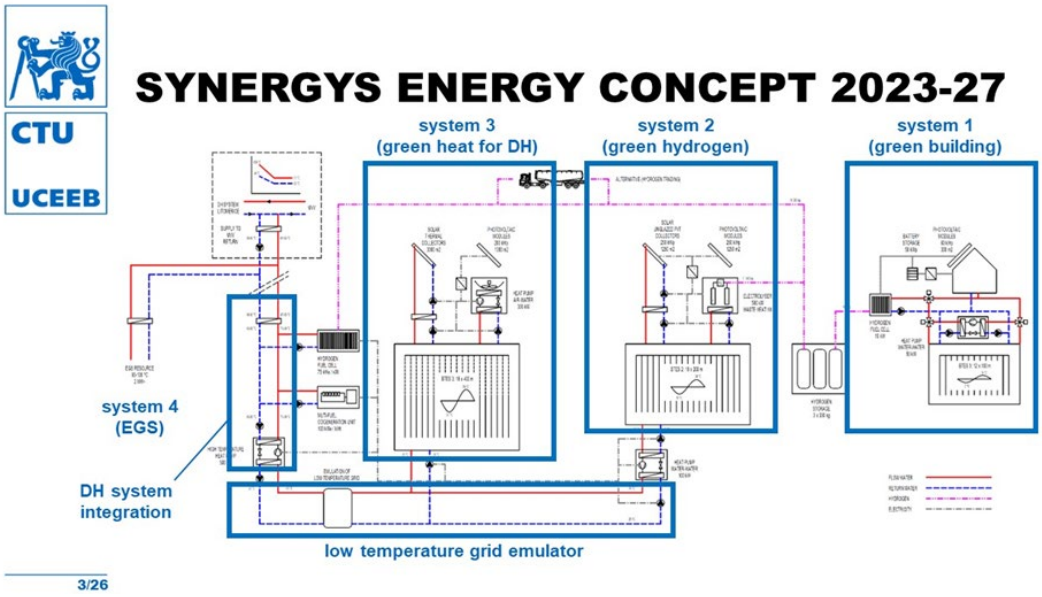

Figure 14: SYNERGYS energy concept for Litoměřice site. Figure copied from https://www.push-it-thermalstorage.eu/pilots/litomerice.

5.3.2. Site History

Initial drilling of the BTES (550 m) and hydrogeological (200 m) boreholes was planned for 2023. Although permissions had been already obtained, the project was delayed by the tendering process which had to be repeated before a contractor was confirmed in June 2023. Further delays were encountered during drilling, which began in January 2024. Unfavourable geological conditions in the upper part of the borehole during wireline coring led to problems with mud loss and borehole collapse, and the decision was made to cease drilling at 160 m and investigate alternative technologies. From the initial drilling phase, 162 m of core was recovered, all Cretaceous in age. Borehole logging was not carried out due to the instability of the borehole. Currently (January 2025), drilling works continue and are to be finished by the end of March 2025.

5.3.3. Stakeholders

Neighbours/Clients

- Faculty of Science, Charles University (http://www.natur.cuni.cz/) – owner and part-funder of RINGEN facility.
- City of Litoměřice – local stakeholder in the facility.
- Czech Army – situated within parts of the facility.
- Institute of Geophysics, Czech Academy of Sciences (http://www.ig.cas.cz/) – involved in research at RINGEN facility.
- Institute of Geonics, Czech Academy of Sciences (http://www.ugn.cas.cz/?l=en) – involved in research at RINGEN facility.
- Institute of Rock Structure and Mechanics, Czech Academy of Sciences (https://www.irsm.cas.cz/index_en.php) – involved in research at RINGEN facility.
- Institute for Nanomaterials, Advanced Technology and Innovation, Technical University of Liberec (https://cxi.tul.cz/en) – involved in research at RINGEN facility.

