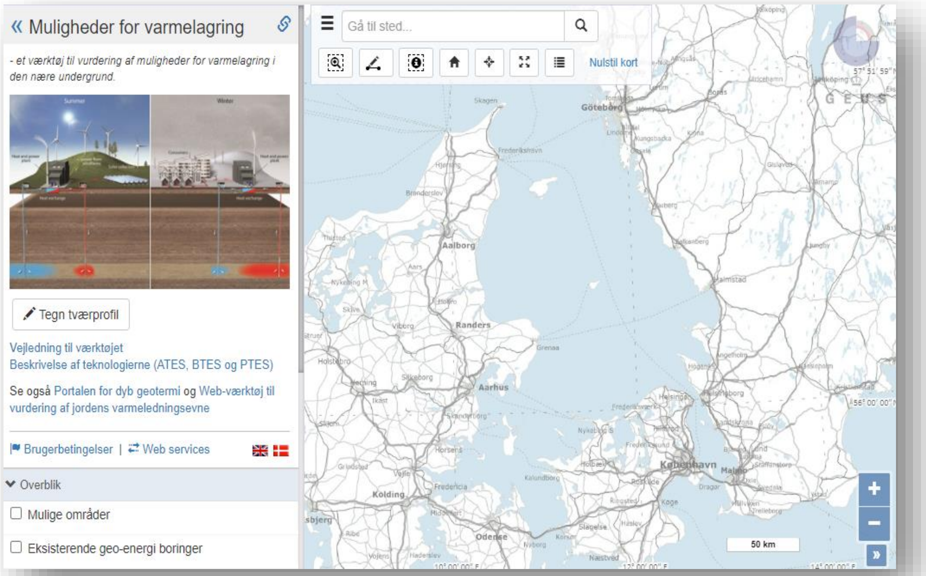
HEATSTORE
HIGH TEMPERATURE UNDERGROUND THERMAL ENERGY STORAGE (HT-UTES)

KNOWLEDGE SHARING AND MONITORING MEETING, 27. OCTOBER 2021

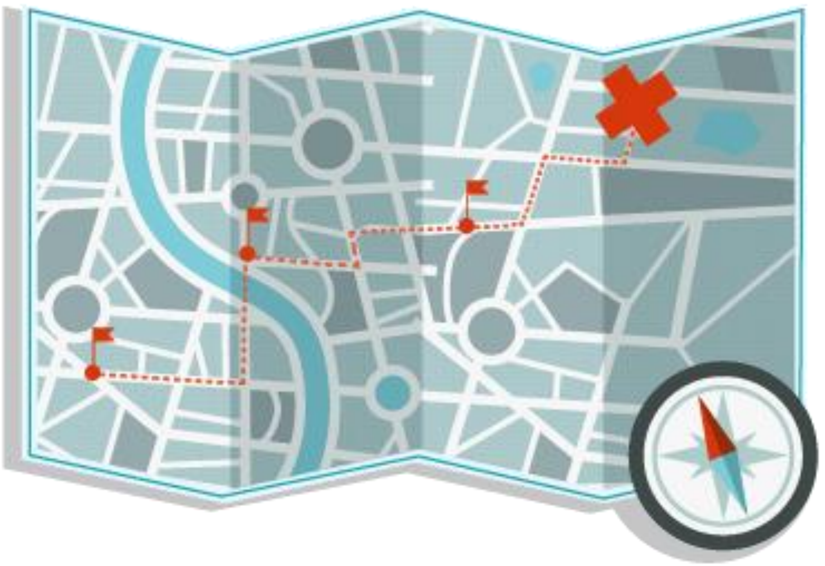
ANDERS JUHL KALLESØE, THOMAS VANGKILDE-PEDERSEN, METTE MORTENSEN, CLAUS DITLEFSEN (GEUS)

PART I
SCREENING OF SHALLOW GEO-ENERGY AND HEAT STORAGE POTENTIAL (WEB TOOL)



PART II
HEATSTORE UTES ROADMAP

VISIONS FOR FLEXIBLE ENERGY SYSTEMS WITH UNDERGROUND THERMAL ENERGY STORAGE TOWARDS 2050



SCREENING OF SHALLOW GEO-ENERGY AND HEAT STORAGE POTENTIAL

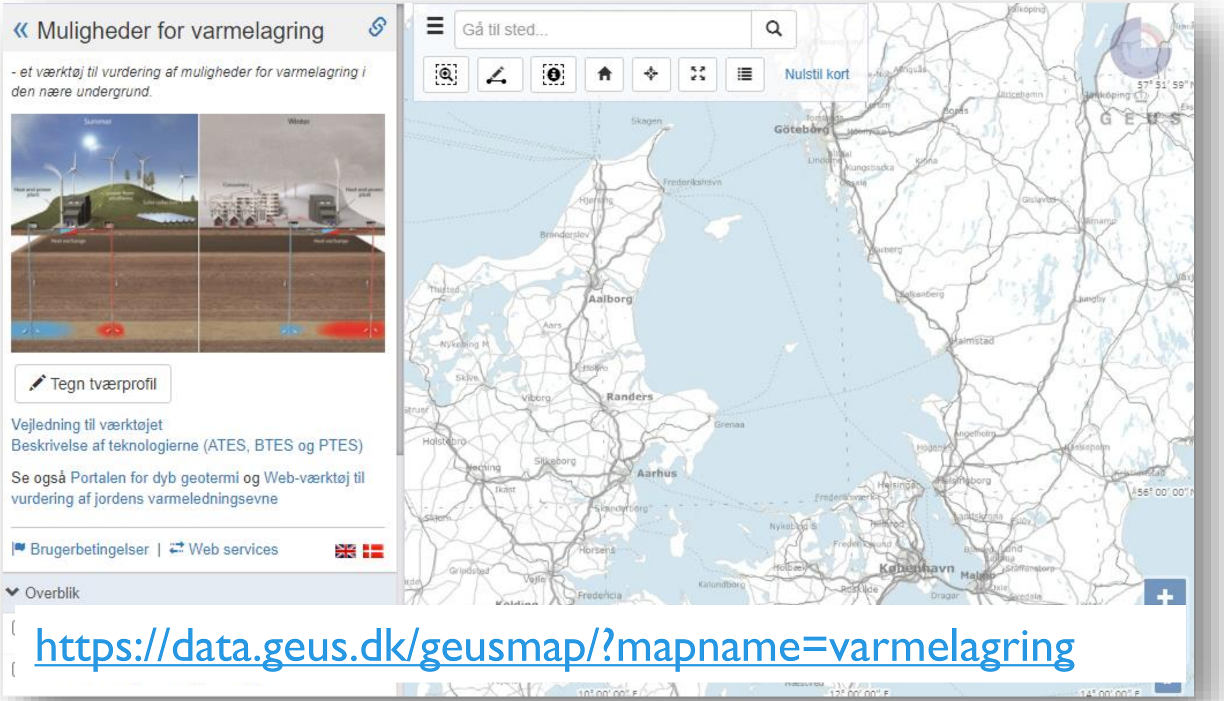
- A GEUS WEB SERVICE (VARMELAGRINGSKORTET)

i. **Background, purpose and target**

ii. **Data and current web solution**

iii. **Outlook**

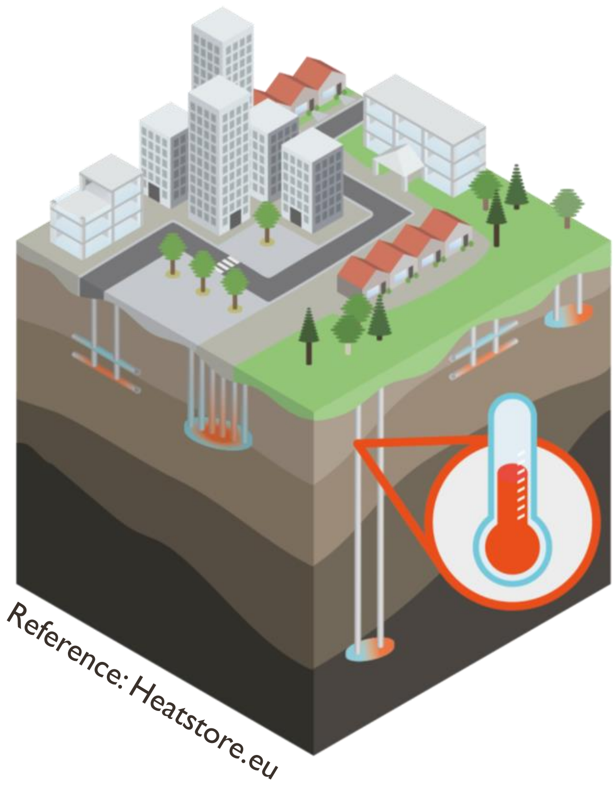
iv. **HEATSTORE GIS storymap**



https://data.geus.dk/geusmap/?mapname=varmelagring

PURPOSE AND TARGET

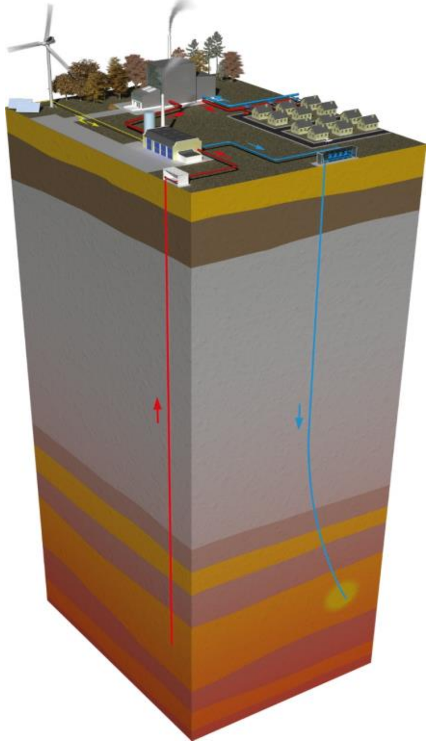
- Communicate and disseminate knowledge on the upper subsurface nationwide (and on European level) !
- Stakeholders should be able to do a first screening - and don't miss out opportunities in the strategic energy planning !
- The subsurface is a very valuable resource in the green transition towards renewables – it is not a "black box"
- Make subsurface data and knowledge easy and free accessible
- Communicate the international use and experiences of shallow geothermal energy (both new and mature technologies, both energy uptake and storage, UTES*)



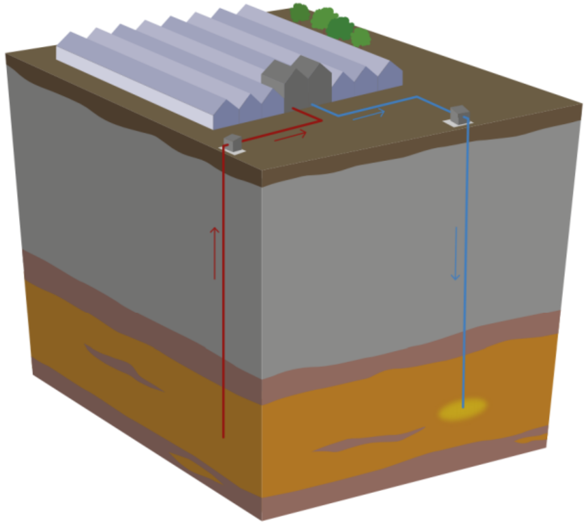
**UTES: Underground Thermal Energy Storage*

THE GEOLOGY AS ENERGY SOURCE AND STORAGE - DENMARK
- DEFINITIONS

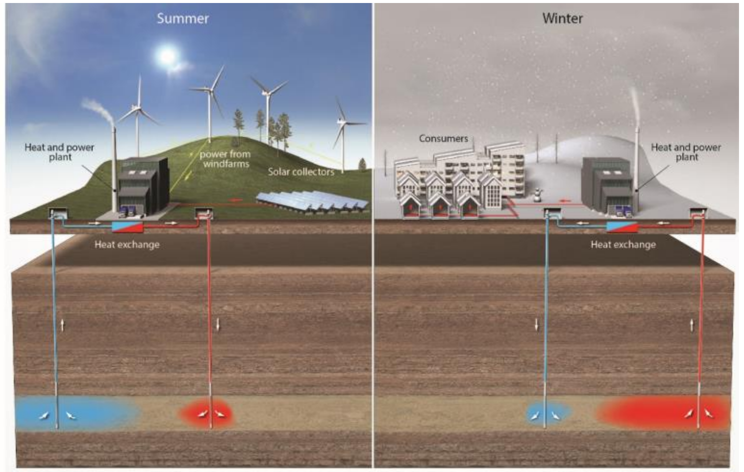
Deep geothermal energy
(≈ 3000–800 m)

