HEATSTORE WEBINAR SERIES

HOW TO DEVELOP UNDERGROUND THERMAL ENERGY STORAGE (UTES) PROJECTS?

Learnings from the European HEATSTORE project

Host: TNO, The Netherlands

heatstore High Temperature Underground Thermal Energy Storage

GEOTHERMICA

7, 14, 21, 28 Sept. and 5, 12 Oct. 2021 | all 15-16 h (CEST)

Register on www.heatstore.eu

HEATSTORE WEBINAR SERIES 2021

All webinars are at 15 – 16 h CEST

Tuesday 7 Sept. (Holger Cremer, TNO): Challenges in Underground Thermal Energy Storage (UTES)

Tuesday 14 Sept. (Thomas Driesner, ETH Zurich): Advances in subsurface characterization and simulation

Tuesday 21 Sept. (Koen Allaerts, VITO): Integrating UTES and DSM in geothermal district heating networks

Tuesday 28 Sept. (Florian Hahn, Fraunhofer IEG): Abandoned coal mines – promising sites to store heat in the underground

Tuesday 5 Oct. (Bas Godschalk, IF Technology): The ECW Energy HT-ATES project in the Netherlands

Tuesday 12 Oct. (Joris Koornneef, TNO): The role of UTES in the future EU energy system – a moderated table discussion.

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HEATSTORE

- HEATSTORE = GEOTHERMICA ERA-NET co-fund project
- 16.3 M€ | 23 partners in 9 EU countries
- 6 demonstration sites, 8 case studies.
- Coordination: TNO Netherlands Organization for Applied Scientific Research)

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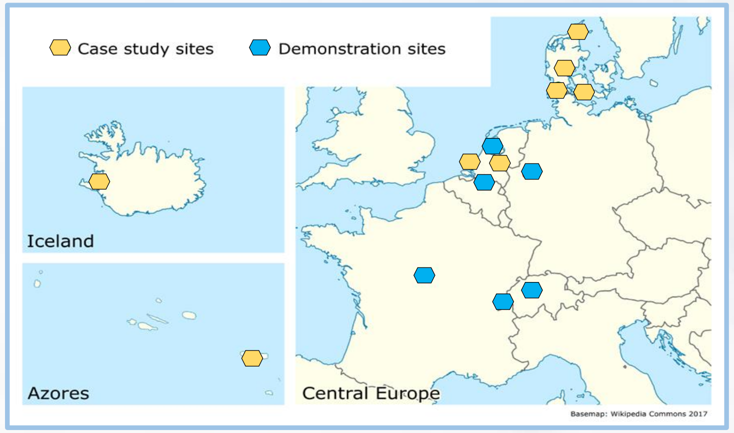


- **Best practice guidelines:** Design & System integration | Business models | Regulatory framework | Stakeholder perception & engagement | Monitoring technical, economic and environmental performance

- Proof and operation of UTES and DSM technologies

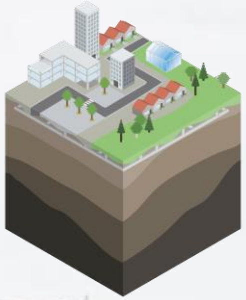
Fast track market uptake

Model & design validation

Demonstration

System performance monitoring

- **Roadmap Europe**: Technical future potential UTES and DSM in Europe | New business models | Stakeholder engagement | Roadmap for fast track uptake



Characterization of UTES

Modelling sub-surface dynamics

Heating system integration & design optimisation

Design → **Demonstration** → **Replication and scale-up**

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HEATSTORE – 7 Sept. 2021
Challenges in Underground Thermal Energy Storage (UTES)

- Holger Cremer (TNO): Convenor & Opening
- Paul Ramsak (Netherlands Enterprise Agency): Welcome note
- Thomas Vangkilde-Pedersen (GEUS): What is UTES? System types, lessons learned and specific challenges

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HIGH TEMPERATURE UNDERGROUND THERMAL ENERGY STORAGE (UTES)

WHAT IS UTES? SYSTEM TYPES, LESSONS LEARNED AND SPECIFIC CHALLENGES

THOMAS VANGKILDE-PEDERSEN, ANDERS JUHL KALLESØE & THE HEATSTORE TEAM

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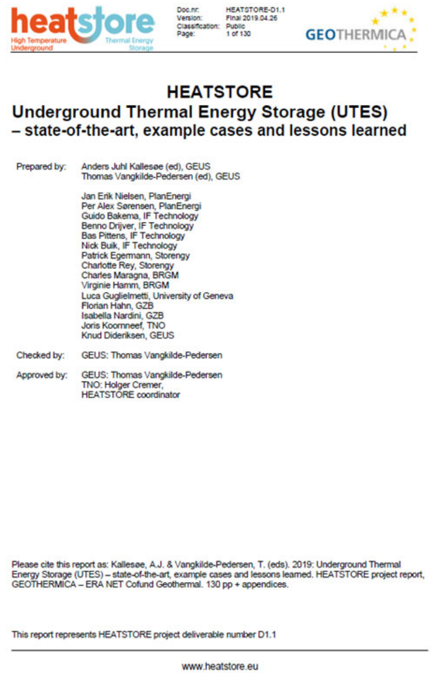
High Temperature Underground Thermal Energy Storage

HEATSTORE WEBINAR, TUESDAY 7TH SEPTEMBER,

CHALLENGES IN UNDERGROUND THERMAL ENERGY STORAGE (UTES)

HEATSTORE PROJECT AND CONSORTIUM

- EU Geothermica Era-Net co-fund
- 23 partners in 9 European countries
- Coordinated by TNO
- Close to 50% industry funding
- 6 demonstration sites, 8 case studies
- 16.3 MEUR total project budget
- Project finish in october 2021



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Page: 1 of 130

HEATSTORE
Underground Thermal Energy Storage (UTES)
– state-of-the-art, example cases and lessons learned

Prepared by: Anders Juhl Kallesøe (ed), GEUS
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TNO: Holger Cremer,
HEATSTORE coordinator

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This report represents HEATSTORE project deliverable number D1.1

