Large-Scale Thermal Energy Storage – The Mutual Benefits to Heat and Electricity

The webinar will commence soon

Webinar
27 April 2022
Please post questions on
slido.com
#HEAT
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Large-Scale Thermal Energy Storage

01
Overview
Philippe Dumas
Heat Balance Introduction
Watson Peat
We have the strong backing of a global company as part of both ScottishPower and Iberdrola, one of the world’s largest integrated utility companies and a global leader in wind energy, and we believe in developing an energy model that prioritises the wellbeing of people and the preservation of the planet.

The ScottishPower group own and operate renewables, networks and retail businesses.
Strategic Innovation Fund (SIF)

- Paid for by GB consumers on their energy bills
- £450m available over the next five years
- Designed to help network users and consumers
- Aimed at energy network innovation

Strategic Objectives
Ofgem and Innovate UK are collaborating to:
1. Deliver a net zero energy system at lowest costs to consumers
2. Position the UK as the ‘Silicon Valley’ of energy systems
   “big, bold, ambitious ideas which will significantly accelerate delivery of net zero in the UK and be rolled out internationally.”

Heat Balance is a Discovery phase project
To meet all our energy needs with non-dispatchable renewables implies **massive over-capacity**
Problem (Cont.)

- Transmission system reaches export capacity at times
- Generators paid to switch off
- Cost £100m+ per year to customers
- Increasing year on year
- Renewable generation needs to quadruple
Large scale TES

Energy storage compensates for the intermittent power generated from renewable power sources.

Allows this power to be stored when the wind is high and the power released and utilised during peak demand periods.

Danish system: Pit-thermal energy storage

Dutch system: Aquifer-thermal energy storage
Partners and work packages

Technical Work Package
Investigate the different options for large-scale TES and assess their compatibility with GB – geology, geography and demographics.

Commercial Work Package
Determine the benefits of large-scale TES to the wider energy system including generation, and electricity transmission & distribution networks.
03 Heat Balance – Grid Considerations
Prof. Daniel Friedrich
Heat Balance: Grid considerations

Daniel Friedrich

Chair of Energy Systems
Institute for Energy Systems
School of Engineering
University of Edinburgh

Heat Balance webinar
April 2022

d.friedrich@ed.ac.uk
System flexibility and energy storage in the UK?

Image from the National Transmission System

Wilson et al., Challenges for the decarbonisation of heat: local gas demand vs electricity supply Winter 2017/2018
Wilson and Rowley, Flexibility in Great Britain's gas networks : analysis of linepack and linepack flexibility using hourly data, 2019
Wind curtailment, electricity prices and waste heat

- Committee on Climate Change estimated that low carbon generation needs to be quadrupled from 2019 levels
- Wind energy curtailment is increasing and predicted to reach costs of £1B

Canbulat et al., Techno-Economic Analysis of On-Site Energy Storage Units to Mitigate Wind Energy Curtailment: A Case Study in Scotland, Energies 2021, 14(6)
McKenna and Norman, Spatial modelling of industrial heat loads and recovery potentials in the UK, Energy Policy, 2010, 38(10)
Seasonality of heating demand and wind curtailment
Curtailment of Scottish windfarms
Costs, emission and demand reduction

- Long-term storage charge rate fixed at 600 kW
- Max weekly electricity demand reduces from 90 MWh to 60 MWh
- Curtailed electricity from Black Law windfarm extension could support 10 district heating networks of this size
Questions?

- Heating and cooling decarbonisation presents significant challenges but also huge opportunities.
- Integration of different energy systems and vectors is key to balance the system and to increase the utilisation of the variable resource.
- STES can provide flexibility to the wider energy system.

Thank you for your attention!