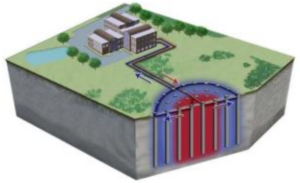


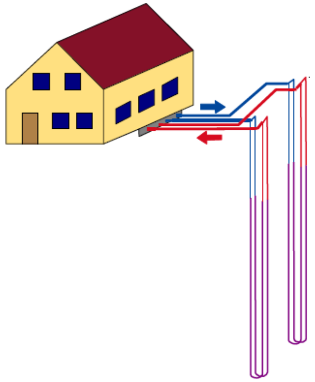
Semi-deep geothermal/ heat storage
(≈ 800–250 m)

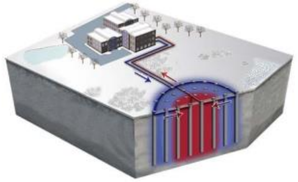


Shallow geothermal/heat storage
(≈ 250–1 m)

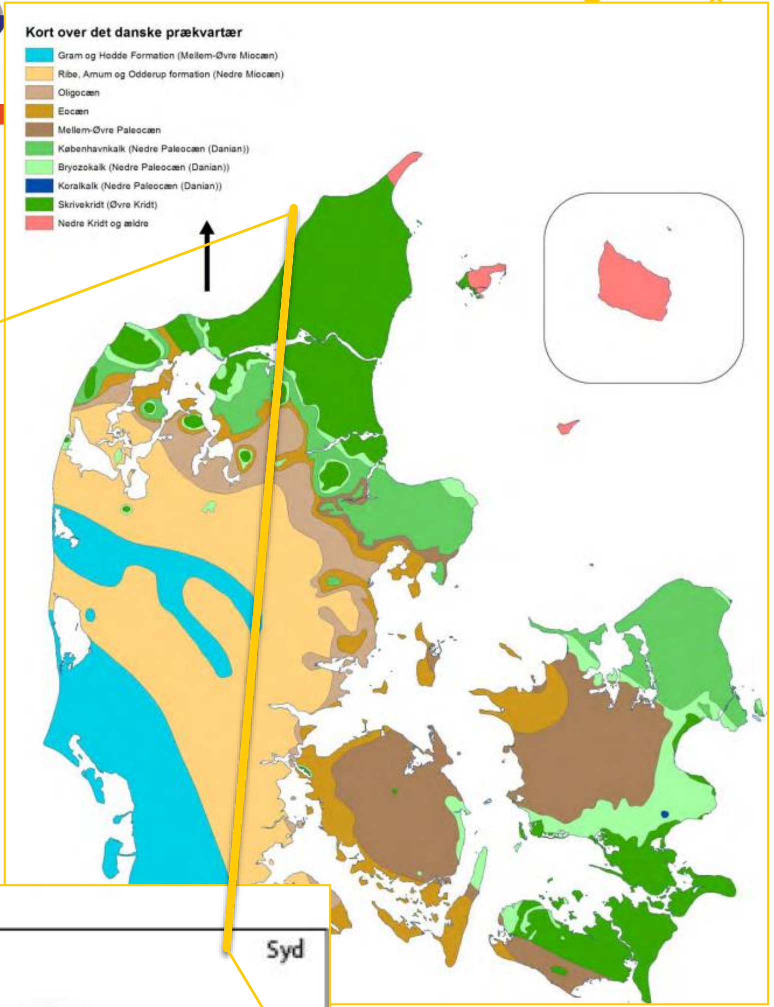


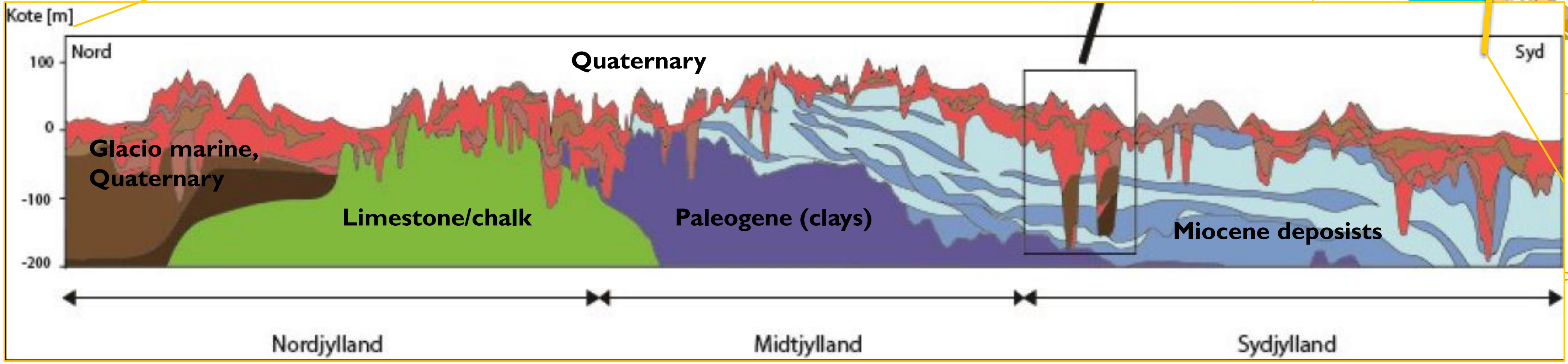






THE DANISH GEOLOGY
- NATURE BOUND FRAMEWORK





SUBSURFACE SCREENING AND FEASIBILITY REVIEW OF GEOLOGICAL CONDITIONS

Theoretical storage potential

Technical storage potential

Economic & market potential

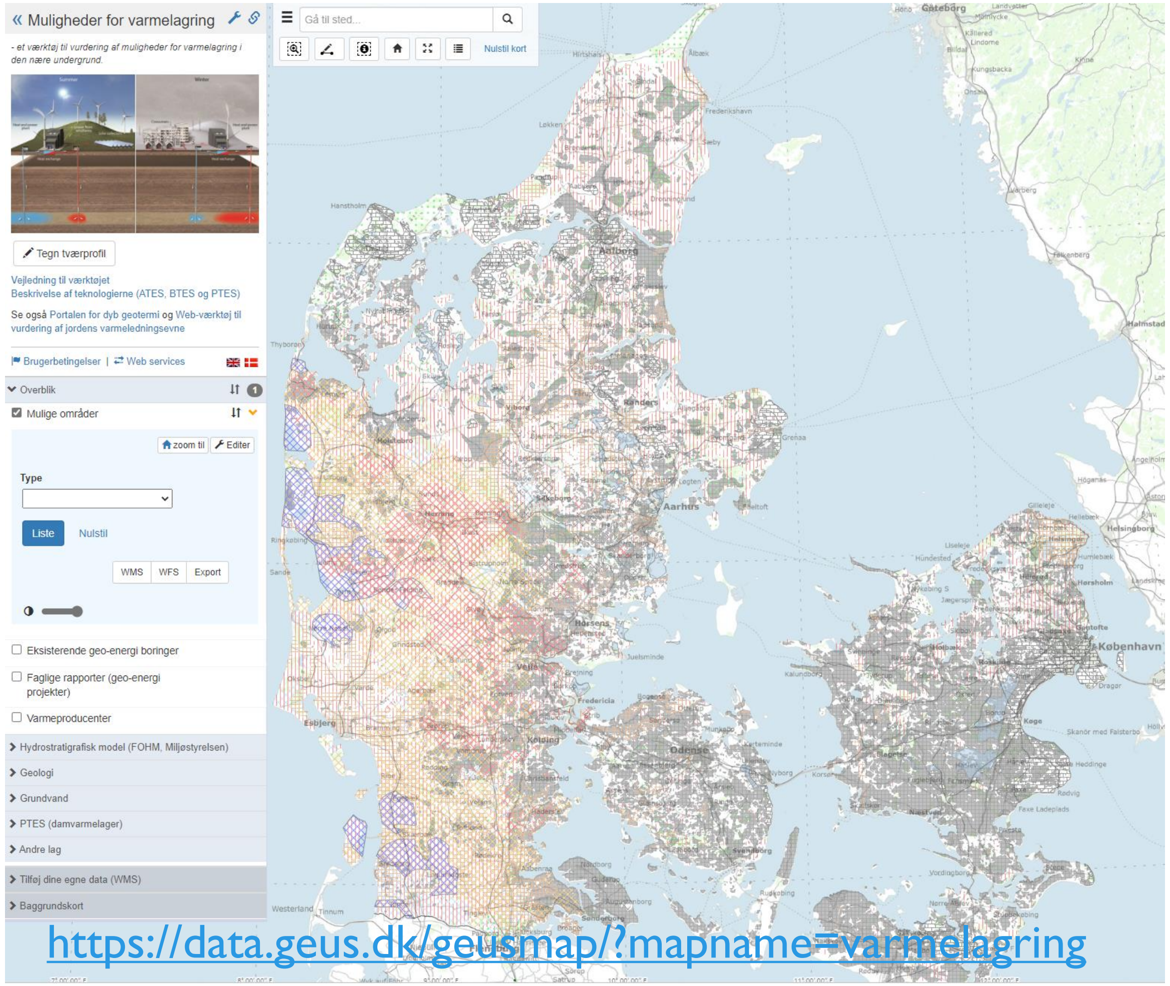
Critical information needed

- Depth of aquifers and aquitards
- Net thickness of aquifers and aquitards
- Permeability, porosity, transmissivity
- Groundwater properties (flow, salinity, viscosity, temperature, density)
- Hot well injection temperature
- Cold well injection temperature

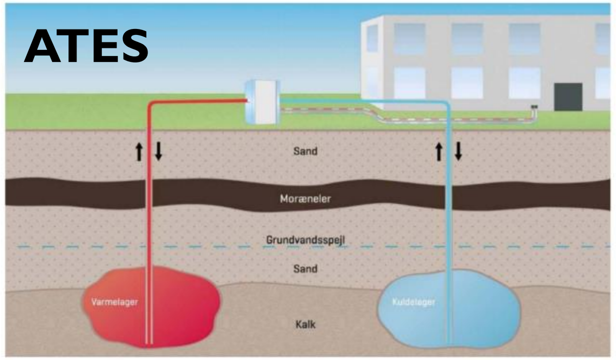
*Methodological framework of assessing theoretical, technical and economic &market potential of **HT-ATES** (reused from https://doi.org/10.1016/j.energy.2018.01.072 with permission by Elsevier Ltd. under Creative Commons license CC-BY-NC-NDhttps://creativecommons.org/licenses/by-nc-nd/4.0/189)*