- Jan Evangelista Purkyně University in Ústí nad Labem (https://www.ujep.cz/en/) – involved in research at RINGEN facility.
- Technical university of Ostrava (https://www.vsb.cz/en) – involved in research at RINGEN facility.
- Czech Technical University in Prague – University Centre for Energy Efficient Buildings (http://ceg.fsv.cvut.cz/) – involved in research at RINGEN facility.
- TG Masaryk Water Management research Institute. TGM: www.vuv.cz, https://heis.vuv.cz) – involved in research at RINGEN facility.
- All state, regional and local public authorities involved in the permitting process listed above.
- District heating operator (Energie Holding a.s.).
- Local community – open days, public hearings and other events are organised to gain support and inform about geothermal energy exploration and utilisation.
- Regional and nation-wide operating drilling suppliers for whom expert workshops will be organised presenting activities of other PUSH-IT sites.

6. United Kingdom

6.1. General Regulatory Framework

6.1.1. General Context

Deployment of shallow geothermal technologies in the UK is growing. While overall numbers of ground source heat pumps remain considerably lower (<50,000) (Gonzalez Quiros et al., 2024) than in many other European countries, the UK has made notable progress in the development of mine water geothermal systems. Several systems are now in operation in the UK, but none have incorporated thermal energy storage options. Overall, the market for underground thermal energy storage (UTES) is still emerging in the UK, with about 11-12 ATES systems currently in operation (Stemmle et al. 2024; Jackson et al., 2024).

Regulatory frameworks for shallow geothermal systems, which currently also apply to thermal energy storage, exist in the different nations of the UK (England, Wales, Scotland and Northern Ireland). They are set out to prevent environmental harm. While clear regulatory guidelines are in place to protect the environment, geothermal energy is not legally recognised as a natural resource in the UK (Abesser & Walker, 2022). This means that the abstraction / injection / storage of heat itself is not currently regulated. When injected using water (e.g. open loop systems, ATES), and as heat is considered a pollutant, temperature limits can be imposed by the regulator. This does not apply to heat transferred to the ground via borehole heat exchangers. Overall, the regulatory process for UTES system in the UK is still in its infancy, and largely untested.

Regulation of geothermal exploitation is determined by the devolved administrations in the UK. None of the four UK nations have bespoke planning rules, environmental regulation or licencing systems specific for the planning and operation of geothermal schemes. Instead, geothermal aspects are covered by existing regulation, involving several public bodies in the regulation and control of activities which may be undertaken during the exploration and exploitation of geothermal energy. Depending on the type of systems and drilling depths, these involve local planning authorities (LPA), Environmental regulators and, for deep geothermal wells, the Health and Safety Executive (HSE).

The following sections review regulation and processes that are relevant for the development and operation of UTES systems. The review focusses on regulatory requirements and processes in England as this is where the follower site is located.

The Local Planning Authority is responsible for granting planning permission for works associated with borehole construction and wellhead development. They also decide if an Environmental Impact Assessment is required as part of a planning application.

Environmental regulators (i.e. the Environment Agency in England) regulate activities that may cause pollution or pose a risk to the environment. In respect of geothermal, this includes regulation of abstractions from and discharges of water to the environment. None of these environmental regulations evaluate the impact of the planned operation on the available heat resource.

The HSE oversees regulation of workplace health, safety and welfare. The HSE will take a risk-based approach to drilling of boreholes for geothermal operations and all activity within the workplace of geothermal operations.

Other public bodies like the Mining Remediation Authority (MRA) (previously Coal Authority) and the North Sea Transition Authority (NSTA) (previously Oil and Gas Authority) have responsibilities where geothermal operation involve coal mining areas or the repurposing of oil and gas wells. The British Geological Survey should be contacted to report new geological and geophysical data acquired during the drilling of geothermal wells.

6.1.2. Legislation in England

Water Legislation

Water Resources Act 1991

https://www.legislation.gov.uk/ukpga/1991/57

Act of the Parliament of the United Kingdom introduced in 1991 to regulate water resources, water quality and flood defences. It was introduced to replace and consolidate existing water rules spread over a number of separate pieces of legislation.