Questions?
Heat Balance – Sub-Surface
Prof. Gioia Falcone

Gioia Falcone, Isa Kolo, Chris Brown
Overview

- Underground Thermal Energy Storage (UTES) - Potential in the UK
  - Aquifer Thermal Energy Storage (BTES)
  - Mine Thermal Energy Storages (MTES)
  - Borehole Thermal Energy Storage (ATES)

- UTES Modelling for a UK Case Study
  - Easter-Bush Campus in Edinburgh
  - ATES Modelling
  - BTES Modelling
ATES and MTES Potential in the UK

- Many aquifers with proven hydraulic characteristics for abstraction (Fig 1)
- Vast areas in England, and then Wales, Scotland and Ireland
- Over 23,000 flooded coal mines with potential for storage and extraction (Fig 2)

Figure 1: Major aquifers in the UK (Gluyas et al., 2020)
Figure 2: Potential MTES sites in the UK. (Gluyas et al., 2020)
ATES and MTES Potential in the UK

- Storage capacity based on existing water in aquifers and mines
- Temperature increase from 5 – 15°C
- Storage capacity in the range of $10^4 - 10^5$ Petajoules (PJ) for aquifers and $10^2$ PJ for abandoned mines
- 1 PJ = $10^{15}$ Joules.
- Heat networks in the UK supply 12000 GWh ($4.32 \times 10^{-5}$ PJ)

Figure 3: Storage capacity of aquifers and abandoned mines in the UK (modified from Giuyas et al., 2020)
1 Petajoule (PJ) = $10^{15}$ Joules (J).
BTES Potential in the UK

- BTES has less geological constraints
- BTES systems commonly operate with solar thermal systems
- Can be used in regions with high solar irradiation (Fig 4)
- Waste heat also represents an abundant resource that can be stored (Fig 5)

Figure 4: UK solar irradiation map (www.solargis.com)

Figure 5: UK total waste heat map (Albert et al. (2022))
UTES Modelling Case Study: University of Edinburgh Easter-Bush Campus

- Useable space of 27000m\(^2\) with a solar farm consisting of 5000 solar panels and a large thermal store (100m\(^2\)) as buffer facility.
- Has large heat demand from applied research and teaching facilities
- Has demand and infrastructure to generate heat and facilitate UTES
- Annual demand shows a peak load of 1283 kW in November (Fig 6)

Figure 6: Easter-Bush campus heat demand
BTES and ATES Modelling

- ATES - Doublet system with 2, 4 and 5 months charge and 1 week rest period
- BTES - 300m Borehole Heat Exchanger (BHE) with 2 and 4 months charge period
- For both systems, longer charge period (hence, higher temp) will improve system longevity
- 300 - 400kW available from ATES system which is equivalent to 43-58 BHEs. Up to 184 BHEs needed to meet campus demand
- Technologies widely applicable across the UK since potentials exist
Thank you
HEATSTORE Project
Luca Guglielmetti
HEATSTORE
FLEXIBLE ENERGY SYSTEMS WITH UNDERGROUND THERMAL ENERGY STORAGE

WHAT IS UTES? WHY IS IT OF RELEVANCE? WHAT DO WE NEED TO PROGRESS IT?

LUCA GUGLIELMETTI (UNIVERSITY OF GENEVA) AND THE ENTIRE HEATSTORE CONSORTIUM

https://www.heatstore.eu/
WE NEED SOLVE THIS DEMAND PROFILE....
HEATSTORE IMPACT

Improved performance (target efficiency of 75%) and economics of UTES technologies

Advanced system integration using UTES and smart demand side management

Significantly higher integration of sustainable and surplus heat sources in heating networks (geothermal, solar and industrial surplus heat)

Bringing multiple underground thermal energy storage concepts and demand side management techniques further;

Key advancements in the science related to challenges identified in earlier pilot projects for the demonstrated concepts, including environmental impacts
HEATSTORE PROJECT AND CONSORTIUM

- 23 partners in 9 European countries
- EU Geothermica Era-Net co-fund
- 16.3 MEUR total project budget
- 6 demonstration sites, 8 case studies
THE UTES TECHNOLOGIES IN HEATSTORE