VARMELAGRINGSKORTET – ACCESS TO DATA AND SUBSURFACE KNOWLEDGE

- SCREENING OF SUBSURFACE POTENTIAL – ALSO UPPER SOIL AND NEAR-SURFACE GROUNDWATER CONDITIONS

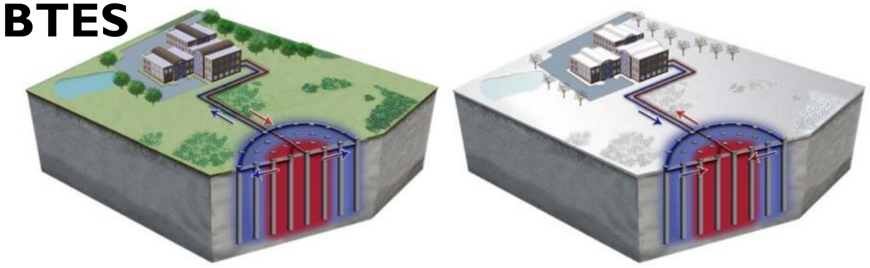


https://data.geus.dk/geusmap/?mapname=varmelagring



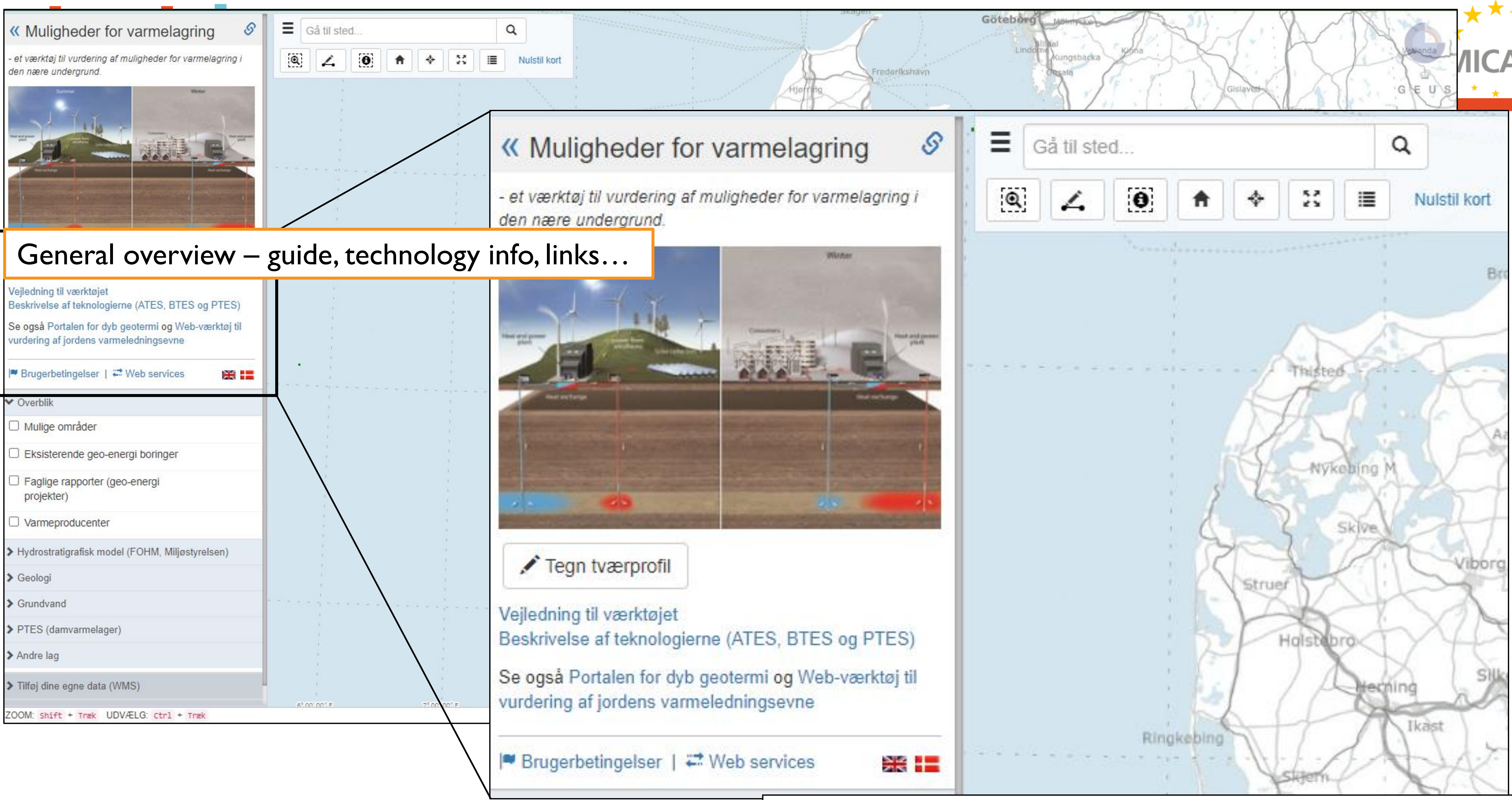
https://hs.geoenergi.org/xpdf/modelberegniger_varmelagring_oevre_undergrund.pdf

BTES



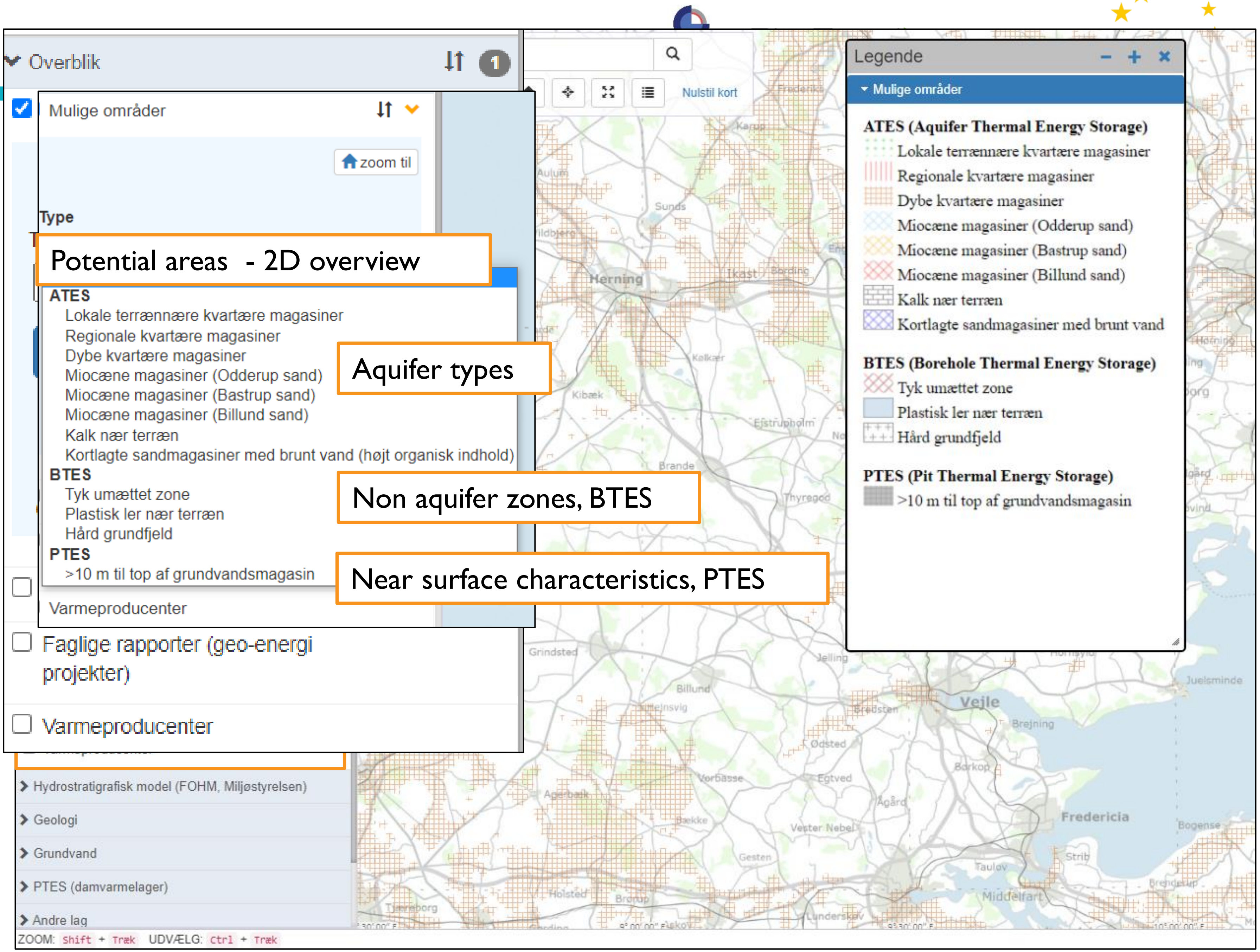
Kilde: http://underground-energy.com/our-technology/btes/

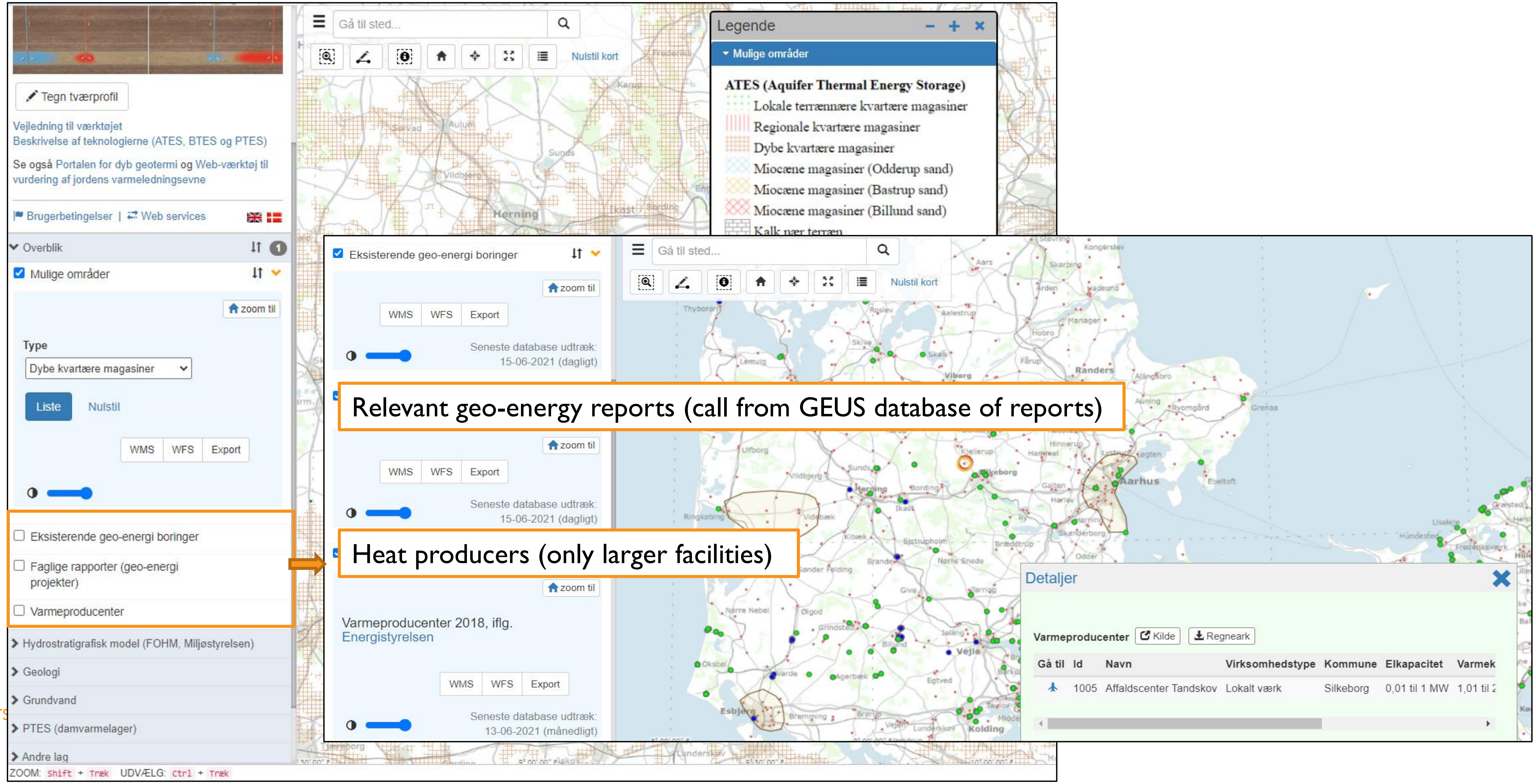
General overview – guide, technology info, links…



GEUS' WMS/WFS
Here, you can import layers into your own GIS tools.
Insert this URL in your GIS client:
http://data.geus.dk/geusmap/ows/25832.jsp?mapname=varmelagring&whoami=[email]

OVERVIEW


Overblik
Mulige områder
zoom til
Type
Potential areas - 2D overview
ATES
Lokale terrænnære kvartære magasiner
Regionale kvartære magasiner
Dybe kvartære magasiner
Miocæne magasiner (Odderup sand)
Miocæne magasiner (Bastrup sand)
Miocæne magasiner (Billund sand)
Kalk nær terræn
Kortlagte sandmagasiner med brunt vand (højt organisk indhold)
BTES
Tyk umættet zone
Plastisk ler nær terræn
Hård grundfjeld
PTES
>10 m til top af grundvandsmagasin
Aquifer types
Non aquifer zones, BTES
Near surface characteristics, PTES
Varmeproducenter
Faglige rapporter (geo-energi projekter)
Varmeproducenter
Hydrostratigrafisk model (FOHM, Miljøstyrelsen)
Geologi
Grundvand
PTES (damvarmelager)
Andre lag
ZOOM: Shift + Træk UDVÆLG: Ctrl + Træk
Nulstil kort
Legende
Mulige områder
ATES (Aquifer Thermal Energy Storage)
Lokale terrænnære kvartære magasiner
Regionale kvartære magasiner
Dybe kvartære magasiner
Miocæne magasiner (Odderup sand)
Miocæne magasiner (Bastrup sand)
Miocæne magasiner (Billund sand)
Kalk nær terræn
Kortlagte sandmagasiner med brunt vand
BTES (Borehole Thermal Energy Storage)
Tyk umættet zone
Plastisk ler nær terræn
Hård grundfjeld
PTES (Pit Thermal Energy Storage)
>10 m til top af grundvandsmagasin
Herning
Vejle
Fredericia