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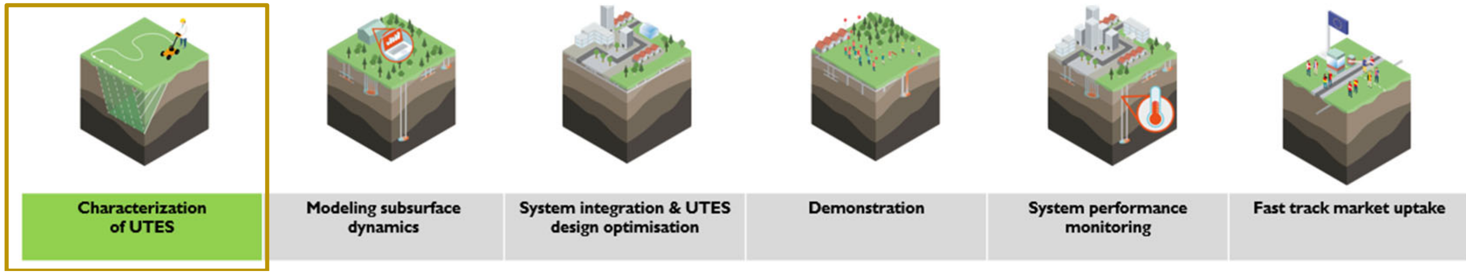
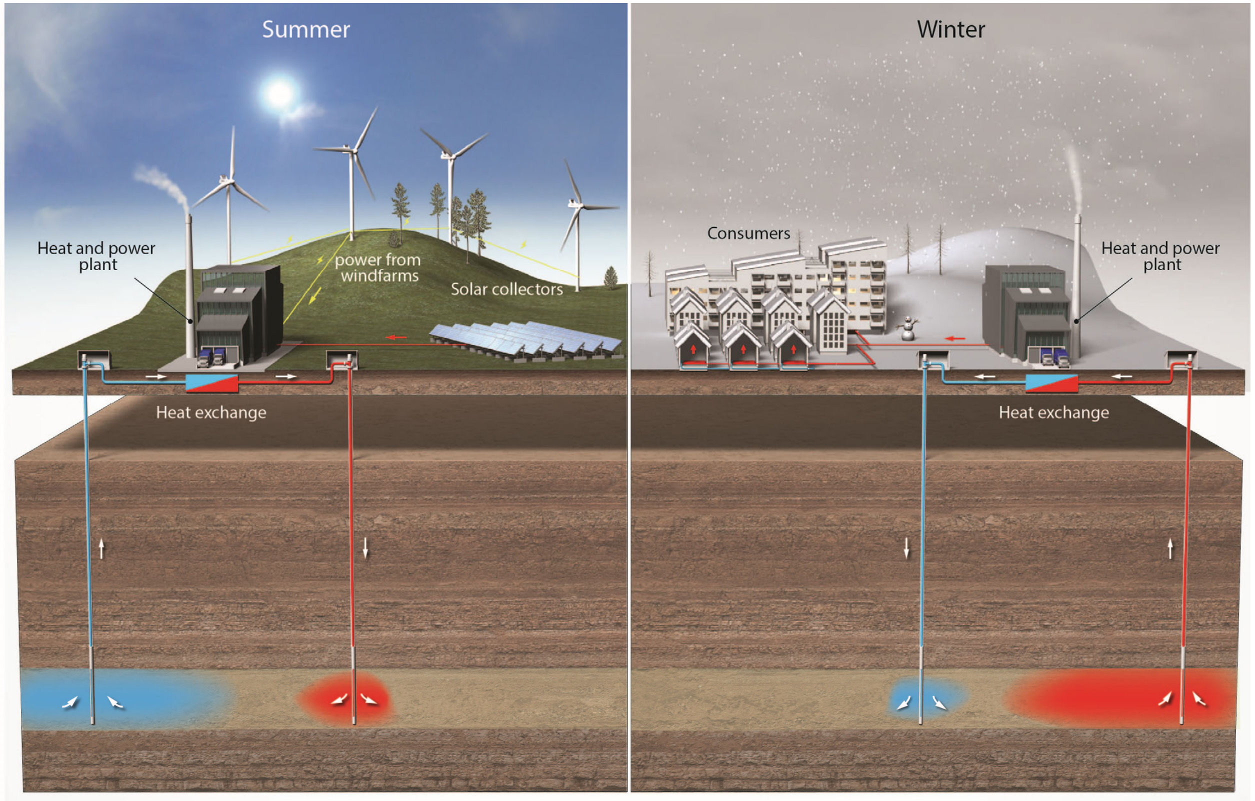


THE UTES TECHNOLOGIES IN HEATSTORE

- High Temperature Aquifer Thermal Energy Storage (HT-ATES)
- Borehole Thermal Energy Storage (BTES)
- Pit Thermal Energy Storage (PTES)
- Mine Thermal Energy Storage (MTES)



Reference: GEUS

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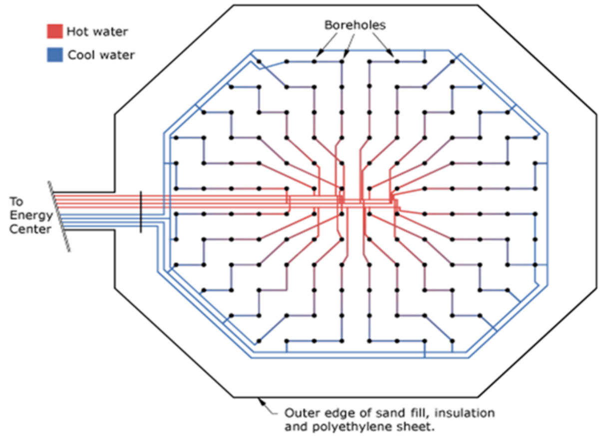
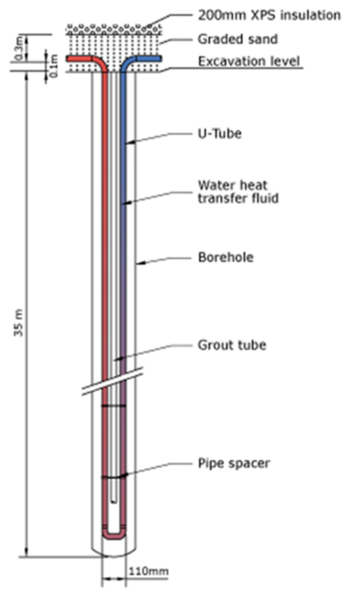
THE UTES TECHNOLOGIES IN HEATSTORE

- High Temperature Aquifer Thermal Energy Storage (HT-ATES)
- **Borehole Thermal Energy Storage (BTES)**
- Pit Thermal Energy Storage (PTES)
- Mine Thermal Energy Storage (MTES)

Reference: Underground-Energy.com





Reference: Sibbitt B. & McClenahan D. 2015

THE UTES TECHNOLOGIES IN HEATSTORE

High Temperature Aquifer Thermal Energy Storage (HT-ATES)

Borehole Thermal Energy Storage (BTES)

Pit Thermal Energy Storage (PTES)