It transfers and confers to the competent authority, since 1996 the Environment Agency (EA) in England, the duty and the power to exercise the function of controlling water quality and protecting water and the environment against threats such as pollution.

Environmental Permitting Regulations

The Environmental Permitting (England and Wales) Regulations 2016

https://www.legislation.gov.uk/uksi/2016/1154

Includes provisions that regulate through environmental permitting regime activities in which systems reinject groundwater or discharge water to the surface, such as open-loop geothermal systems. These regulations apply to England and Wales.

Energy Legislation

Energy Act 2013

https://www.legislation.gov.uk/ukpga/2013/32

Energy Act 2023

https://www.legislation.gov.uk/ukpga/2023/52

The 2023 Act includes provision for energy production and security and regulation of the energy market. Includes provisions about the carbon emissions, carbon capture, low-carbon heat schemes or heat networks. Geothermal energy is not included specifically in the Act, but heat pumps are considered.

Drilling Regulations

Borehole Sites and Operations Regulations

https://www.legislation.gov.uk/uksi/1995/2038

Health and Safety Regulations

Health and Safety at Work Act

https://www.legislation.gov.uk/ukpga/1974/37/contents

Legislation includes provisions for securing the health, safety and welfare of persons at work. The Act created the Health and Safety Executive (HSE), the public body responsible of the regulation and enforcement.

6.2. Regulatory Framework for Geothermal and Thermal Energy Storage in England

For England, the most recent guidance for open-loop geothermal systems from the Environment Agency was updated on 2 October 2023[35]. At the time of writing (Dec 2024), the UK Department for Energy Security and Net Zero developing new guidance on the regulatory framework for exploring and exploiting geothermal resources in England. The main aspects of current legislation are summarised below[36].

6.2.1. Geothermal Regulation

There is not currently difference in the regulatory approach taken for shallow or deep geothermal activities. Deep geothermal is generally considered to be below depths of approximately 300 m. Different permits and licences are required for different geothermal technologies as summarised in Table 7.

Table 7: Likely permits/licenses required for different geothermal systems

Permits/Licences	Responsible authority	Closed Loop + BTES - any depth[1]	Open Loop + ATES - any depth[1]	Minewater + MTES
Groundwater Investigation Consent (GIC)	EA	No	Yes	For open-loop only
Abstraction License	EA	No	Yes	For open-loop only
Environmental Permit	EA	Yes unless they meet all exemption conditions	Yes unless they meet all exemption conditions	Yes
Planning Permission	LA	For larger systems	For larger systems	For larger systems
Heat Access Agreement	CA	No	No	Yes
HSE Notification	HSE	Yes	Yes	Yes

[35] https://www.gov.uk/guidance/open-loop-heat-pump-systems-permits-consents-and-licences

[36] This report provides the information relevant to England as this is where the PUSH-IT follower site is located. Regulatory guidance for Scotland has been published in 2024 in https://www.gov.scot/publications/accessing-scotlands-geothermal-resource-regulatory-guidance/pages/3/. Wales regulatory guidance is available in https://naturalresourceswales.gov.uk/permits-and-permissions/water-discharges-and-septic-tanks/discharges-to-surface-water-and-groundwater/permits-and-licences-needed-for-a-heat-pump?lang=en Northern Ireland guidance is published in https://www.nidirect.gov.uk/articles/heat-pumps

Permits/Licences	Responsible authority	Closed Loop + BTES - any depth[1]	Open Loop + ATES - any depth[1]	Minewater + MTES
British Geological Survey Notification	BGS	No legal requirement but encouraged	Yes	Yes

[1] Excluding mine workings

Drilling

There are no regulations specific to the drilling of an onshore borehole (well) for the purposes of exploring and exploiting the geothermal resource, except when the drilling takes place within 1 km of a mining area. Existing regulations apply only to boreholes (wells) drilled with a view to the extraction of petroleum which is regulated under a UK Petroleum Exploration and Development Licence (PEDL).