Tegn tværprofil
Vejledning til værktøjet
Beskrivelse af teknologierne (ATES, BTES og PTES)
Se også Portalen for dyb geotermi og Web-værktøj til vurdering af jordens varmeledningsevne
Brugerbetingelser | Web services
Overblik
Mulige områder
zoom til
Type
Dybe kvartære magasiner
Liste
Nulstil
WMS
WFS
Export
Eksisterende geo-energi boringer
Faglige rapporter (geo-energi projekter)
Varmeproducenter
Hydrostratigrafisk model (FOHM, Miljøstyrelsen)
Geologi
Grundvand
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Andre lag
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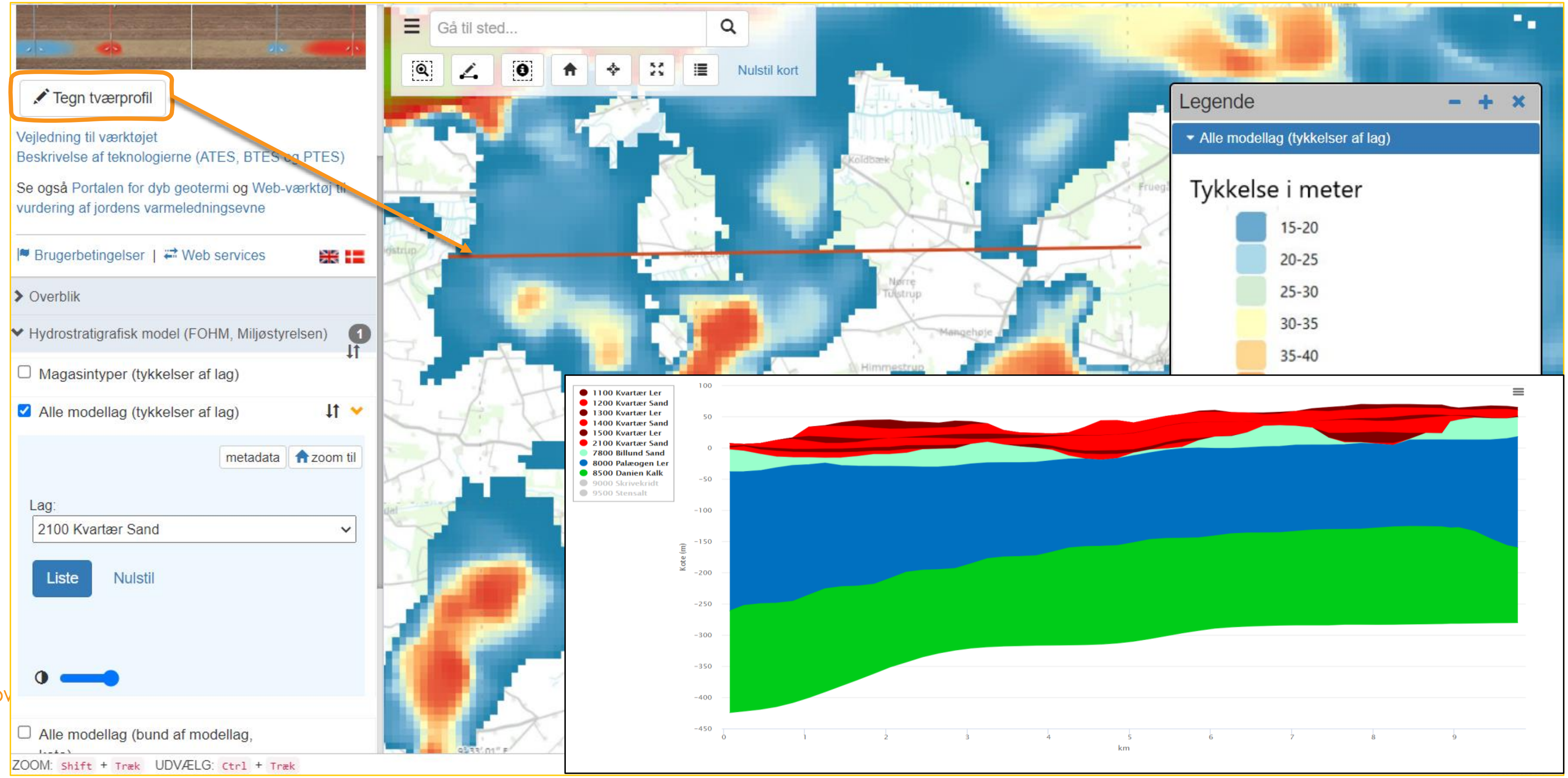
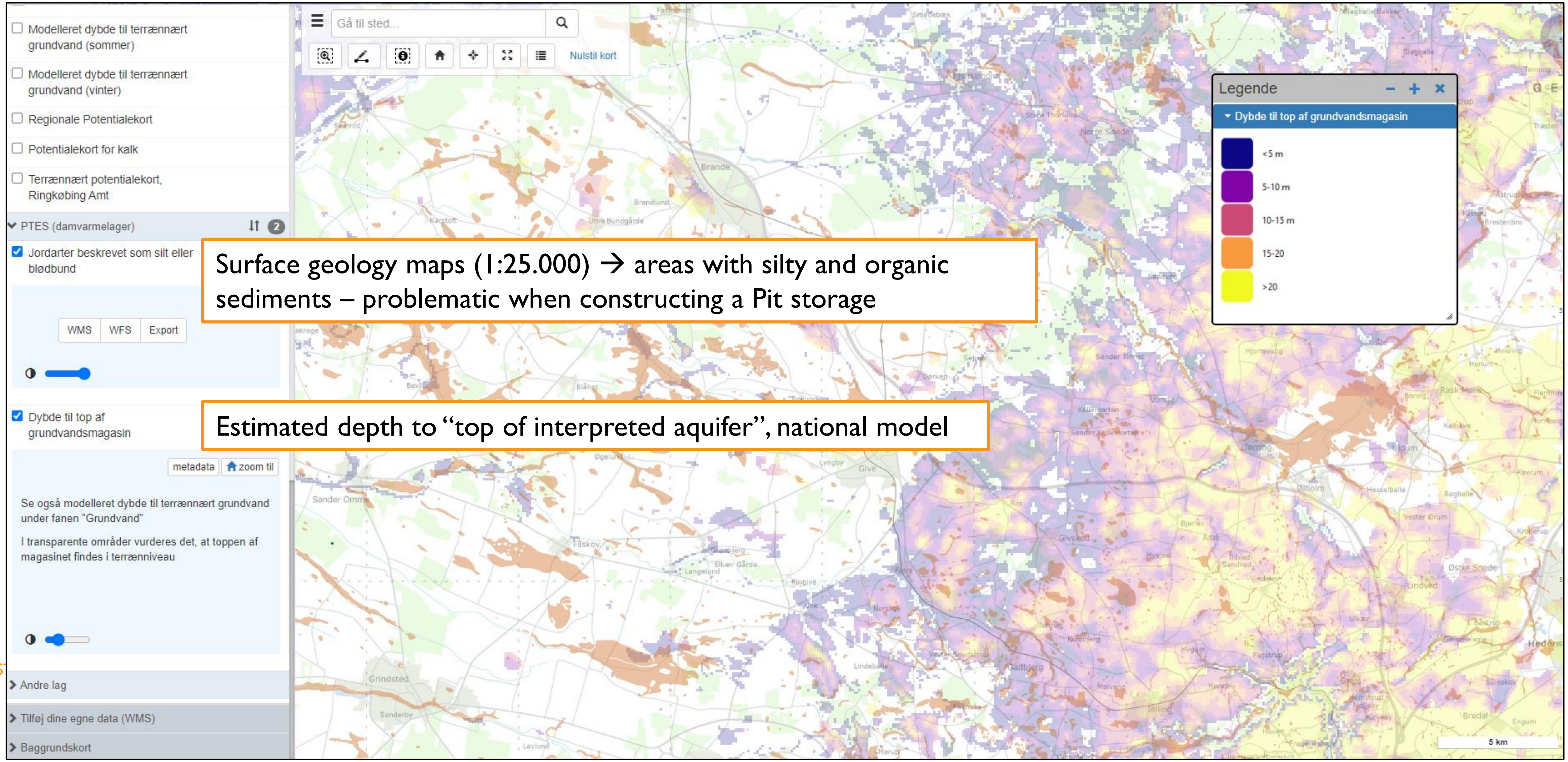
Gå til sted...
Nulstil kort
Legende
Mulige områder
ATES (Aquifer Thermal Energy Storage)
Lokale terrænnære kvartære magasiner
Regionale kvartære magasiner
Dybe kvartære magasiner
Miocæne magasiner (Odderup sand)
Miocæne magasiner (Bastrup sand)
Miocæne magasiner (Billund sand)
Kalk nær terræn
Seneste database udtræk: 15-06-2021 (dagligt)
Relevant geo-energy reports (call from GEUS database of reports)
Heat producers (only larger facilities)
Varmeproducenter 2018, iflg. Energistyrelsen
Seneste database udtræk: 13-06-2021 (månedligt)
Detaljer
Varmeproducenter
Kilde
Regneark
Gå til | Id | Navn | Virksomhedstype | Kommune | Elkapacitet | Varmek
1005 | Affaldscenter Tandskov | Lokalt værk | Silkeborg | 0,01 til 1 MW | 1,01 til 2

SELECTED FEATURES – CROSS SECTIONS



VARMELAGRINGSKORTET – PIT THERMAL ENERGY STORAGE (PTES)



Surface geology maps (1:25.000) → areas with silty and organic sediments – problematic when constructing a Pit storage

Estimated depth to "top of interpreted aquifer", national model

WEBSITE VIEW

OUTLOOK – BRIDGING EXISTING KNOWLEDGE TO A WIDE RANGE OF END-USERS ?

FUTURE MAP ? … connecting surface and subsurface knowledge better

Lagliste

Energy sources

- ON SURFACE
  - ✓ Energy producers, surplus heat…
- SUBSURFACE
  - ✓ Geology, groundwater…