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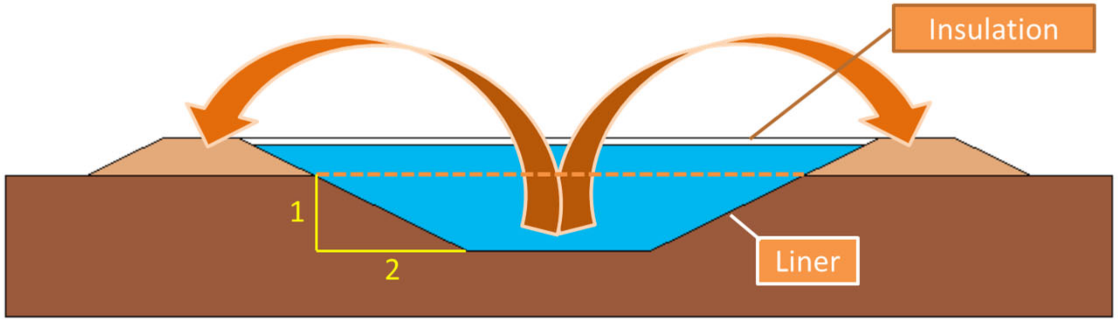

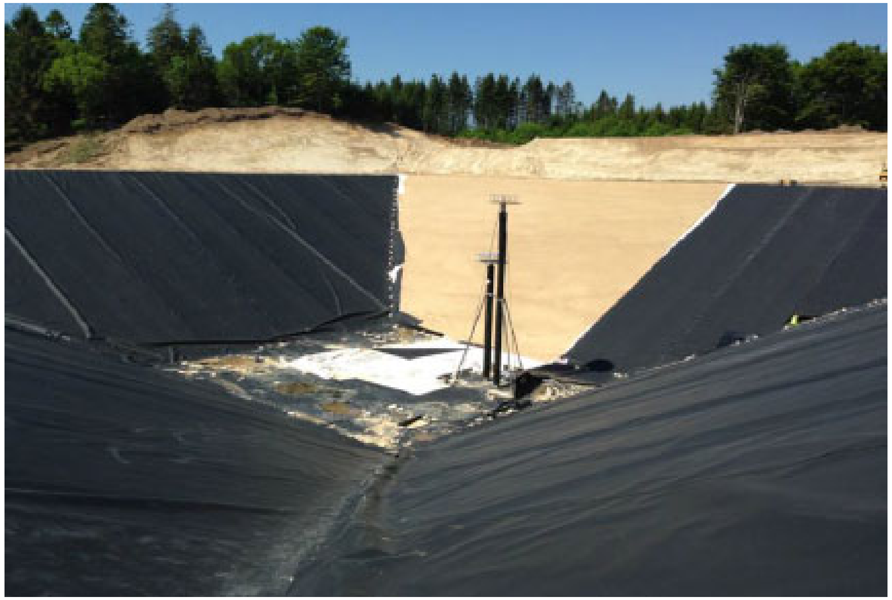

Reference: PlanEnergi

THE UTES TECHNOLOGIES IN HEATSTORE

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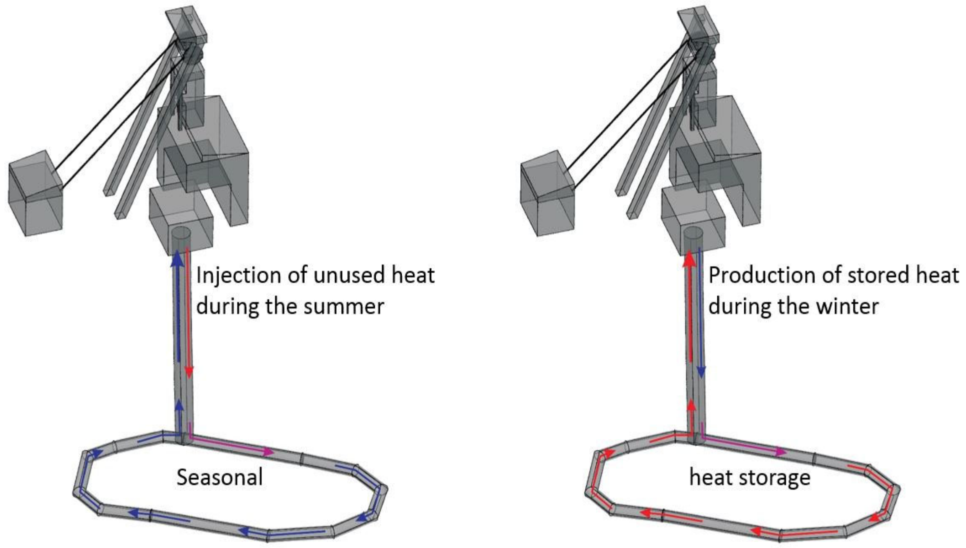

Reference: Frauenhofer IEG, F. Hahn

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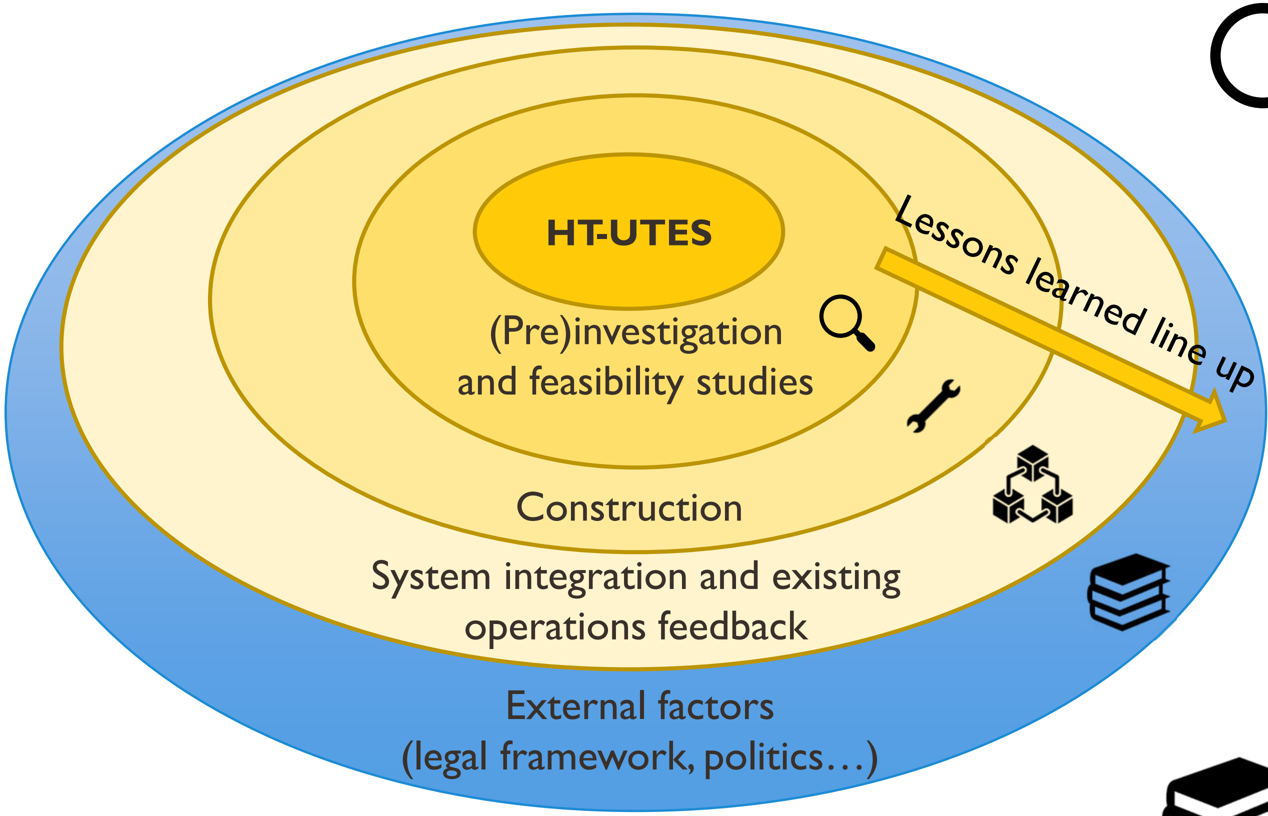
HT-UTES – LESSONS LEARNED FROM DIFFERENT PHASES