The broad framework of the Health and Safety at Work etc Act 1974 (HSWA) applies to all workplaces.

Open-loop systems

Applications for the installations of ground source, open-loop system require:

- a groundwater investigation consent
- **an abstraction licence** – when abstracting more than 20 cubic metres per day
- **an environmental permit** to discharge the water (or a registered exemption) unless the criteria for a low-risk activity are met

The licences and permits required, and the respective exemptions are described below.

Groundwater Investigation Consent

An application for a consent to investigate for groundwater source is required before any drilling or test pumping. The consent is not required for closed-loop systems.

As with the abstraction licence, this is only required when this is for plans to abstract more than 20 cubic metres per day. Abstraction licensing strategies are accessible to find out how much water is available in the area of interest. EA groundwater support teams for each region can be contacted to discuss the details.

The consent is required to apply for the abstraction licence or the environment permit. Groundwater investigation consent is required for all boreholes.

The application form (*Water Resources Act 1991 (as amended by the Water Act 2003), Environment Act 1995*) must include the details of the applicant (or the company), a map showing the proposed abstraction point and details of the borehole, well or excavation proposed.

The EA states that the application will be reviewed and replied to within 15 working days, but it may take longer if the proposal is closer to sensitive conservative sites, or is complex i.e. could impact other stakeholders.

Abstraction License

The abstraction licence only applies for the purpose of abstracting more than 20 cubic metres a day.

When the EA grants a licence for the first time it is usually valid between 6 and 18 years, but these can be shorter if they think there may be issues. In some circumstances can also be longer for up to 24 years.

The renewal of a license is normally for another 12 years and is the licence holder responsibility to apply to renew the licence.

The charges vary depending on the volume abstracted and other conditions such as the area.

Environmental Permit for Discharge

For discharge or reinjection, an environmental permit to discharge is required in the following situations (exemptions apply):

- a cooled aquifer system with a volume of less than 1,500 cubic metres per day
- a balanced system with a volume of less than 430 cubic metres per day
- a heated aquifer system with a volume of less than 215 cubic metres per day

To be eligible for the exemption, the system discharge temperature cannot be above 25°C and not vary by more than 10°C compared to that in the aquifer from which it was abstracted, and the discharged water must be reinjected within the same aquifer it was abstracted. In addition, the water must not have any substance added and cannot be used for any other purpose. It is required that the discharge is not done to a groundwater source protection zone 1 (SPZ1) or within 50 metres of any watercourse, groundwater-fed wetland or other groundwater abstraction.

The applicant will need to check with the owners of neighbouring properties to find out if they have a private water supply or other type of abstraction.

When some of these circumstances cannot be met, the applicant will need to apply for a bespoke permit.

Exempt GSHC systems

Even if the ground source system is exempt registration is required.

Closed-loop systems

The Environmental Permitting (England and Wales) Regulation 2016 amended (The Environmental Permitting (England and Wales) (Amendment) (England) Regulations 2023) entered into force in October 2023: The amendment of Schedule 3, 6 “Closed-loop ground source heating and cooling systems: England” includes additional specifications related with the characteristics of closed-loop systems (fully sealed, do not take water from, or discharge into, the environment). The operators must ensure that the system is a closed-loop system only and that there is no discharge of pollutants other than the transfer of heat to the environment, does not cause pollution of surface water or groundwater, it is not located within a groundwater Source Protection Zone 1 or within 50 m of a well, spring or borehole used to supply water for domestic or food production purposes, and at a certain distance from an ancient woodland dependent on the size of the system.

Mine water systems

In addition to the above, any activity which intersects, disturbs or enters coal seams requires prior written authorisation from the Mining Remediation Authority[37] (MRA). The MRA is a non-departmental public body with primary responsibilities for managing the UK's coal assets and legacy, including liabilities associated with past coal mining and unworked coal. Drilling into or through a coal mine or seam requires a permit to enter, while installation of a borehole for the abstraction of heat currently requires a **heat access agreement** and a supplementary agreement for the actual borehole location.