Energy demand

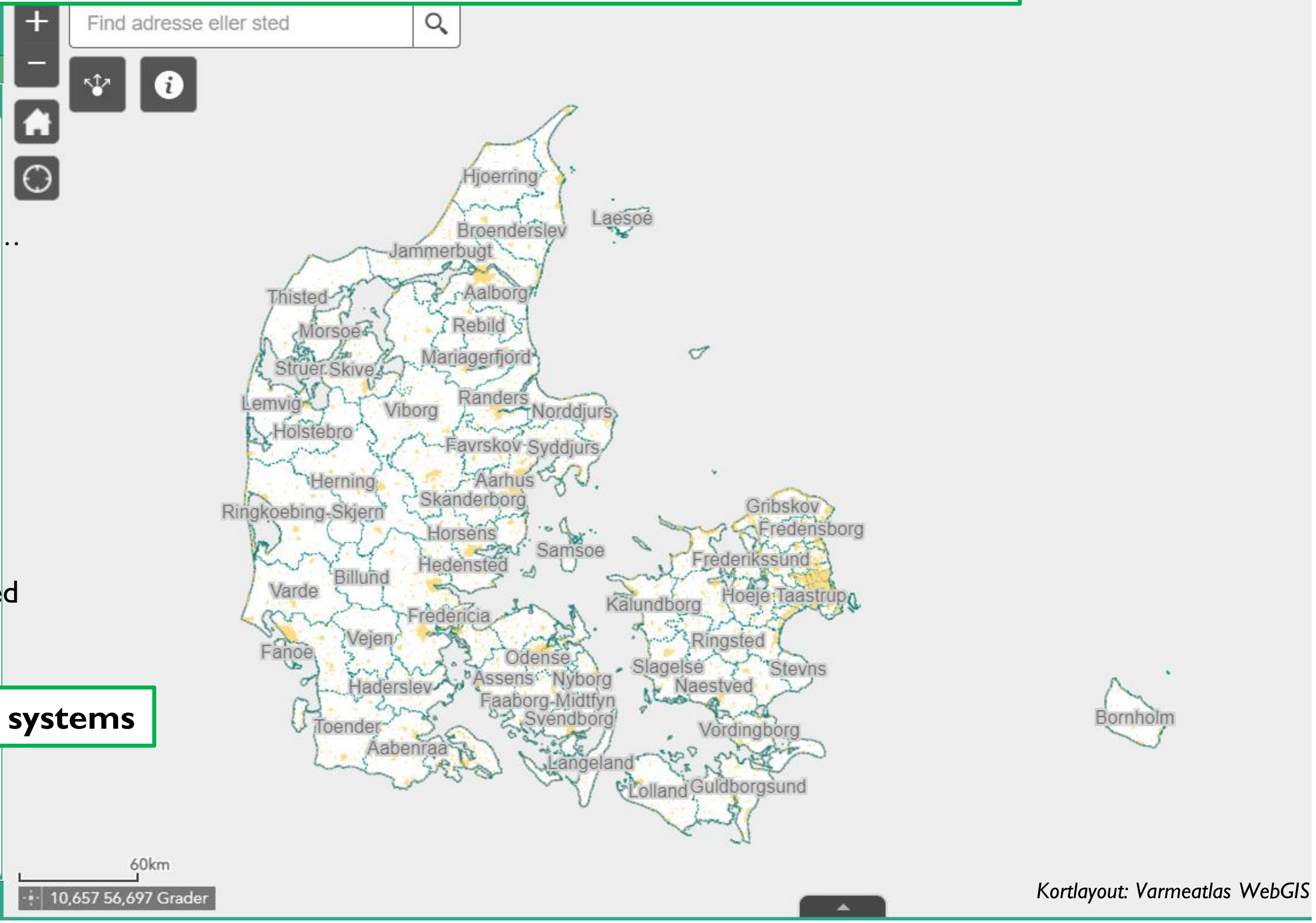
- ✓ National/local heat-atlas data
- ✓ Industry...

Calculation tools

- ✓ Energy-catalog/ experience based

Existing geo-energy and UTES systems

- ✓ Locations and type
  - ✓ System data
  - ✓ Operation data



Kortlayout: Varmeatlas WebGIS

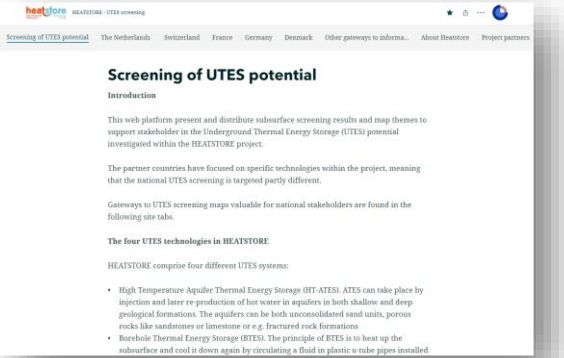
THE INTERNATIONAL GIS OUTCOME OF HEATSTORE

Understanding the subsurface conditions

insight into value of pre-feasibility drilling before project start to optimize design of UTES

First Step towards Better maps of UTES potential across EU countries

new characterisation tools



heatstore HEATSTORE - UTES screening

Screening of UTES potential | The Netherlands | Switzerland | France | Germany | Denmark | Other gateways to informa... | About Heatstore | Project partners

Screening of UTES potential

Introduction

This web platform present and distribute subsurface screening results and map themes to support stakeholder in the Underground Thermal Energy Storage (UTES) potential investigated within the HEATSTORE project.

The partner countries have focused on specific technologies within the project, meaning that the national UTES screening is targeted partly different.

Gateways to UTES screening maps valuable for national stakeholders are found in the following site tabs.

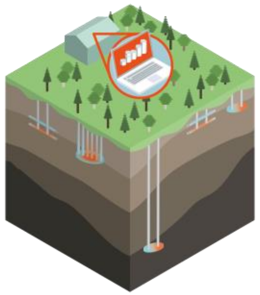
The four UTES technologies in HEATSTORE

HEATSTORE comprise four different UTES systems:

- High Temperature Aquifer Thermal Energy Storage (HT-ATES). ATES can take place by injection and later re-production of hot water in aquifers in both shallow and deep geological formations. The aquifers can be both unconsolidated sand units, porous rocks like sandstones or limestone or e.g. fractured rock formations
- Borehole Thermal Energy Storage (BTES). The principle of BTES is to heat up the subsurface and cool it down again by circulating a fluid in plastic u-tube pipes installed

https://arcg.is/0qyP4a

Modelling subsurface dynamics



Enhanced models to simulate subsurface performance of UTES technologies

Heating system integration & UTES design optimisation

Heat grid Integration: inclusion of UTES performance (proxy) modelling and demand side response controller in heat grid optimisation software packages of design and operation.

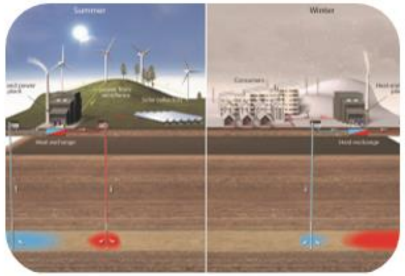
Demonstration and monitoring

Succesfull start up of new UTES projects within the project duration and enhanced monitoring in existing UTES projects.

Best practices and replication

- Start of an international UTES community to share learnings of successes and failures on:
- Design & System integration
- Business model
- Regulatory framework
- Stakeholder perception & engagement
- Monitoring & Environmental performance

THE FOUR TECHNOLOGIES IN THE GIS STORYMAP – DIFFERENT NATIONAL FOCUS IN HEATSTORE

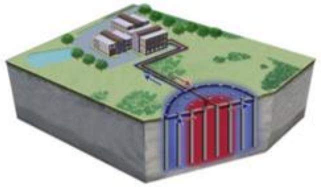


Aquifer Thermal Energy Storage

- ATES can take place by injection and later re-production of hot water in aquifers in both shallow and deep geological formations. The aquifers can be both unconsolidated sand units, porous rocks like sandstones or limestone or e.g. fractured rock formations. It is an open system using geothermal or water wells and storing the heat in the groundwater and in the formation around it.

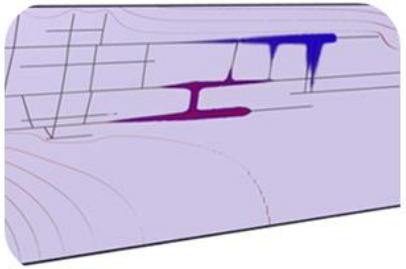
Pit Thermal Energy Storage

- Hot water is stored in very large (multiple) excavated basins with an insulated lid. Sides and bottom are typically covered by a polymer-liner, but can also be made of concrete.



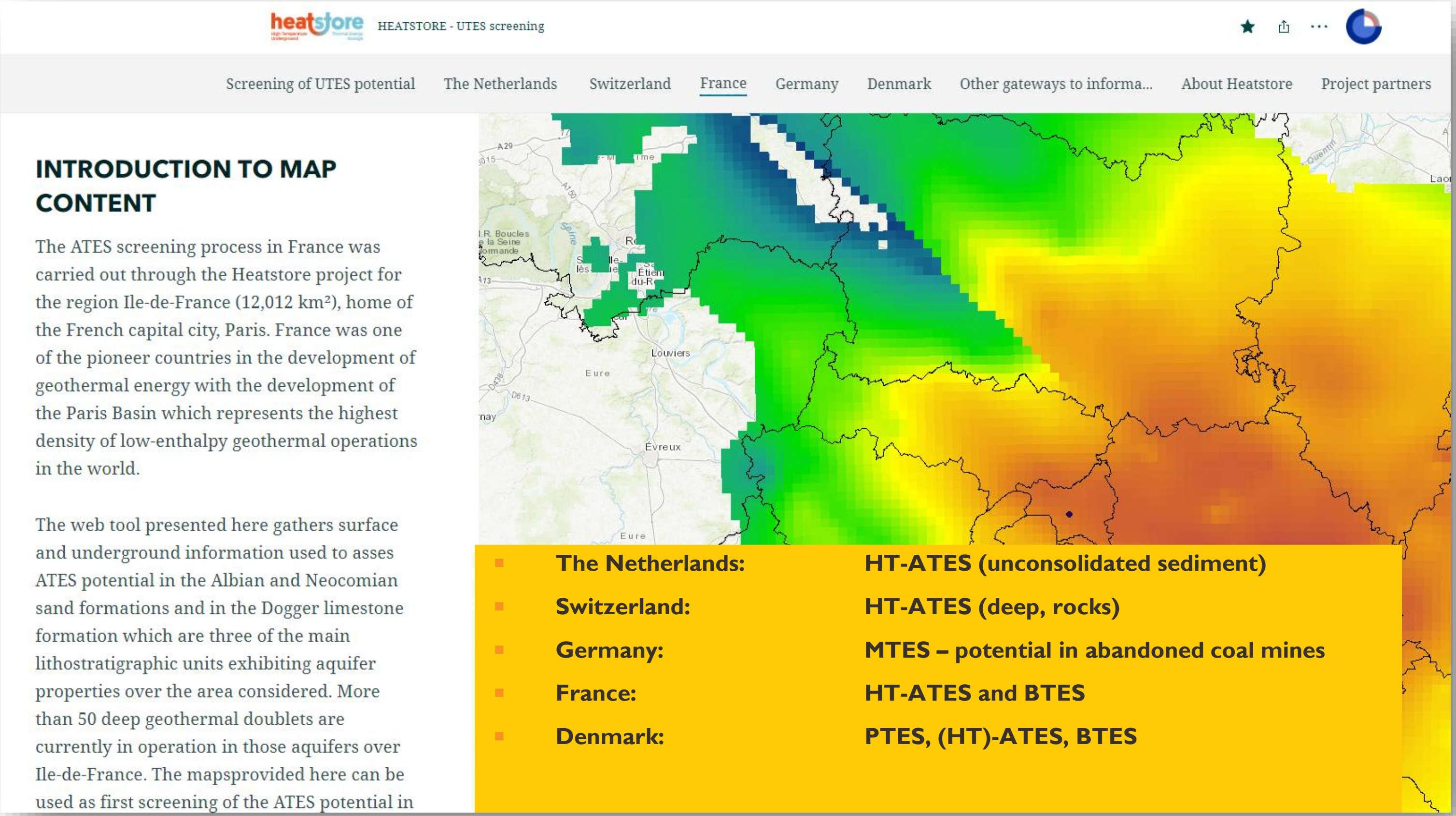
Borehole Thermal Energy Storage

- The natural heat capacity in a large volume of underground (unconsolidated) soil or rock is used to store thermal energy with or without groundwater as the storage medium. It typically has several closely spaced boreholes, between 50 and 200 m deep; they act as heat exchangers to the underground, usually in U-pipe form.