Screening for geographical parameters is essential (subsurface and surface)

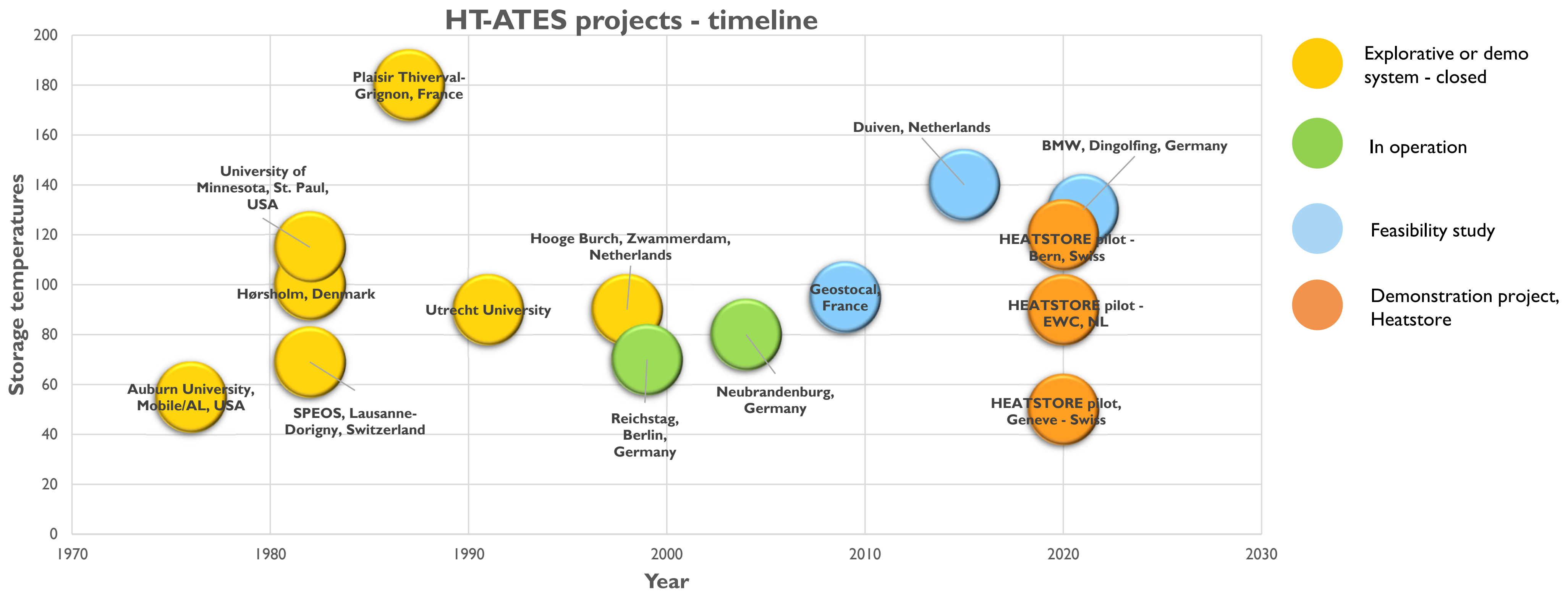
Modelling of the entire energy system

Experiences from drilling, borehole completion, design and selection of materials

Experiences from system operations and integration

Socio-economic factors
Legal/regulatory barriers

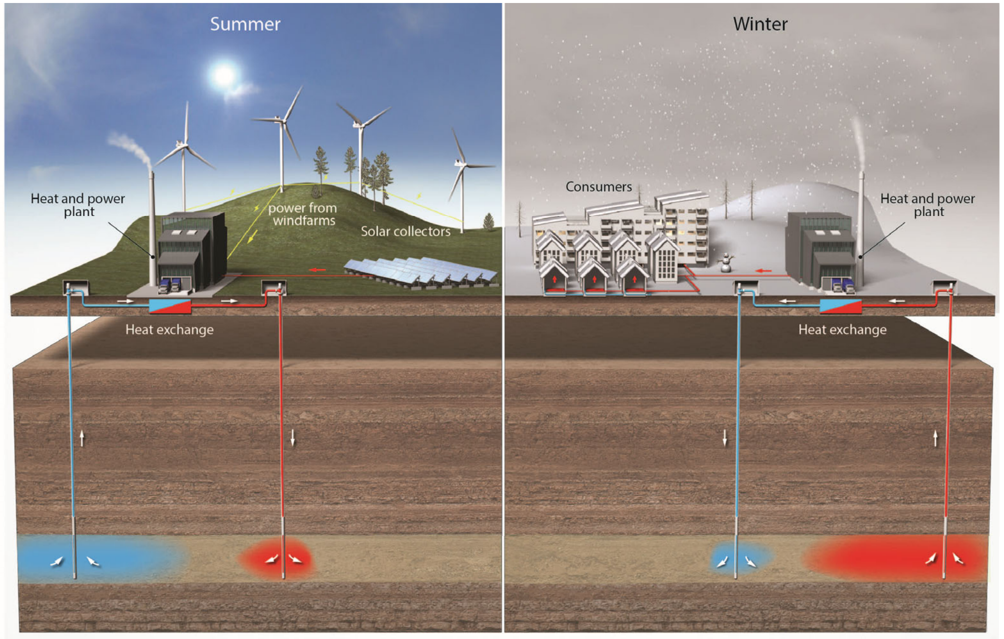
THE HISTORY OF **HT-ATES** PROJECTS



- Open system using aquifers as storage media
- Storage temperatures from 50°C to 150°C
- Storage depths: < 100 m to > 1000 m

- 7 closed systems – the first pilot in 1976
- 2 existing systems in operation
- 3 feasibility studies
- 3 planned/underconstruction (2021)