Most other mines (e.g. metal mines) are in private ownership, and as there is no legislation relating to the ownership of geothermal energy in the UK, accessing these mines for geothermal / thermal energy storage is likely to require permission from the mine owner as well as planning permission from the responsible mineral planning authority which typically sits within the Local authority.

The IEA geothermal mine water energy expert group recently published a document which explains the regulatory requirements for using mine water as ground source heating and cooling[38].

6.2.2. Competent Authorities and Stakeholders in Geothermal Projects

Environmental and Water Regulators

The Environment Agency[39]

The Environment Agency (EA) regulates some open-loop systems through the Water Resources Act and Environmental Permitting Regulations (EPR) as described in section 6.2.1. Since the introduction of new amendments to the EPR in 2023 that recognised heat as a pollutant in groundwater, the EA also regulates some closed-loop systems (EA, 2024).

Local Authority

Planning permission for drilling.

Highways permission.

Traffic Management plan.

Landowners

Permission to access land.

Permission for the drilling equipment.

Permission to perform pumping tests.

Permission to construct an energy centre.

Health and Safety Executive

Submission of arrangements to meet statutory requirements for drilling and other construction activities https://www.hse.gov.uk/construction/

[37] Formerly the Coal Authority.

[38] Summary of the Regulatory Framework for Coal Mine Water Geothermal Developments Across the UK https://drive.google.com/file/d/1G1j3psBJYQawQVmExWbEkCnwAjV4LKim/view

[39] Scottish Environment Protection Agency in Scotland, Natural Resources Wales in Wales, and the Northern Ireland Environment Agency in Northern Ireland

Mining Remediation Authority

Permission for any activity which intersects, disturbs or enters coal seams.

6.3. United Downs (HT-MTES)

The PUSH-IT HT-MTS project in Cornwall is linked with the deep geothermal project in United Downs. The underground mines in the area could be used for thermal energy storage of the excess heat produced in the deep geothermal project, which is currently used primarily for power generation. Well head temperatures reach approximately 180°C.

Because of the current uncertainty around both the mine system and the technological solution to be used, it is not possible to detail the requirements in terms of permissions that will be required by the project developer and operator (Geothermal Engineering Ltd., GEL).

7. Discussion and Future Work

7.1. Summary of Regulatory Framework in Selected Countries

General Regulatory context/perspective

The technologies evaluated and targeted for development by the PUSH-IT project, particularly HT-UTES, are innovative and not yet widely adopted in the partner countries or across the EU. While existing regulations has been deployed to regulate use of the technology and prevent potential environmental harm, these often do not fully account for specific system characteristics or potential environmental impacts associated with HT-UTES such as temperature changes, microbiological changes, or chemical alterations. This is, in part, because HT-UTES is a new technology, and the impacts of these systems are not yet fully known and can only be fully assessed once the technology has been operational over prolonged periods of time in a range of geological and environmental settings.

However, in some countries the legislation is frequently updated as new knowledge emerges, and geothermal-related regulations have evolved since the start of the PUSH-IT project. For example, in January 2024, the Netherlands introduced new legislation that significantly overhauled the permitting process, simplifying it by consolidating applications into a single procedure. In Germany, new legislation is under discussion and expected to pass in 2025, reflecting the country's proactive approach to geothermal and thermal energy storage technologies.

In contrast, the regulatory landscape in the UK and Czechia remains largely reliant on existing frameworks. Deployment of geothermal and thermal energy storage systems in these countries has been slower, resulting in regulations that are adapting more gradually to these emerging technologies.

7.1.1. Competent Authorities

Regulation of thermal energy storage systems in the Netherlands, Germany, Czechia, and the UK involves a mix of national, regional, and local authorities, with notable differences in their approaches. Table 8 summarises the competent authorities at each project site, including the permitting and some related activities during project development.