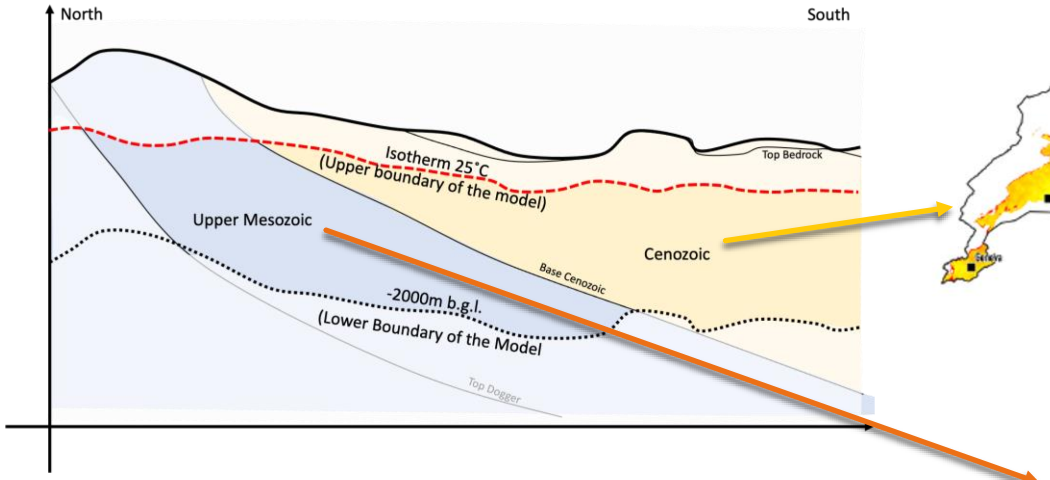
Mine Thermal Energy Storage

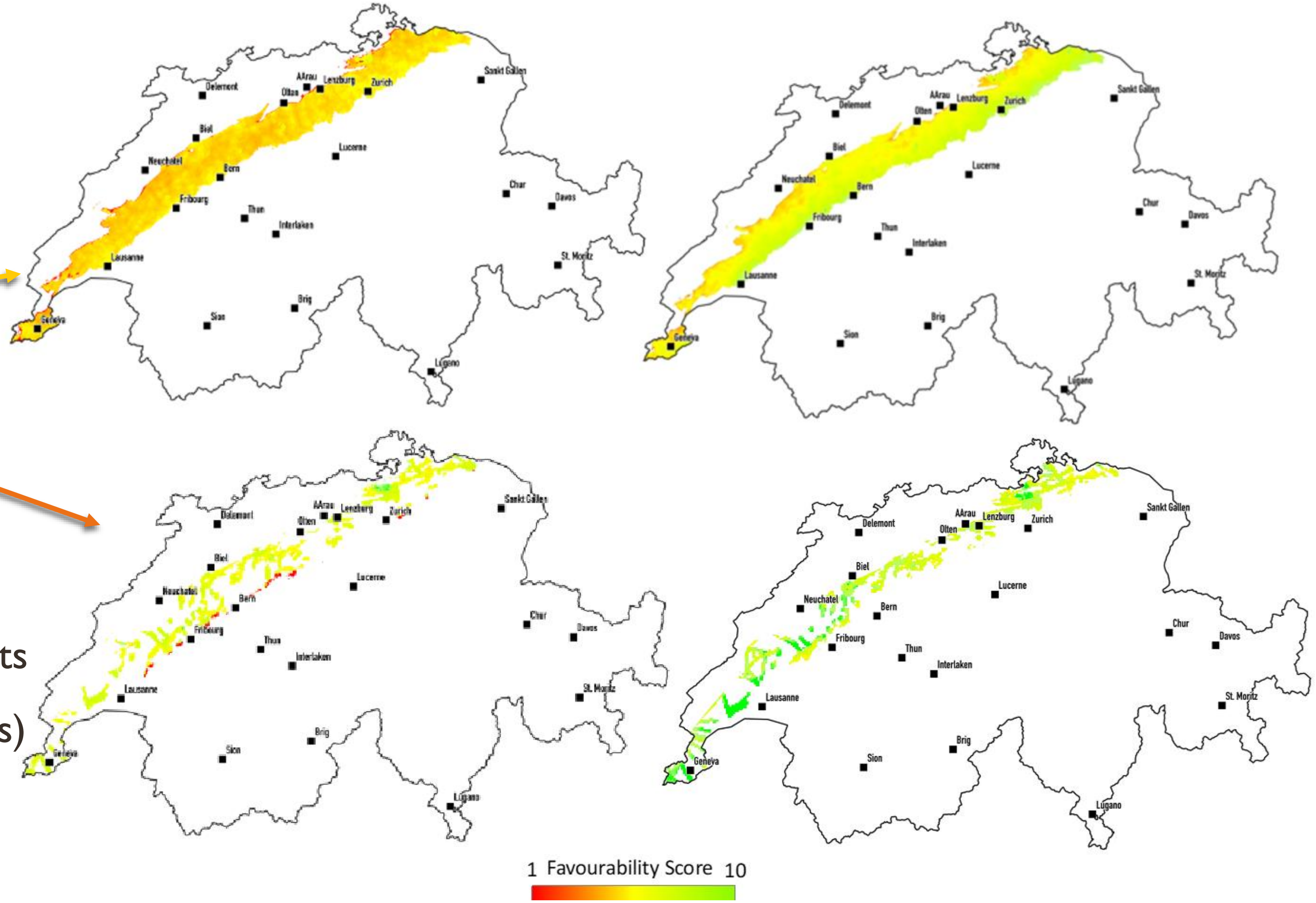
- Mine water of abandoned and flooded mines is used as a storage medium for high temperature storage. The mine water can also be used as an ambient energy source in combination with heat pumps.



The Netherlands:	**HT-ATES (unconsolidated sediment)**
Switzerland:	**HT-ATES (deep, rocks)**
Germany:	**MTES – potential in abandoned coal mines**
France:	**HT-ATES and BTES**
Denmark:	**PTES, (HT)-ATES, BTES**

EXAMPLE – SWITZERLAND



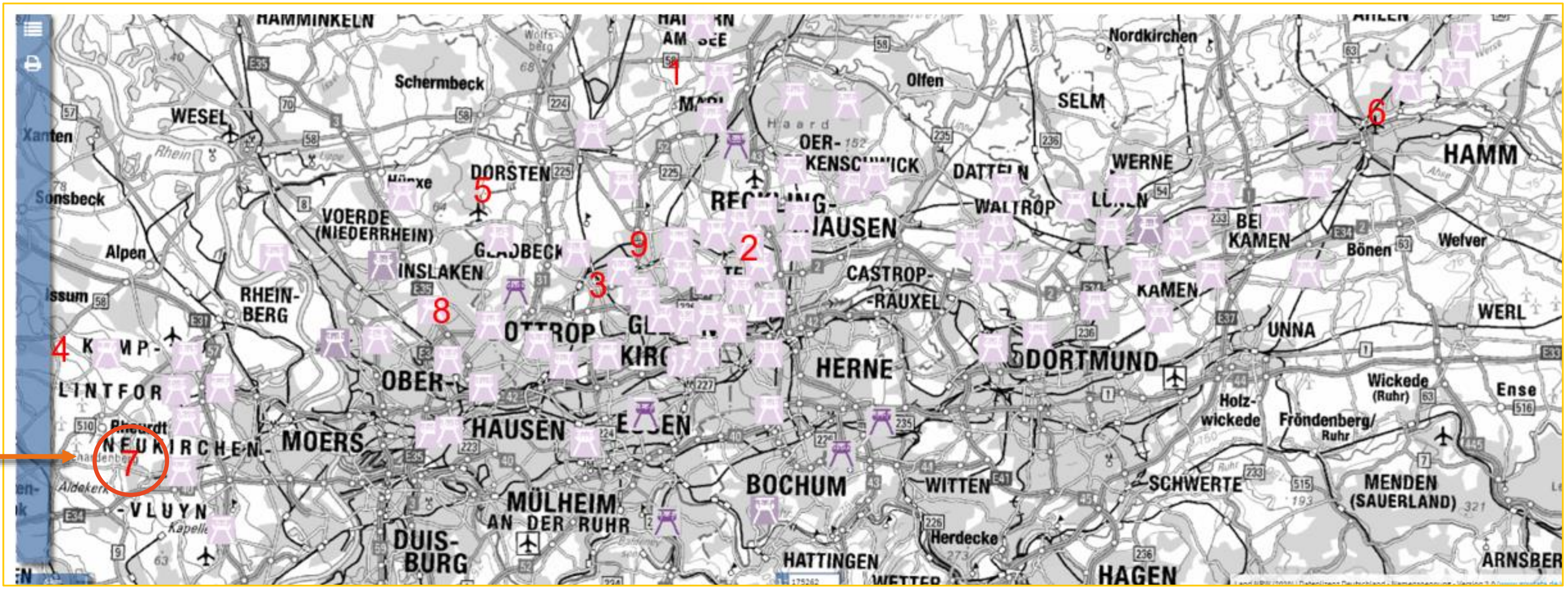


- Focus on two hardrock reservoirs
- Favorability scores based on multiple datasets
- Geneva and Bern pilots (waste heat sources)

EXAMPLE - GERMANY

- Focus on mine and energy infrastructure in Ruhr district
- Selection of most favorable old mine systems

Prioritized areas



Map of the screening results for commercial national MTES locations in NRW (Germany)

LINKS TO OTHER RELEVANT GATEWAYS - HOTMAPS

HEATSTORE - UTES screening

Screening of UTES potential | The Netherlands | Switzerland | France | Germany | Denmark | Other gateways to informa... | About Heatstore | Project partners

HOTMAPS PROJECT

The overarching goal of Hotmaps is the development of an open source heating / cooling mapping and planning toolbox and to provide default data for EU28 at national and local level. These data and tool allow public authorities to identify, analyse, model and map resources and solutions to supply energy needs within their territory of responsibility in a resource and cost efficient way. Those results will help authorities to develop heating and cooling strategies on local, regional and national scale which are in line with RES and CO2-Emission targets on national and EU level.

Hotmaps is a GIS-based online software that supports authorities and energy planners to set up a strategic heating and cooling plan for their region. The first version of the tool is now available at

HOTMAPS

The **Hotmaps** project aims at designing an open source toolbox to support public authorities, energy agencies and urban planners in strategic heating and cooling planning on local, regional and national levels, and in line with EU policies.
More information on the project can be found here: https://www.hotmaps-project.eu

Hotmaps Wiki: For details about tool functionalities as well as the manual for using the calculation modules, please refer to the Hotmaps Wiki: https://wiki.hotmaps.eu

Open source: The developed tool and all related modules run without requiring any other commercial tool or software. Use of and access to Source Code is subject to Open Source Licenses. The datasets that are used in the tool can be found at https://www.gitlab.com/hotmaps The source code of the tool can be accessed via https://www.github.com/hotmaps

Feedback and contributions: We are happy to receive feedback on the tool. Please use the feedback-button in the toolbox to let us know your opinions and suggestions for the tool. Hotmaps also invites other developers to contribute with additional calculation modules or datasets that can be integrated in the toolbox. Please also get in contact with us if you want to take part in the future development of the toolbox.

Supported browsers:

Firefox version 76.0.1

Increase awareness of shallow geothermal energy solutions
Communicate data and knowledge to a larger group of stakeholders

Bridge the gap between geoscientists and energy engineers

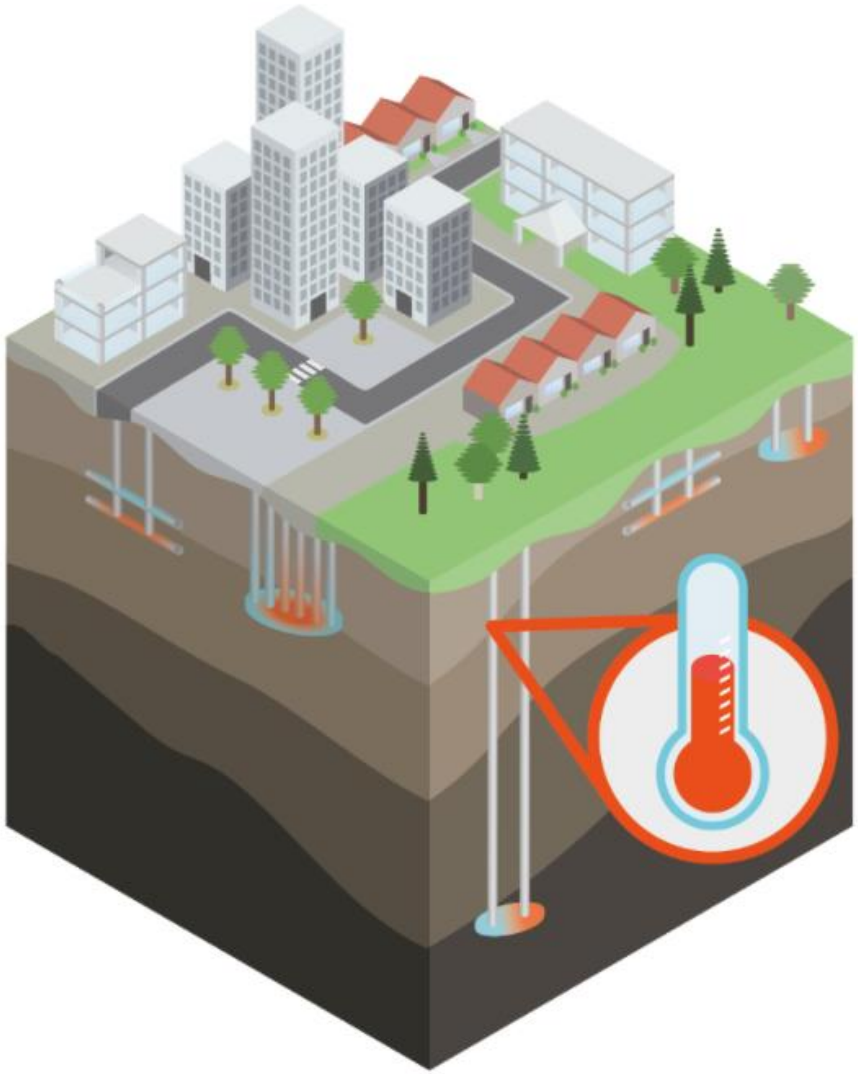
Extend with accessibility to further data sources – subsurface
and especially **surface data** (energy sources and demand)