HT-ATES – IMPORTANT LESSONS LEARNED



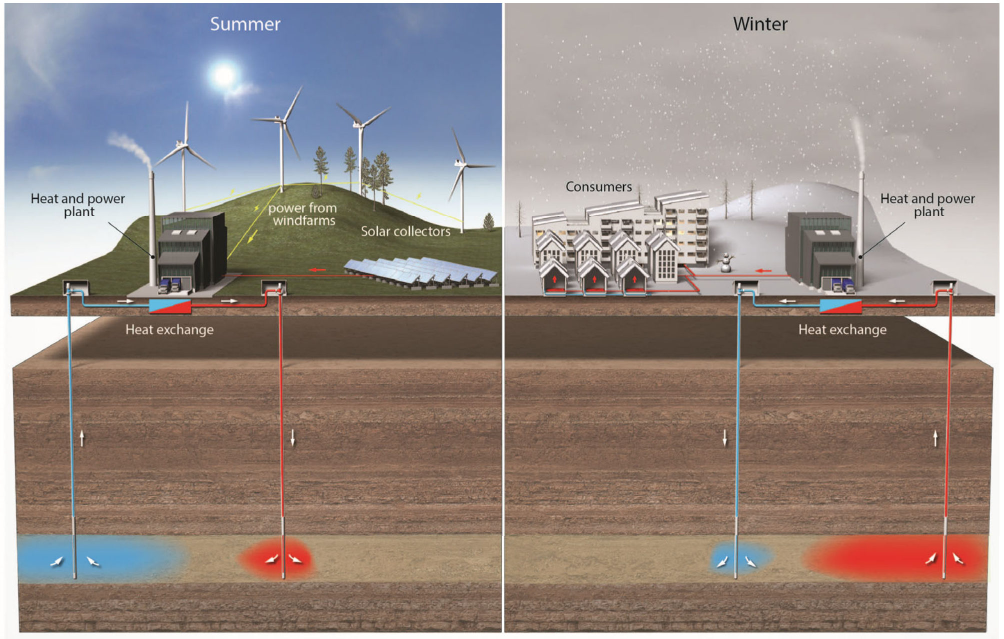
- **Screening** for availability of aquifer/reservoir, infrastructure and potential conflicts of interests is a prerequisite
- **Test drilling** including pumping tests and water samples
- **Modelling:**
  - **3D heat transport** → Geological and hydrological models
  - **Geochemistry (water)**
- **Permeability** is required for efficient production/injection → but too high hydraulic conductivity may cause **density driven groundwater-/heat flow**
- **Water treatment** should be considered at temperatures >50°C
- Well construction and **choice of materials** (pumps, casing and screens) depend highly on temperatures and water/sediment geochemistry
- Well capacity (and **declining well capacity**) needs to be evaluated and not overestimated

HT-ATES - IMPORTANT LESSONS LEARNED

(IF Technology)

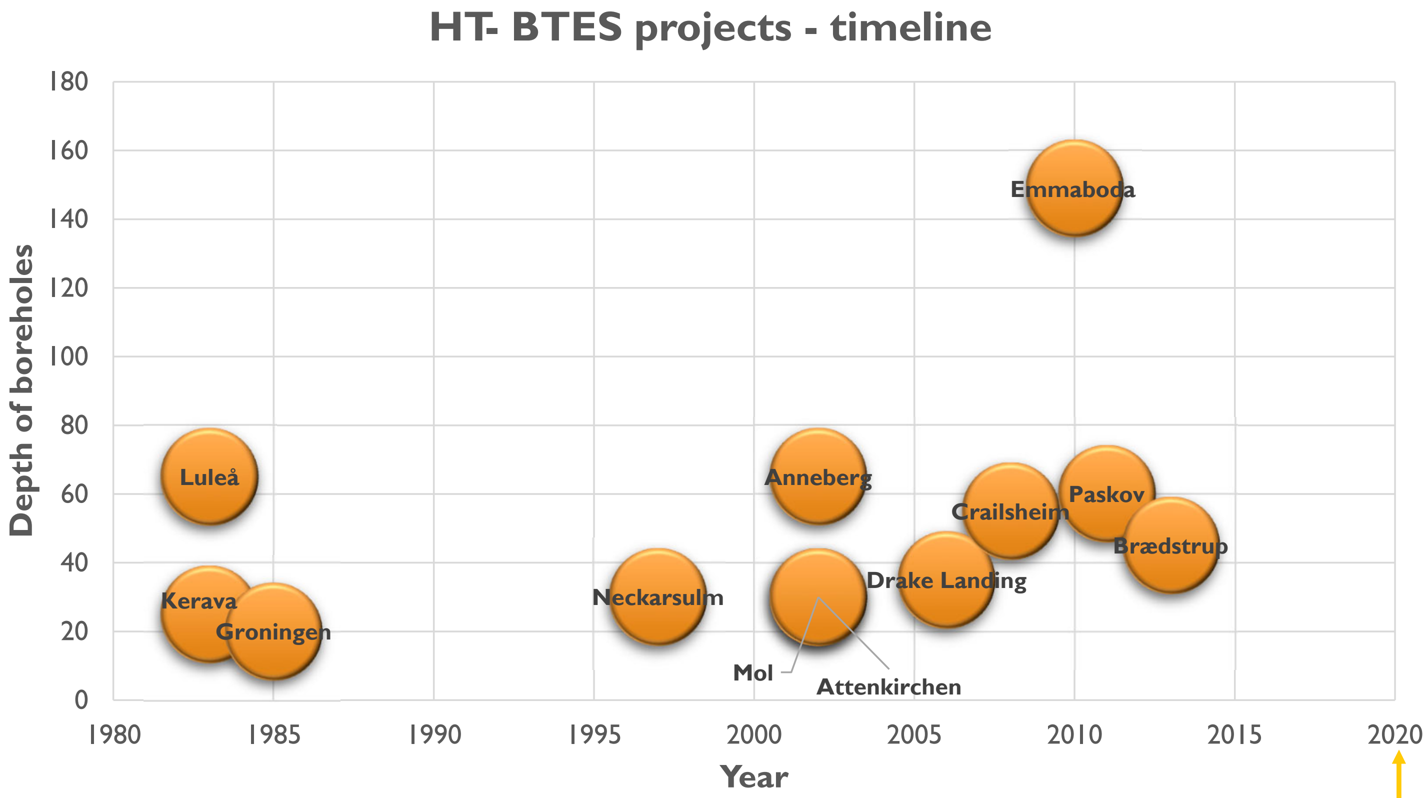
- Careful **monitoring** is highly recommended in order to **diagnose and optimize the system**
- Repeated **re-generation of wells** should be implemented in the maintenance budget
- Do **visual inspection** of well heads, valves, transmitters and heat exchangers for leakage and corrosion as preventive maintenance
- **Thermal losses** are higher for smaller systems and for higher storage temperatures
  - Storage volume of **at least 300.000 m^3** of water is recommended
  - Demand side requirement of minimum **5 MW thermal power** is recommended
  - Most efficient if used as base load during unloading
- Important that the entire **energy system** is fitted to possible temperature ranges in the ATES system
  - The lower the useable (cut-off) temperature the better