Aquifer Thermal Energy Storage
- Injection and later reproduction 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.
YES, NO, MAYBE

- 70 MW peak demand
- 43 MW geothermal (3 doublets)
- Biomass and gas fired CHP plants
- Network operating temperature of 85 °C
- Storage capacity: 20-28 GWh
- Efficiency: ~70-75% (estimate)
- T injection (summer/winter): 85-90 °C / 30°C
- Max charge/discharge capacity: 16 MW/ 12 MW
- Flow rate: max 150m³/ hour
- Water displacement: 600,000 – 700,000 m³ per season
- Investment/capacity: 0.2 €/kWh
- Investment/max charge capacity: 200-400 €/kW
## ENVIRONMENTAL EFFECTS

<table>
<thead>
<tr>
<th>Effect</th>
<th>HT-ATES</th>
<th>MTES</th>
<th>BTES</th>
<th>PTES</th>
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<td>Air quality</td>
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<td>Noise and vibration</td>
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<td>Surface clear water</td>
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<td>CO2 Intensity reduction</td>
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### Risk Levels
- L: Low
- M: Medium
- H: High

### Energy Efficiency

**Avoided CO2 intensity** (Danillidis et al. 2022)
MARKET & ECONOMICS

HEAT STORAGE SERVICES/ACTIVITIES/VALUE PROPOSITION
Example Netherlands demo
Value proposition for HT-ATES ECW

- Reduced peak generation / peak shaving
- DHN investment deferral
- Conventional generation replacement
- Biomass generation replacement
- Time-shifting for curtailment avoidance of sustainable heat and waste heat
- Support thermal ramping

- Reduce distribution grid congestion electricity grid (with heat pump)
- Optimal performance for generators - Stabilizing demand for generators
- Optimal performance for generators - co-gen plants
- (Seasonal) Arbitrage
- Security of supply (N + 1)
- Strategic reserve (beyond DHN boundaries)

- Optimization of RE output
- Time-shifting for industrial process optimization
- Energy security
- Surface space conservation
- Public image
- Ecological value

- Prevent damage geothermal doublet, reducing maintenance costs
- Other energy sources (Solar thermal) become interesting option due to storage
- Future upscaling of geothermal energy storage is needed

Impacts of subsurface parameters on LCOH (Danillidis et al. 2022)
POLICY & REGULATION

- Create a joint vision on UTES
- Provide clear regulatory framework
- Adapt policy to UTES: support programme to lower financial risks
SPATIAL MULTI-CRITERIA ANALYSIS FOR FAVOURABILITY ASSESSMENT

- Integration of subsurface and surface components
- Need for a common framework
- Need to include Environmental, Social and Economic pillars

https://storymaps.arcgis.com/stories/f8f3f6ad4d7a4278b914c38cf698ea1f
HT-UTES – LESSONS LEARNED FROM DIFFERENT PHASES

- (Pre)investigation and feasibility studies
- Construction
- System integration and existing operations feedback
- External factors (legal framework, politics…)

Lessons learned line up

- 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
KEY RECOMMENDATIONS FOR THE SHORT TERM

- Strong need for awareness and strategy on local, national and European level
- Help early movers with financial de-risking and support scheme for early commercialisation
- Launch the European Underground Thermal Energy Storage Alliance
Welcome
This is the HEATSTORE project website, where you can find information about the project. See the links below for more information about the project, results, and webinars.