Connect data accessibility to established business cases, operational data and lessons learned

HEATSTORE ROADMAP

Roadmap for flexible energy systems with Underground Thermal Energy Storage towards 2050

HEATSTORE D6.4 roadmap report



HEATSTORE KNOWLEDGE SHARING AND MONITORING MEETING

HEATSTORE ROADMAP
→ WHAT ARE THE MAIN ADVANTAGES OF UTES

- **UTES supports the transition to a sustainable heat supply**;
- It enables **more efficient use of (local) sustainable heat sources**;
- It has the capacity to **store large quantities of thermal energy** (potentially >10 GWh) over a large period in order to match seasonal supply and demand;
- It increases **operational flexibility** of energy systems;
- Depending on the technology, it has **the capability to serve different energy systems**, from large scale district heating and cooling networks and industrial applications, to small scale systems for commercial buildings and household dwellings.
- It can provide **flexibility to the electricity grid** via electric boilers and heat pumps allowing surplus electricity to be efficiently stored as heat for later use in heating and cooling networks
- UTES can **store energy on different timescales**: days, weeks or even months.
- Peak shaving and heat storage can **help to balance demand and supply** to make better use of infrastructure and assets (e.g. increase full load hours for geothermal heat sources).

- UTES benefits from a typically **lower range of storage costs compared to other heat/ energy storage technologies**

ENERGY STORAGE CAPACITIES REQUIRED IN A FUTURE EUROPEAN ENERGY SYSTEM

- Victoria et al 2019: European scenario study

Individual

Central

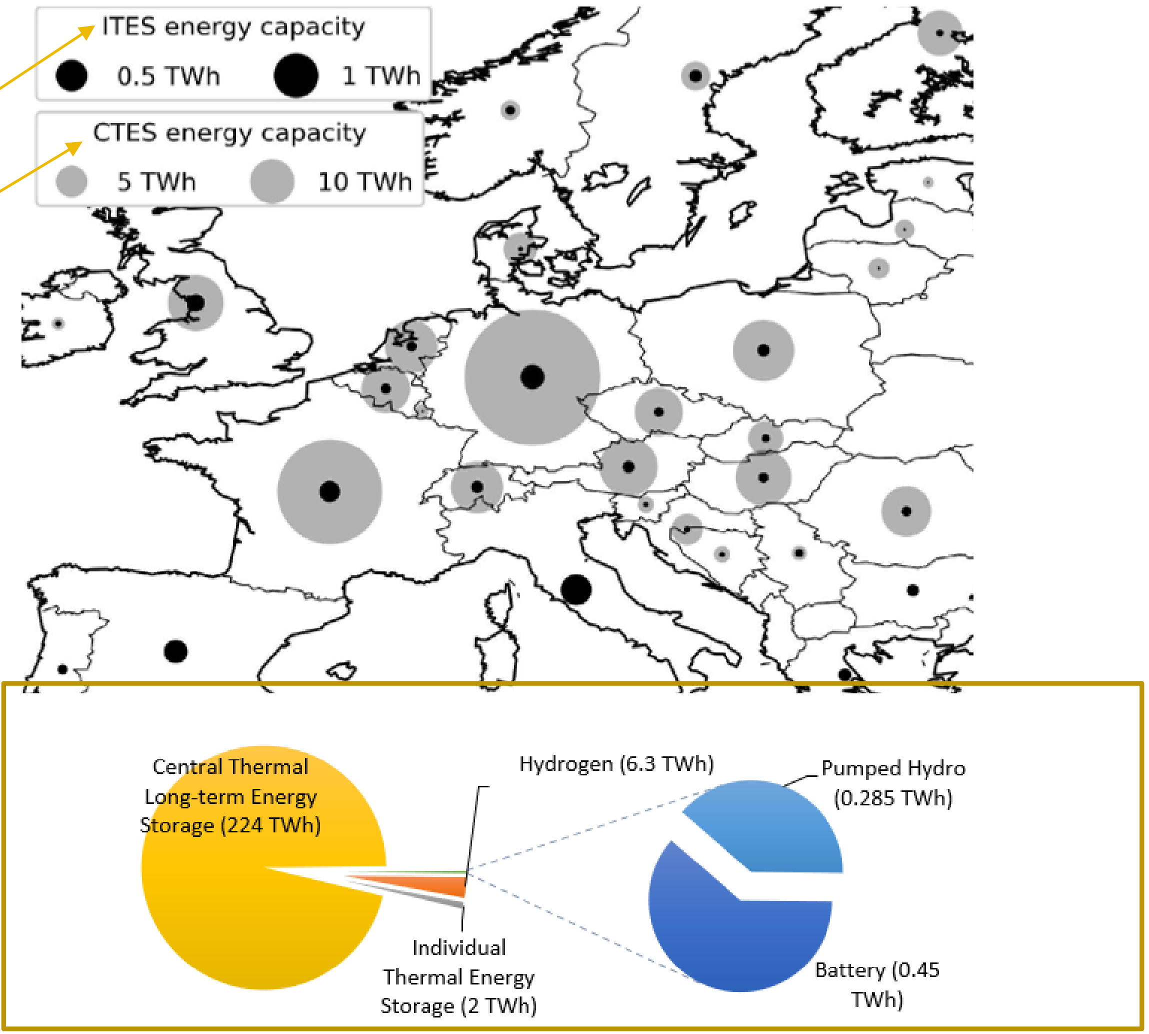


Figure 8 Energy storage capacities required in a future European energy system scenario with 95% CO_2 emissions reduction (source Victoria et al. 2019). High res: https://ars.els-cdn.com/content/image/1-s2.0-S0196890419309835-gr5_lrg.jpg

*"Overall, the integration of low carbon heat sources in the energy system implies that **hundreds to even thousands of large scale UTES systems need to become operational in Europe in the next thirty years** in order for the European heating and cooling sector to contribute to the sustainability goals of the Paris agreement and EUs Green Deal."*

D6.4 HEATSTORE report

REFERENCE: Marta Victoria et. al, "The role of storage technologies throughout the decarbonisation of the sector-coupled European energy system", 2019, Energy Conversion and Management, 201. The Central Thermal Energy Storage option in this study can be seen as a valid proxy to understand the potential role of (seasonal) UTES technologies in similar scenarios.

PILLARS OF IMPORTANCE – PROJECT EXPERIENCES AND COMMON GOALS

- Gain skills and experience
- Integrate UTES in heat grids
- Reduce subsurface uncertainty
- Improve UTES efficiency
- Reduce operational risks

Technology & Innovation

- Robust business model
- CAPEX reduction
- Create business model revenue
- Transparency – ownership, market player

Market & Economics

- Evaluate and monitor
- Solid spatial planning
- Create social awareness

Society & Environment

- Create joined vision on UTES
- Provide regulatory framework
- Adapt policy to UTES

Policy & Regulations

Policy & Regulations

Society & Environment

Market & Economics

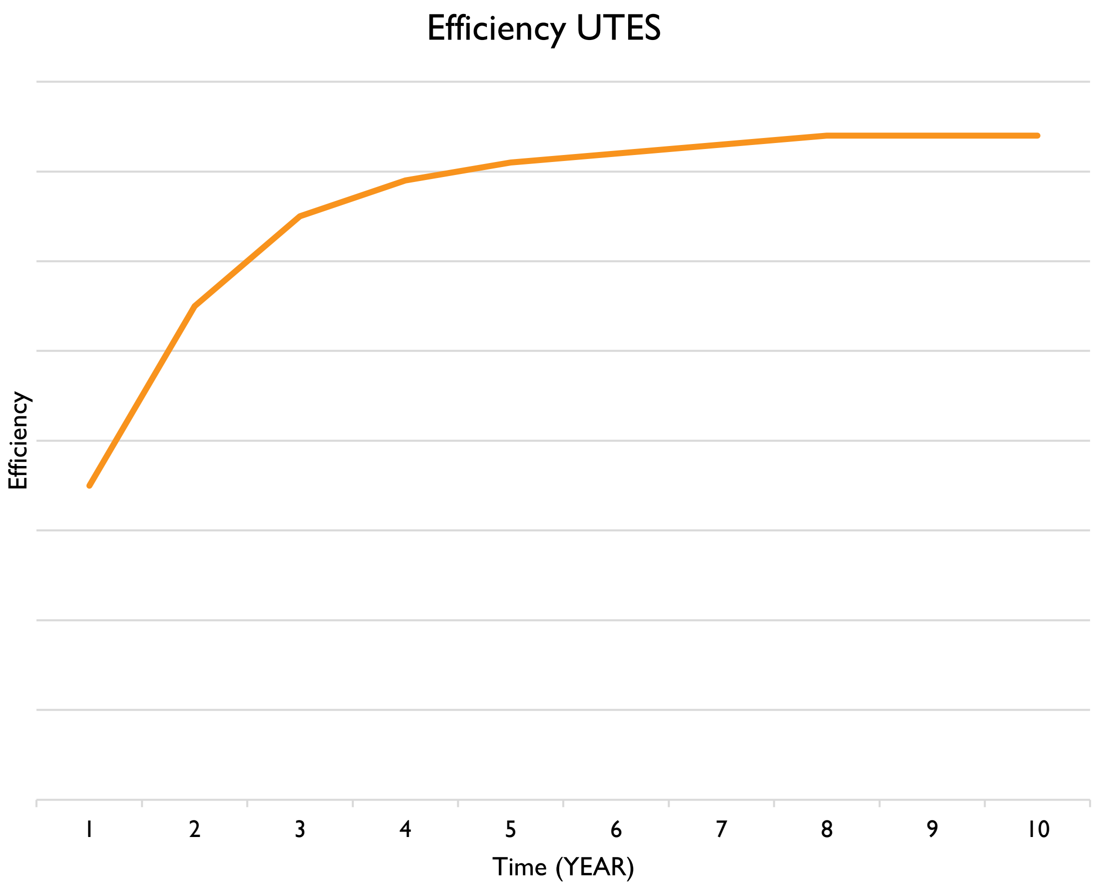
Technology & Innovation

Common goals:

- **European demo programme**
- **reduce tech risks and improve performance**
- **Lower the project costs and investment risks for market development of UTES**
- **National vision on UTES including supporting regulatory framework**
- **Facilitate early engagement with stakeholders to provide information on environmental risks and benefits**

Technology & Innovation

- Reduce subsurface risks → enhanced public available data, and mapping/modelling of the subsurface → reduce drilling risk (ATES)
- Improve efficiency in the first operational years (?)
- Reduce operational risks (e.g. corrosion or scaling in piping system (ATES), top insulation (PTES), …)