HT-ATES – SPECIFIC CHALLENGES



- Maximum **injection temperature** (20-25°C) in the regulation in some countries is a serious limiting factor
- General lack of clear regulation
- The **"geological risk"** regarding the aquifer/geothermal reservoir is significant – the deeper the reservoir, the higher the risk
  - In HEATSTORE TNO has been working in **better subsurface characterization** through reprocessing of existing seismic data
  - In HEATSTORE ETHZ and others has been working on improving models for **characterization of reservoir dynamics**
- Clogging of **fines** and **calcite scaling** are known problems
  - **Ca/Na ion exchanges** can be used to prevent precipitation of $CaCO_3$, but may cause **clay swelling**
  - **HCl-treatment** is effective, but expensive and subject to public acceptance
- Large initial **investment** for preinvestigations and modelling

THE HISTORY OF **HT-BTES** PROJECTS



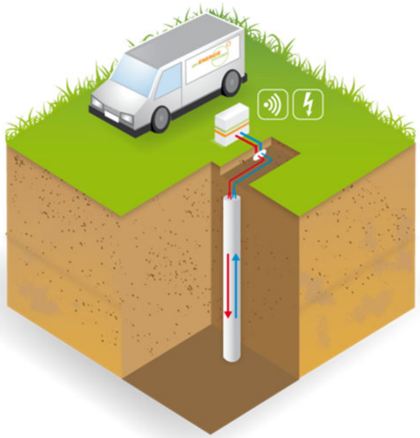
- Closed loop system using soil/bedrock volume as storage media
- Storage temperatures from 45°C to 80°C
- Storage capacities from 100 to 3800 MWh

Existing systems (12)
Sweden (4), Germany (3), Czech Republic (1), Canada (1), Denmark (1), Netherlands (1), Belgium (1), Finland (1), France (1)

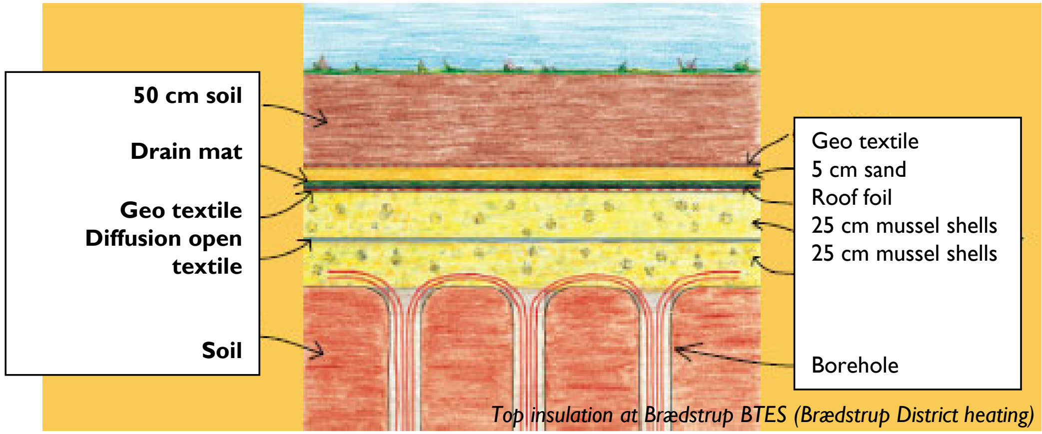
*BTES, Gothenburg, Sweden in construction
*HT-BTES, Annecy, France

HT-BTES – IMPORTANT LESSONS LEARNED

Reference: IEA 2020



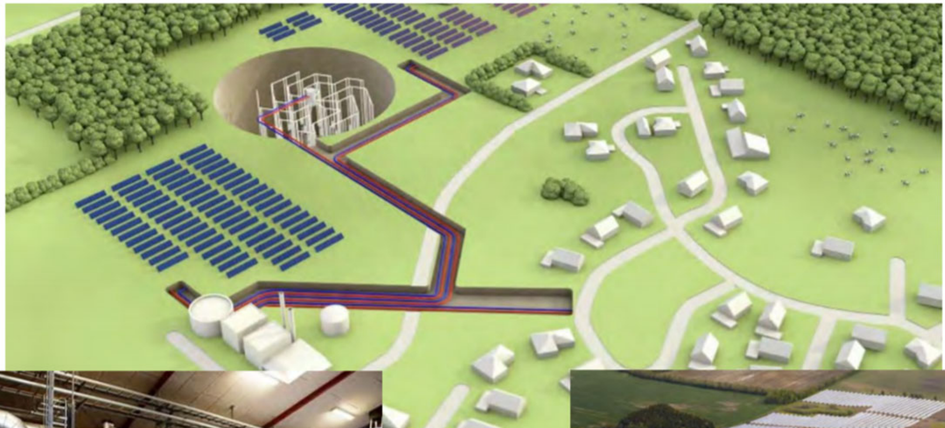
(www.geoenergie-kozept.de)



Top insulation at Brædstrup BTES (Brædstrup District heating)

- **Screening** for geology, groundwater flow, thermal properties, infrastructure etc.
- Perform a **test drilling** to verify the ground conditions and the estimated drilling costs and include a **thermal response test** to verify the thermal properties of the site
- A low **thermal conductivity** increase the recovery efficiency, but decrease the rate of charging/discharging
- In soft sediments **grout sealing** of the boreholes is always recommended (and often required) in order to protect groundwater resources and to obtain thermal conductivity in unsaturated conditions
- The **drilling cost** may account for approx. 50% of the total construction costs
- A **top insulation** of the BTES is necessary to reduce the heat loss and may account for 25% of the total construction costs
- A BTES **reacts slowly** during charging and discharging and normally a buffer heat storage like a water tank is necessary, especially if the heat source is solar