- Webinar registration
- Project description
- Work packages
- Partners
- Downloads
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 subsidised 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).
ECW HT-ATES full scale pilot
Bas Godschalk (recorded)
HT-ATES - heat & electricity networks

IF Technology - Bas Godschalk - April 27th 2022
IF Technology

• Consultant and engineering company in shallow and deep geothermal energy systems
• Employing approx. 90 (hydro-)geologists, civil-, mechanical- and well engineers and energy consultants
• Founded in 1989 and based in Arnhem in the Netherlands. We worked on 3,000 projects.
• www.iftechnology.nl | www.iftechnology.com

Bas Godschalk

• Business developer HT-ATES and International Projects at IF Technology (14 years)
• Before: 7 years at a soil remediation company with electro(bio)reclamation
• Projects from first idea to design, realisation and exploitation in the Netherlands and abroad.
• B.godschalk@iftechnology.nl // +31 6 3088 7473
Aquifer Thermal Energy Storage Systems

- Storage of seasonal energy = battery
- Cold well (range 5-10 °C)
- Warm well (range 13-17 °C) (max 25 °C)
- Depth 40 to 250 m
- Flow rates 25 - 250 m³/h per doublet
- Energy and CO₂ savings up to 80%
Mid and High Aquifer Thermal Energy Storage (HT-ATES)

MT-ATES: storage temp.: 25-45°C
HT-ATES: storage temp. 45-90°C
Why should we use an HT-ATES?

- Balance heat demand and production
- Stable geothermal operation - lower costs and smaller risks failures pumps
High temperature storage - heat balance

Sources
- Geothermal wells
- Solar collectors
- Waste heat
- Industrial heat

Users
- District heating networks
- Greenhouses
- Residential areas
- Big buildings
High temperature storage - electricity balance

Sources
- CHP
  - Provides electricity
- Power to heat
  - $\text{H}_2$ production
  - E-boilers
  - Heat pumps

Users
- District heating networks
- Greenhouses
- Residential areas
- Big buildings
Full scale demo project HT-ATES ECW
Full scale HT-ATES project ECW
## HT-ATES project ECW

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<th>10 MW</th>
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<td>Target flow</td>
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<td>Average injection T</td>
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<tr>
<td>Energy supply and charge</td>
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A few pictures of the HT-ATES installation
European Heat Demand

- HT-ATES great solution as heat buffer
- Fits well with District Heating Networks
- Heat demand is high in Europe
- In the Netherlands 100 - 200 HT-ATES systems expected
- In Europe up to thousands
Conclusions

We believe and we know that geothermal technologies are more and more essential for our energy transition!
07 Flooded Mines
Ben Laenen
FLOODED MINES FOR LARGE-SCALE HEAT AND COLD STORAGE

Ben Laenen - VITO
AN ENERGY CONCEPT FOR OLD MINING DISTRICTS

Minewater | Minewater (mijnwater.com)
PRIMARY GOALS OF THE ‘MINEWATER’ PROJECT (INTERREG IIIB)

- Use of an abandoned colliery to meet local energy & climate goals
- Use of an abandoned colliery for large scale cold and heat storage
- In combination with low-exergy principles for climatization for buildings
  - Low temperature heating: 25 – 28°C supply temperature
  - High temperature cooling: 15 – 18°C supply temperature
- Technical feasibility
- Economic feasibility
- Environmental impact
  - Savings on primary energy resources
  - Reduction of CO2 emissions
- Juridical aspect
UNDERSTAND WHAT HAPPENS UNDERGROUND
UNDERSTANDING THE HEAT & COLD STORAGE
MATCHING THE HEATING & COOLING DEMAND
TRADITIONAL WAY OF MATCHING THE HEATING & COOLING DEMAND

<table>
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<th>Conventional</th>
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E 40% → COP 2.5 → W 80%

18000 → 7200 → 25200 → 18000

15000 → 3000

1250
MATCHING THE HEATING & COOLING DEMAND – THE ‘MINEWATER’ APPROACH
A ‘LOWEX’ CONCEPT FOR ‘MINEWATER-PROOF’ BUILDING

‘Gemeenschapshuis’- building at Heerlerheide (a Heerlen city quarter)
INTEGRATION WITH RENEWABLE HEAT SOURCES

“Changing the world is too big an effort for one man. Only by working together in respect and confidence we can create a new world where it is good to live for all.”
Questions?
slido.com
#HEAT
Thank you for attending