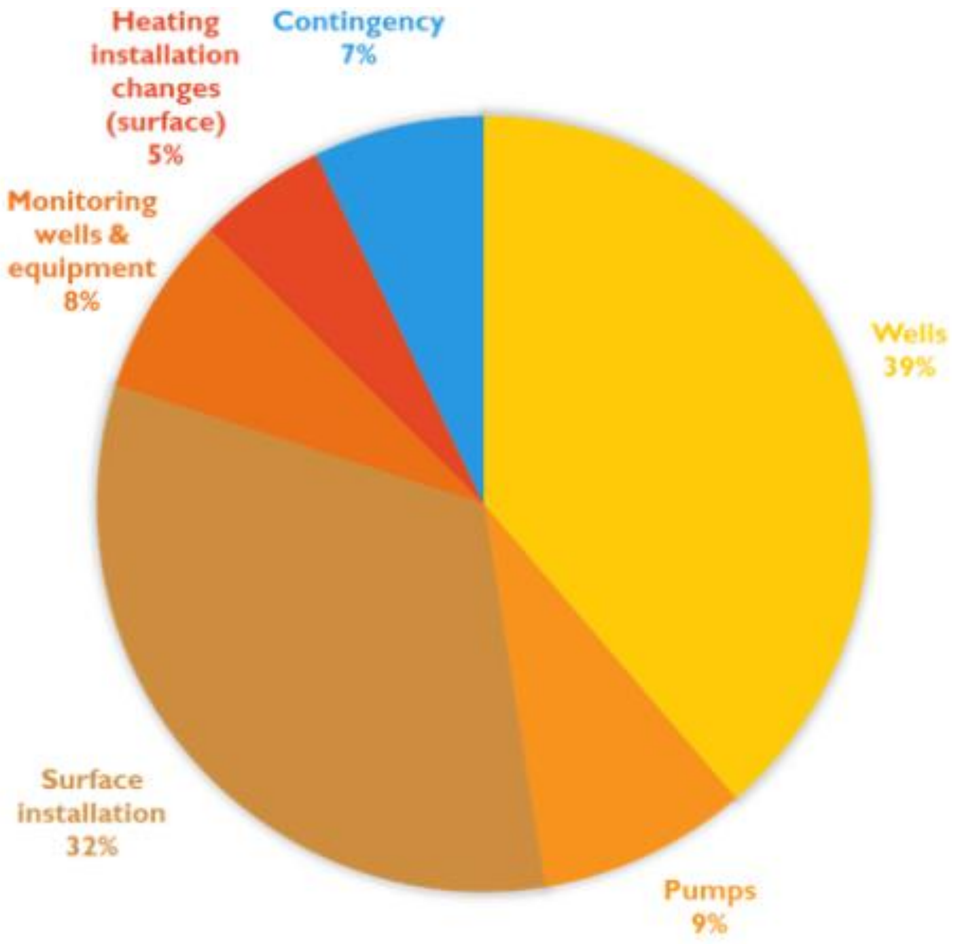
General UTES efficiency plot with low efficiency in the first years.

Market & Economics

HEATSTORE investment example – ECW HT-ATES pilot

Important actions to reduce overall project costs are:

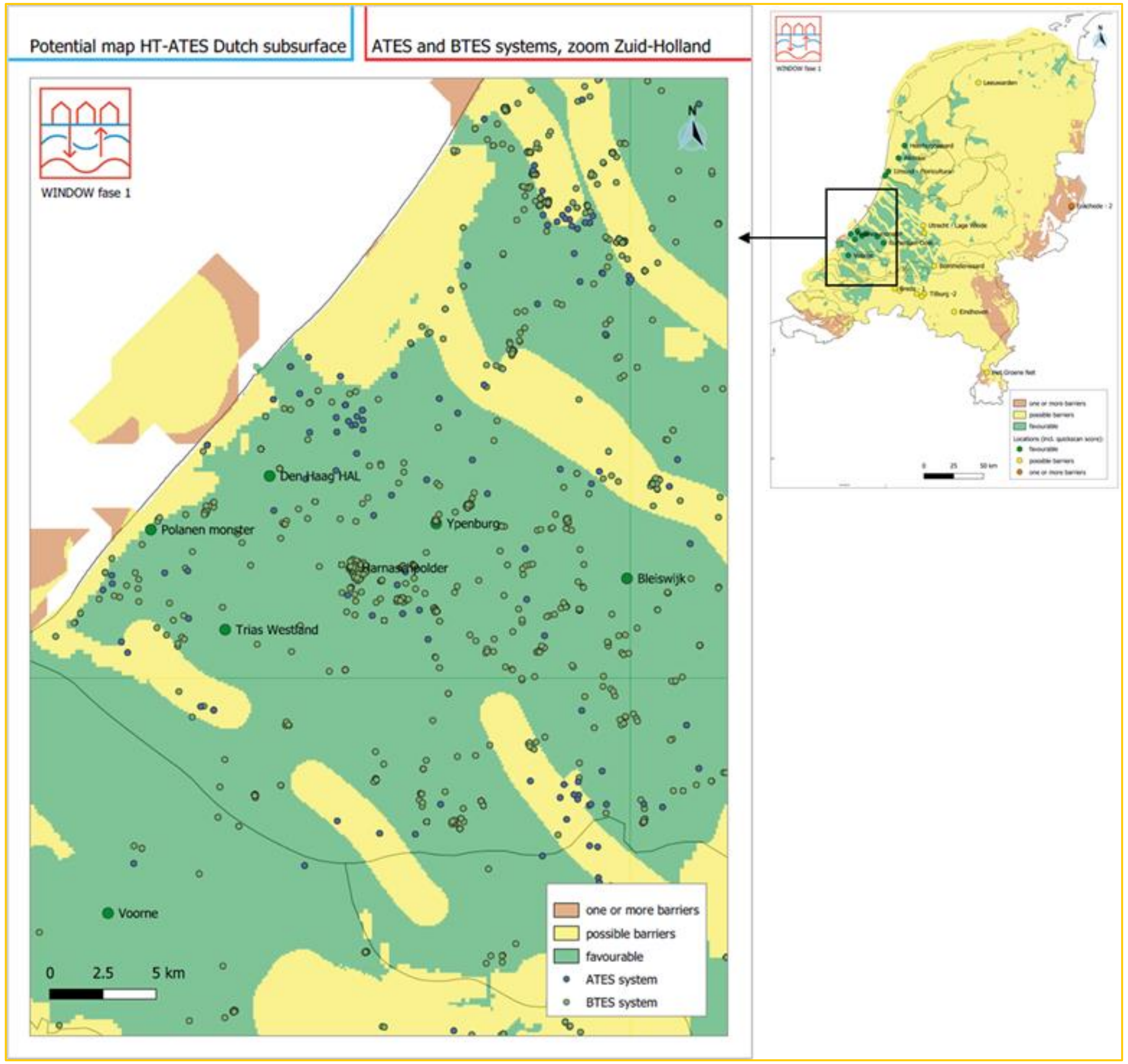
- **Developing new and establish experience with applying low cost materials for UTES**. Examples are high temperature resistant liners for PTES and low cost high temperature resistant well and pump cost reduction for ATES.
- **Improved modelling, design and integration of UTES in the heat network and energy system** to better size and fit the system with the energy system needs.
- **Develop industry standards in material selection and design procedures for UTES systems**
- **Learning curve cost reductions**: *replication of projects* with similar conditions opens up cost reduction in the supply chain for UTES projects as components and realisation costs decrease due to increased experiences.



Investment cost breakdown for HT-ATES facility in Middenmeer, the Netherlands.

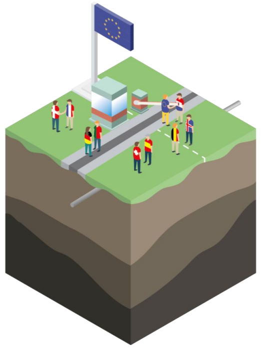
Society & Environment

- Thorough spatial planning of the subsurface and surface → increase accessibility to environmental data, administrative data, existing systems etc.
- Communication is key
  - Create early general awareness of UTES and build trust by showing lessons learned from demos and early projects
  - Facility early engagement with stakeholders and involvement of the public for specific UTES projects
  - Develop social engagement programmes



Low temperature ATES and BTES systems in the Dutch subsurface. The zoom shows the densely populated area in the Western part of the Netherlands, where potential for HT-ATES is high (green)

Policy & Regulations



To increase awareness and create a good strategy for adoption and governance of UTES, **UTES should be placed higher on the political agenda.**

Clear regulations specifically for UTES technologies need to be developed to promote the large scale adoption of UTES.

Simple and clear support schemes are required to support stakeholders in the development of UTES systems.

HEATSTORE vision… the role of UTES in the European energy system

- Underground thermal energy storage has the potential to **overcome short and long-term mismatch between demand and supply** and therefore support the energy system by providing flexibility and adequacy in a sustainable way.

- The application of UTES helps **reduce the carbon footprint of the energy sector**. The application is widely applicable in energy infrastructures supplying sustainable and low carbon heat to industry, agriculture and district heating grids.
  - Additional benefits of storing heat underground, although technology dependent, **help reduce the spatial footprint of the future energy system at surface level (e.g. HT-ATES)**.

- Compared to other storage techniques, UTES can store heat over long periods of time (seasons), is **economically feasible and compatible with many renewable energy sources**.

- It is an environmentally friendly storage technique which requires a **low use of rare earth materials**.

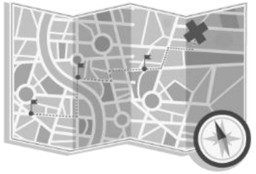
HEATSTORE vision… the role of Underground thermal energy storage in the European energy system

- …*but* in order **to make UTES a success**
  - development of a strategic portfolio of demonstration sites necessary
  - a mature regulatory framework
  - a positive public opinion are crucial
  - A European UTES alliance can play a key role

  - → This will help develop UTES towards a standard technology for new sustainable energy infrastructures

HEATSTORE vision… an European UTES alliance

National roadmaps



The alliance can built a repository for **long-term monitoring programmes** of UTES project performance (techno-economic and Health Safety and Environment).

Stakeholder strategy
Communication and awareness

Platform for knowledge and experience sharing from UTES flagship projects

European UTES alliance

Training of local engineers, geological surveys, governments, consultancies, local equipment and service providers.

Bring the needed input to develop a comprehensive **framework of regulatory and non-regulatory measures** to support UTES technology development and implementation across the EU

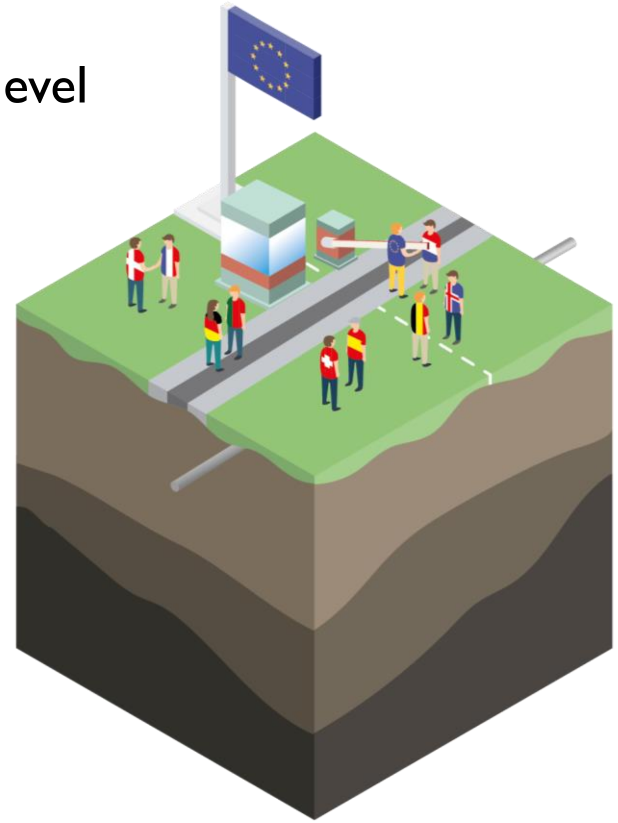
Builds innovation ecosystems across Europe and build local value chains that are needed for UTES technologies to be implemented

The alliance will help to refine the European Strategic Energy Technology Plan and It can facilitate RD&I infrastructure sharing

References
https://www.euroheat.org/wp-content/uploads/2021/05/DHC-SRIA-FINAL-1.pdf
https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

KEY TAKE AWAY MESSAGES…from the HEATSTORE consortium

- Strong need for awareness and strategy on local, national and European level
- Help early movers with:
    - Financial de-risking
    - Support schemes for the early movers in the different EU countries
- Launch the European UTES alliance



THANK YOU FOR YOUR ATTENTION

HEATSTORE (170153-4401) is one of nine projects under the GEOTHERMICA – ERA NET Cofund aimed at accelerating the uptake of geothermal energy by 1) advancing and integrating different types of underground thermal energy storage (UTES) in the energy system, 2) providing a means to maximise geothermal heat production and optimise the business case of geothermal heat production doublets, 3) addressing technical, economic, environmental, regulatory and policy aspects that are necessary to support efficient and cost-effective deployment of UTES technologies in Europe. The three-year project will stimulate a fast-track market uptake in Europe, promoting development from demonstration phase to commercial deployment within two to five years, and provide an outlook for utilisation potential towards 2030 and 2050.

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