In the Netherlands, oversight for UTES is primarily managed by regional authorities, with recent reforms simplifying permitting processes through a single application system. With new legislation that entered into force in January 2024, the local authority will handle the permitting for most UTES projects when these are part of other activity (such as a building development). This is an important change from the previous framework and requires adaptation and coordination between authorities.

Germany's regulation is more decentralised, with federal laws setting broad standards and implementation carried out by state (Länder) authorities, which leads to regional variations in permitting and enforcement. For shallower projects that abstract/reinject groundwater, the water authority deals with the main permits, while the mining authority is mainly responsible for the drilling, with especial considerations in some of the projects (for example regarding potential occurrence in the Bochum project). For deeper projects, such as in Darmstadt, the process is dealt with by the mining authority.

In Czechia, the Ministry of Industry and Trade and the Ministry of Environment oversee the regulation of thermal energy storage systems.

Regulatory oversight in the United Kingdom is devolved, with agencies such as the Environment Agency (England), SEPA (Scotland), NRW (Wales), and NIEA (Northern Ireland) playing key roles, alongside local planning authorities.

Table 8: Main competent authorities for the project sites. See respective chapters for the original nomenclature.

	UTES Main Permit(s)	Groundwater / Environment	Drilling and testing	Other
HT-ATES Delft Netherlands	Delf Municipality (South Holland Province)	South Holland Province	South Holland Province Local Delfland Water Board (discharge of abstracted water)	
HT-BTES Darmstadt Germany	Mining authority - Darmstadt Regional Council	Lower Water Authority Darmstadt Hessian Agency for Nature Conservation, Environment and Geology (HLNUG)	Mining authority - Darmstadt Regional Council	Hessian Agency for Nature Conservation, Environment and Geology (HLNUG)
HT-MTES Bochum Germany	Lower Water Authority Bochum	Lower Water Authority Bochum	Department 6: Mining and Energy in NRW of the Arnsberg District Government	Geological Survey NRW
HT-ATES Berlin Germany	Water Authority of Senate Department for Mobility, Transport, Climate Protection and the Environment Berlin	Water Authority of Senate Department for Mobility, Transport, Climate Protection and the Environment Berlin	State Office for Mining, Geology and Raw Materials State Brandenburg (LBGR)	Senate Department for Urban Development, Construction and Housing "Department of Integrative Environmental Protection" Berlin
HT-BTES Litoměřice Czechia	Czech State Mining Authority; regional office for the territory of the Ústecký region	Ministry of Environment (regional office) Regional Authority (usually department of environment [Krajský úřad - odbor životního prostředí])	Mining Authority and Ministry of Environment	Czech Geological Survey (ČGS) Local Construction Authority
HT-MTES United Downs United Kingdom	Environment Agency	Environment Agency	Cornwall Council	British Geological Survey

	UTES Main Permit(s)	Groundwater / Environment	Drilling and testing	Other
	Cornwall Council		Health and Safety Executive (HSE)	

7.1.2. Differences and Similarities

The regulatory frameworks for High-Temperature Underground Thermal Energy Storage (HT-UTES) systems vary across the Netherlands, Germany, Czechia, and the United Kingdom, each requiring specific permits and approvals. A common requirement across these countries is the need for environmental assessments and permits related to water usage and potential impacts on groundwater. However, differences are observed in the complexity of the regulatory process and whether UTES is recognised as a stand-alone technology.

In the Netherlands, HT-UTES systems are primarily regulated under the national Water Act, requiring permits from provincial authorities. Recent legislative reforms have streamlined the permitting process, consolidating applications into a single procedure to facilitate the deployment of such technologies. The Netherlands has implemented centralised reforms that specifically recognise UTES, including HT-UTES, within its regulatory framework.

Germany's federal structure means that permitting processes can vary by state (Länder). However, UTES is recognised in national guidelines on the "Thermal Use of the Underground," which provide comprehensive technical standards and recommendations for the planning, implementation, and operation of UTES systems. HT-UTES projects generally require compliance with federal water and mining laws, with specific permits issued by state environmental agencies. In states such as Hesse, North Rhine-Westphalia, and Berlin, developers must engage with the respective state authorities to obtain the necessary environmental and construction permits. Notably, Germany is drafting legislation to expedite approval processes for geothermal plants and heat storage systems, aiming to streamline bureaucratic procedures and reduce barriers.