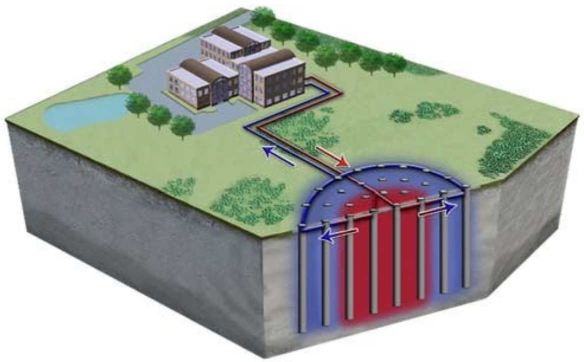
HT-BTES – IMPORTANT LESSONS LEARNED

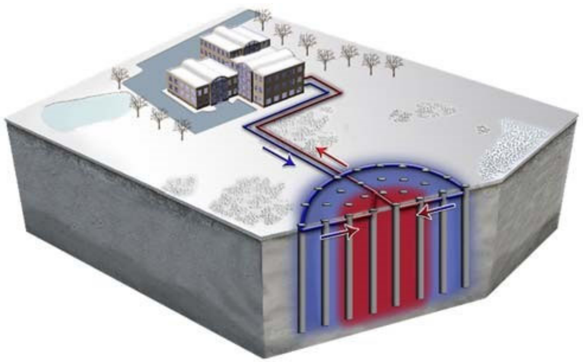


Reference: Brædstrup DH Utility, BTES facility

- High quality **cross-linked high density polyethylene (PEX)** tubes are normally used as they are strong, chemical resistant and can withstand high pressures and high temperatures
- **Double U-tubes** are found to be more efficient than single U-tubes
- The **storage efficiency** (where known, **45% - 60%)** is often lower than expected/modelled
- In general, a **start-up period of a few years** should be expected to heat up the storage and the surroundings
- the specific costs drops significantly with increasing storage size and in general BTES systems **larger than 20,000 m^3 of storage volume** are recommended