In Czechia, the regulatory system is centralised and aligned with EU directives. UTES systems are not explicitly recognised as a distinct category in Czech regulations. Instead, HT-UTES systems generally fall under regulations related to geothermal energy and groundwater use, particularly concerning environmental impact assessments (EIAs) and water management permits. Projects typically require EIAs and water management permits to ensure compliance with national legislation aligned with EU directives. It is envisaged that the newly formed (January 1st 2024) Czech Central Construction, Transport and Energy Authority will shortly take on responsibility for large-scale energy projects including geothermal.

In the United Kingdom, regulatory oversight is devolved among the constituent nations. Developers must obtain environmental permits from agencies such as the Environment Agency (England), the Scottish Environment Protection Agency (SEPA), Natural Resources Wales (NRW), or the Northern Ireland Environment Agency (NIEA), depending on the project's location. While UTES is not explicitly recognised as a stand-alone technology in UK regulations, it is subject to various regulatory frameworks that govern energy, environmental protection, and land use. UTES systems generally fall under broader categories such as geothermal energy or ground source heat pumps. Additionally, planning permissions from local authorities are necessary, and projects must comply with regulations concerning groundwater protection and environmental impact assessments.

Between these countries, there are also notable differences in the pace at which regulations are adapting to emerging technologies. While the Netherlands and Germany are actively reforming

legislation to facilitate the deployment of new technologies, Czechia and the UK maintain older frameworks and are generally slower in integrating these systems into national energy strategies.

7.2. Future Work

During the second part of the project work in T2.2, interviews with relevant stakeholders, including competent authorities and project operators, are being conducted at the sites to gain a more direct understanding of the local frameworks and the specific particularities at each site.

A special focus will be to understand the several enabling aspects (guidelines, best practices, masterplans, public databases, decision-making tools, workflows, etc.) and barriers (multiple permits, coordination between authorities, lack of information and guidelines, etc) that facilitate or delay project realisation.

The results of the interviews will be analysed in combination with the findings obtained during the review presented in this report (and any new legislative updates). The results of the analysis will be included in the final report, that will contain a complete analysis, including a comparison and discussion of the differences and similarities between technologies and countries, and a set of recommendations based on the project learnings informed by the direct interaction with project stakeholders.

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The EU aims to have a net-zero greenhouse gas (GHG) economy by 2050, with 55% reduction on 1990 levels by 2030. At present, heating and cooling represent around 50% of the final energy demand in Europe and are mainly supplied by fossil fuel derived energy. It is therefore essential for heating and cooling to decarbonise to achieve EU ambitions.

A challenge for decarbonizing heat systems is the size of the seasonal mismatch between demand for heat and heat generation from sustainable sources – this mismatch is much larger than the equivalent intermittency in electricity supply and demand. The two main solutions to address this mismatch are: (i) to install a large capacity, so that peak demands can be met even at low production levels; or (ii) to store energy for later use if it is not needed at time of conversion. Many sustainable heat supply systems are characterised by high capital expenditure and low operational costs. Therefore, an installed capacity tailored at peak demand is not cost effective, while extending the annual operation period is advantageous for meeting energy needs, reducing levelised cost of energy (LCOE) and decarbonisation. Optimal utilisation of sustainable heat requires storing large amounts of heat to account for seasonal supply and demand fluctuations. Various technologies have been proposed for large-scale heat storage in geothermal reservoirs and low temperature storage is routinely applied. PUSH-IT focuses on extending storage temperature ranges to high temperatures. We will tackle remaining barriers, demonstrate applicability, increase public engagement, and optimise and de-risk operations. We will showcase three technology options that are fit for a wide variety of geological conditions covering most locations in Europe.

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