HT-BTES – SPECIFIC CHALLENGES

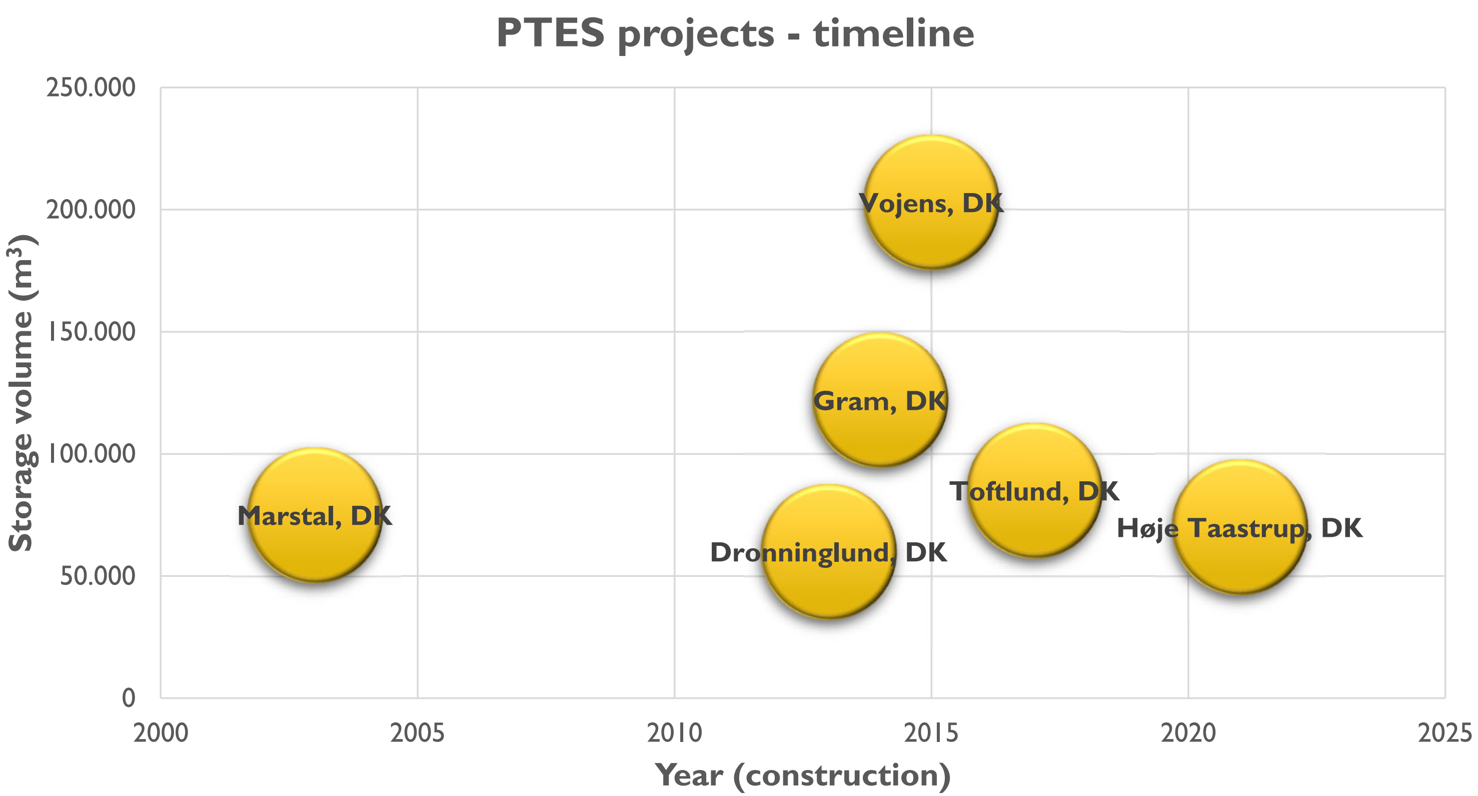




Reference: Underground-Energy.com

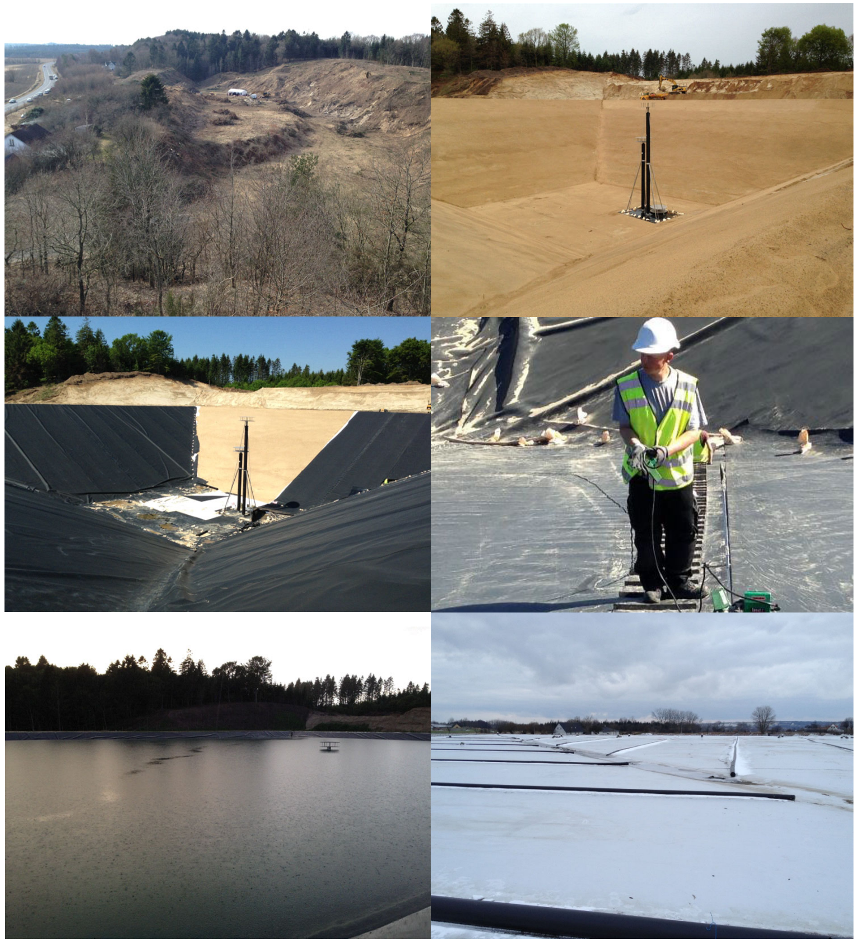
- There is good business case for **BHE systems** for seasonal heating and cooling of buildings and there are several hundred of systems in Europe – but for heat storage alone, **BTES** can be an **expensive solution**, especially if a high thermal power is needed
- Large initial **investment** for drilling and top isolation
- A **clear regulative framework** is missing in many countries
- Risks of **not** getting a permit and/or a **long permit procedure**
- In HEATSTORE STORENGY is **transforming** an existing, but depleted (too cold), **BHE system into a BTES** for surplus heat storage

THE HISTORY OF PTES PROJECTS



- Pit storage is using water as storage media
  - 6 existing systems in Denmark
  - More systems planned
- Storage temperatures up to 90°C
- Storage volumes 60.000 m^3 to >200.000 m^3
- Storage capacities from 3000 to >12.000 MWh
- Storage efficiency up to 60-90%
- Effective for both short- and long term storage
- High charge- and discharge capacity

PTES – IMPORTANT LESSONS LEARNED



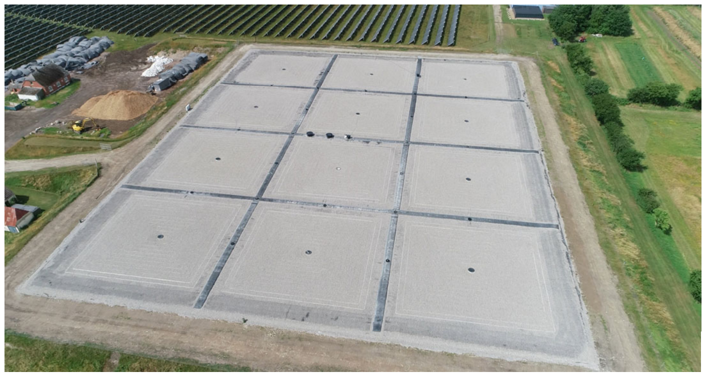
- **Soil properties/geotechnical parameters** must be checked in order to utilize the excavated soil as banks
- **Groundwater flow** is unwanted in order to prevent heat loss from sides and bottom and avoid bank instability
- Relatively large **space requirements**
- The top of the banks must be **levelled,** and the excavated soil must be **compressed** when rebuilt into the banks
- **Plastic liners** and **insulating lid** is critical elements for the performance
  - A **floating lid** is the cheapest, but most sensitive option
  - Must be **tight** and dry and with **no air pockets** below and rain water must be **drained** from the top

PTES – IMPORTANT LESSONS LEARNED

Reference: *PlanEnergi and Aalborg CSP*

- **Temperature monitoring** from bottom to top in the storage is necessary for optimization of operation
- **Water quality** must be checked and **filters cleaned** at regular intervals
- Check the construction by **diver inspection** and **check for leakage** and **wet insulation**
- Check regularly for **wet insulation** to avoid heat loss
- **Environmental Impact Assessment -** Screening is required
  - Permission for seepage of groundwater drainage and drainage water from lid-top is necessary
  - Permission for seepage/drainage of (salty) return water from softening unit when filling storage
  - Permission for new water supply drillings for water to fill storage (can be very time-consuming)

PTES – SPECIFIC CHALLENGES



Reference: PlanEnergi and Aalborg CSP

- **Large space requirements** – not ideal in urban areas
- Straight forward, but time consuming **permit procedure**
- Generally, **very successful** systems with recovery efficiencies up to 60-90%
- One PTES system has experienced a **leak from the basin** which could be repaired after the unloading period
- **Rainwater lakes/water ponds** on the top lid can be a problem
- Some PTES systems has experienced problems with **leaks in the insulating lid** and wet insulation material
- In Denmark, focus in recent years has been to **improve the construction of the lid**
  - Sectioned lid constructions
  - Layering of insulation material
  - Better materials

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MTES - MINE THERMAL ENERGY STORAGE

- **Mine water** of abandoned and flooded mines has until now only been used as **low-temperature energy source** for heating buildings and a few plants exist in Germany and the Netherlands:
  - The Mijnwater-project in Heerlen (Netherlands), 28°C

Reference: Hahn et al. 2020

- No **mine water heat storage** has been realized so far
  - Within the **Ruhr area**, abandoned and flooded **mine infrastructures** in combination with available **surplus heat** from power plants and industry provides a vast potential for large scale heat storage
  - Pilot project in HEATSTORE → Small colliery below the premises of the **IEG in Bochum**
- A **large mine water volume**, safe and close to a district heating network is needed
- Information on **mine layout, depth and condition**
- Modelling of **hydrology, thermal impact and hydro-geochemistry** coupling the mine hydraulic and thermal behaviour to the surrounding rock mass and aquifers
- **Permit procedure** can be complex

COMPARISON OF HT-UTES CONCEPTS

	HT-ATES	HT-BTES	PTES
Storage medium	Groundwater/sediments	Sediments/groundwater	Water
Subsurface requirements	XXX	XX	X
Required pre-investigation	XXX	XX	X
Maximum storage capacity	XX(X)	X	XXX
Storage volumes	XXX	XX	XX
Space requirements	X	X	XXX
Peak load response	X(X)	X	XXX
Investment costs	X(x)	XXX	XX
Maintenance	XXX	X	X(x)
Environmental interaction	XXX	XX	X

** Current assessment / interpretation*

*** MTES – first of its kind, not included*

High: XXX	Medium: XX	Low: X

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.

This project has been subsidized through the ERANET cofund GEOTHERMICA (Project n. 731117), from the European Commission, RVO (the Netherlands), DETEC (Switzerland), FZJ-PtJ (Germany), ADEME (France), EUDP (Denmark), Rannis (Iceland), VEA (Belgium), FRCT (Portugal), and MINECO (Spain).

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